VITALITY, VARIATION, AND CAUSES OF DECLINE OF TREES IN OSLO CENTER (NORWAY)

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Abstract. To document the health of the most important city trees, a total of 1243 in the Oslo center were surveyed during a five year period. The most frequently planted species in the street environment were *Acer platanoides*, *Aesculus hippocastanum*, *Tilia platyphyllos*, and *Tilia x vulgaris*. Street trees had poorer health and more severe leaf scorch than park trees. Frequent symptoms of stress on street trees were chlorosis, small chlorotic leaves, necrosis, stem injury, dead twigs and branches, and pest attacks. For some species pests were significantly higher on street trees than in park trees. *Tilia platyphyllos* and *Tilia* x *vulgaris* had the highest ratios among the most commonly planted species. They tolerated the difficult growth conditions along streets surprisingly well, but were often attacked by linden spider-mites which can periodically be a serious problem. *Acer platanoides* and *Acer pseudoplatanus* received the lowest ratio and suffered in many cases from severe decline. *Aesculus hippocastanum* and *Betula pendula* showed intermediate fitness to street conditions. The most critical factors affecting the tree growth in the Oslo center, were de-icing salt (NaCl), stem injury due to lack of space for tree growth, pest attack, and relatively high soil pH.

Key words
Urban trees, frequency of species, vigor, causes of decline, leaf injury, and intraspecific variation.

Environmental stress in urban areas causes adverse conditions for vegetation growth. Several authors have listed critical factors such as de-icing salts, pollution of air and soil, soil compaction, limited soil space for roots, mechanical damages, diseases, and insects (8, 14, 20). Some factors may, however, interact synergisticly and tend to influence plants in a way that makes it difficult to isolate the effect of single factors (14).

In urban situations, the soil system is usually physically disturbed, compacted, or chemically altered (22, 29). The compaction of urban soil minimizes total pore space and reduces the proportion of large pores The soil surface above tree root system is commonly sealed by pavement and asphalt which causes reduced oxygen supply (35).

De-icing salt frequently causes comprehensive necrosis and early leafdrop, and is identified by several authors as a principal cause of tree damage (1, 16, 21, 25, 30, 34). Salt injury may also predispose the tree to other stress factors, such as drought and cold-temperature injury (33). Alkalization is another serious problem of the soil, often causing chlorosis and generally poor vigor (9, 19, 31, 32, 37, 40, 41).

A number of studies of vegetation in urban areas have been carried out, however, the types of abiotic and biotic stresses varies with the local environment (1, 7, 12, 13, 39). In Norway, only fragmentary surveys have been conducted, and there is need for better documentation of the fitness of different tree species exposed to environmental stress in urban areas. The aim of this study was to provide further documentation on the health status of the most important tree species, and to identify the cause(s) of reduced vitality of street trees of Oslo.

Materials and Methods

A survey of trees in streets and parks in Oslo center was carried out twice a year, in the middle of June and the beginning of September, in the years 1989, 1990, 1991, 1992, and 1993. Oslo is situated at 59° 55' N latitude and 10° 43' E longitude. The climate in this area is mainly continental with an annual precipitation of 740 mm that is evenly distributed throughout the year. The length of the growing season is about 175 days, from 22 April to 14 October. Mean temperature is -4.7° C in January and 17.3° C in July.

A total of 1243 trees were surveyed in the center of Oslo, 807 along streets, and 436 in parks. All trees located on footpaths, or within a distance of 2 meters from street edges were defined as street trees. All the chosen street sections were heavily trafficked and situated in the inner city of Oslo. Street sections were comparable in both

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traffic intensity (Annual Average Daily Traffic value 16700-29100) and environmental conditions. The mean tree age varied from 50 to 75 years. Around almost all street trees the ground was sealed by pavement or asphalt. Trees of the same species growing in parks or in public gardens were defined as park trees. These trees were used as a reference to assess differences in tree vitality between these two environments.

Table 1. Recording parameters for the study of trees in Oslo center.

Parameter	Score	Description
general impression	0	dead
	5	moderate vigor
	9	excellent vigor
leaf necrosis	0	no leaf injury
	9	severe injury on all leaves
attack by insects and/or mites	0	no attack
	9	whole crown affected
dieback of twigs and branches	0	no dieback
	9	whole crown dead
stem injury	0	no visible injury
	9	extensive and potentially lethal injury

The survey was done on the most important and frequently planted tree species along streets in the Oslo center: *Acer platanoides* L., *Acer pseudoplatanus* L., *Aesculus hippocastanum* L., *Betula pendula Roth*, *Tilia platyphyllos* Scop. and *Tilia* x *vulgaris* Hayne. The species *Prunus avium* L., *Quercus robur* L. 'Fastigiata', *Sorbus intermedia* (Ehrh.) Pers., *Tilia cordata* Mill. and *Tilia* x *euchlora* K. Koch were surveyed too, but these species were present only on few street sections. *P. avium*, *Q. robur* 'Fastigiata', and *S. intermedia* were not surveyed in 1989.

The following parameters were recorded for each tree: Location, species, total height (m), stem height (m), stem diameter (cm), general impression, leaf necrosis, attack or injury caused by insects and/or mites, dieback of twigs and branches, and stem injury. The last five parameters mentioned above were visually evaluated and given scores on a scale ranging from zero to nine (Table 1).

The general impression was not independent of the other parameters but was rather a rating of tree health. Trees which displayed excellent health (recorded as normal density and color of foliage, and good shoot extensions) were given the score nine. A tree was assigned the score three if decline had advanced to a stage where the tree had little chance of surviving in the long run even if it received attention promptly. The Pests were classified into taxonomic groups and assessed by severity of attack by insects and mites.

Leaves with different leaf injury levels were collected to provide further documentation of the causes of decreased vigor. The samples were analyzed for the following elements: Kjeldahl-N and total concentration of K, Mg, Na, P, Cl, Fe, Pb, and Cd.

During the summer of 1993, 256 leaf samples were collected from trees exhibiting differing levels of leaf scorch and chlorosis. The samples were collected June through September, from 15 trees of *A. platanoides*, 6 of *A. pseudoplatanus*, 27 of *A. hippocastanum*, and 16 of *Tilia* spp. (*T. platyphyllos* and *T.* x *vulgaris*). The total contents of Cl, Na, and K were analyzed.

Leaf samples from different positions in the tree crowns of *A. hippocastanum* street trees, were collected in August 1991. Samples were collected from the front facing the street, the opposite side, and crown top. All leaf samples were analyzed for total Cl and Pb content.

Leaf samples were put into paper bags, dried for 48 hours at 85-90°C, milled and analyzed. Total N in dry plant material was analyzed by the Kjeldahl method. To analyze the concentrations of K, Mg, Na, P, Fe, Cd, and Pb, 1 g dry-ash plant materials were digested in 10 ml aqua regia, dried, and 2.5 ml nitric acid (HNO_3) added. The samples were then diluted to 50 ml and analyzed by Inductively Coupled Spectroscopy (ICP) except for Cd which was analyzed by Atomic Absorption Spectrometry (AAS). To analyze the chloride concentration, bicarbonate was added to 1 g plant materials and dry-ashed before being neutralized with nitric acid and diluted in water: The chloride

Table 2. Mean scores for species frequently used as park and street trees in Oslo, 1989-1993.

Species	General impression		Leaf necrosis		Pest attack		Dieback of twigs and branches	
	Street	Park	Street	Park	Street	Park	Street	Park
A. platanoides	4.9c	6.4ab	2.0b	0.2b	0.5d	2.0b	2.4a	0.2a
A. pseudoplatanus	4.7c	6.7ab	2.7a	0.1b	1.1c	1.3b	2.4a	0.0a
A. hippocastanum	5.8b	7.2a	3.3a	0.3ab	0.1e	1.0b	0.4c	0.0a
B. pendula	5.7b	5.9b	0.5c	0.6a	0.3d	0.0c	1.0b	0.1a
T. platyphyllos	6.5a	6.5ab	0.1c	0.1b	3.9a	3.8a	1.1b	0.0a
T. x vulgaris	6.5a	6.3b	0.1c	0.0b	3.1b	2.9a	1.1b	0.2a
Mean (weighted)	**5.8**	**6.5**	**1.7**	**0.2**	**1.3**	**1.9**	**1.1**	**0.1**

- Scale 0-9
- Values followed by the same letter within a column are not significantly different at p=0.05

concentration was detected by Ion Chromatography (IC). The concentrations of the different elements were expressed as follows: Fe, Pb, and Cd as mg/kg and the other elements as g/kg leaf dry weight.

Soil samples were analyzed for pH, total content of Pb, and plant available (ammonium-lactate-extractable fraction (AL)) P, K, Mg, Ca and Na. Lead concentration was analyzed as described for the leaf samples (6). The chemical element concentrations are expressed as mg/l soil dry weight.

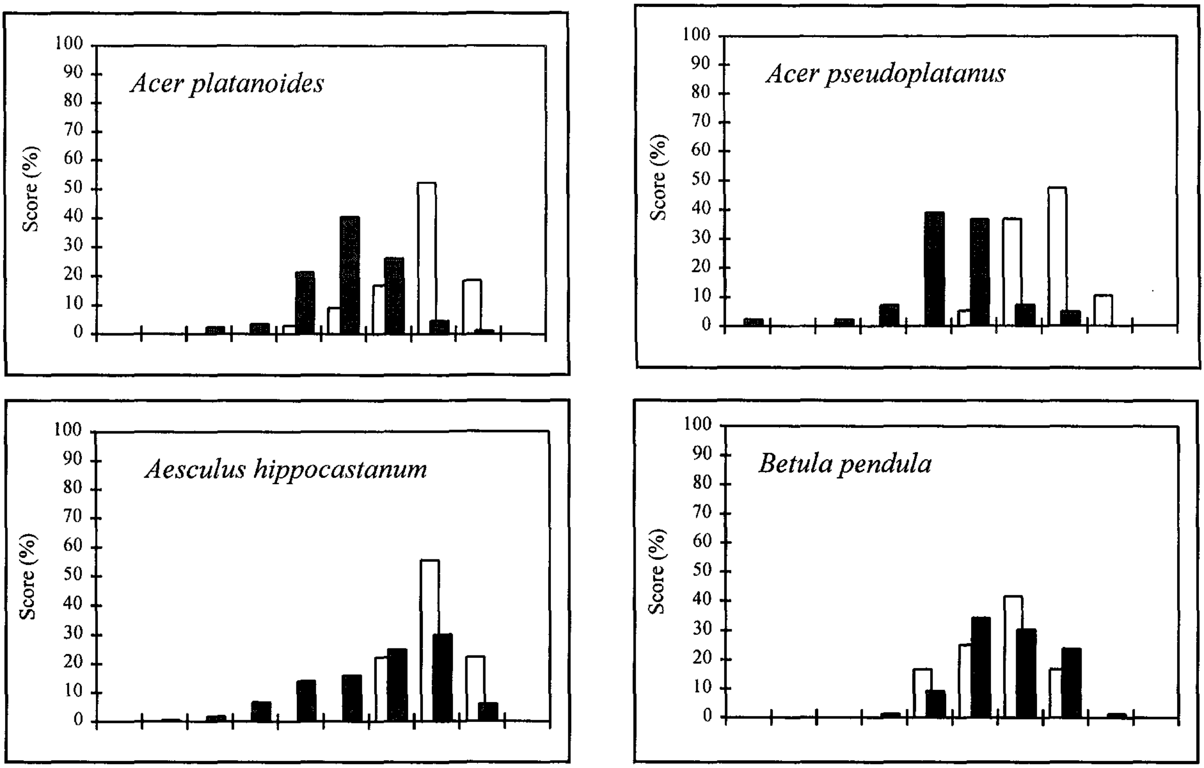
An analysis of variance F-test of unbalanced data was carried out according to the methods described in SAS Institute (27) bulletin. The Ryan-Einot-Gabriel-Welsh (REGWQ) multiple-range tests were carried out with a 5% significance level.

Results

Frequency of species. Of the total population of 1243 trees, three genera accounted for over 66% of the total number of species in the street environment. The most frequently recorded species were *Tilia* spp. (*T. platyphyllos* and *T.* x *vulgaris*) which represented almost 30% of the trees, followed by *A. hippocastanum* with 19%, and *A. platanoides* with 18%. These four tree species also dominated in parks, accounting for 45% of the sample population of park trees. *A. pseudoplatanus, B. pendula, P. avium, Q. robur* 'Fastigiata', and *S. intermedia* were represented with 6, 10, 2, 9, and 9% in street environment respectively. Only a few individuals of *T.* x *euchlora* and *T. cordata* were observed.

Total height and stem height and stem diameter. The average height of trees varied between the street and park environments, 11.3 m and 19.2 m respectively. *B. pendula* had the highest mean value for total height (17.2 m), while the *Acer* spp. had relatively low heights in both environments. *Tilia* spp. had about the same height as *A. pseudoplatanus* along streets, while they were taller in parks. *A. hippocastanum* had the lowest mean height of all surveyed species along streets. Stem height was not significantly different between the two environments. The greatest height of all genera along streets was found in *A. hippocastanum*. Stem diameter was significantly greater in parks than in streets, 45.2 cm and 36.1 cm respectively.

General impression of the trees in the Oslo center. Reduced growth and vitality were common in street trees. Nearly all species were less vital along streets than in parks. Almost 18% of the trees along streets were in poor health (score 1-4) while 40% of the trees had excellent health (score 7-9). In parks only 1% of the trees had poor health, while 76% had excellent health. A great proportion of the street trees had distinct visible symptoms related to specific health parameters.



These parameters influence the general impression of the trees and are presented in Table 2. The most important parameters which contribute to a reduction in general impression were the following: *Acer* spp., leaf injury and dieback of twigs and branches; *A. hippocastanum*, leaf injury; and *Tilia* spp., attack of insects and mites. The other species showed no particular parameters which contribute to a reduction in general impression.

There were clear differences in the general impression scores between tree species with; *A. platanoides* and *A. pseudoplatanus* receiving the lowest vigor rating among the street trees (Table 2). *A. pseudoplatanus* was even less fit for the street environment than *A. platanoides*. Symptoms such as small chlorotic leaves, leaf edge necrosis in part of the crown, and dead twigs and branches were common on these species. *B. pendula* and *A. hippocastanum* showed intermediate health.

Tilia platyphyllos and *T.* x *vulgaris* had the best scores among the street trees. These species showed high tolerance to the street environment. *T.* x *vulgaris* showed a surprising adaptation, being less vigorous in parks than along streets.

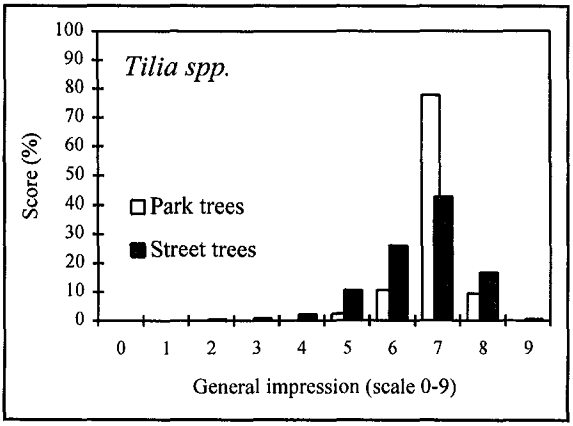


Figure 1. General impression of tree vitality in Oslo center 1990 by percentage distribution.

The less frequently planted street species *P. avium*, *Q. robur* 'Fastigiata', *S. intermedia*, *T. cordata*, and *T.* x *euchlora* were of good health. The mean general impression scores were 6.3, 6.1, 6.7, 6.0, and 7.0, respectively. There were no significant differences in general impression between June and September, and from 1989 to 1993.

Table 3. Variation in street tree leaf edge necrosis during survey period 1989-1993.

Species	1989 Mean	SD	1990 Mean	SD	1991 Mean	SD	1992 Mean	SD	1993 Mean	SD
A. platanoides	2.1b	1.6	2.3b	1.6	2.5b	2.1	1.5c	1.9	1.4b	1.6
A. pseudoplatanus	2.8a	1.9	3.5a	2.4	3.4a	2.7	2.3b	1.8	1.7b	1.7
A. hippocastanum	3.1a	2.1	3.3a	3.2	3.0ab	2.6	3.9a	2.8	2.8a	2.8
B. pendula	0.3c	0.6	0.8c	1.7	0.3c	0.8	0.0d	0.0	0.0c	0.0
T. platyphyllos	0.3c	0.5	0.1c	0.5	0.1c	0.3	0.0d	0.2	0.0c	0.0
T. x vulgaris	0.2c	0.4	0.3c	0.7	0.0c	0.0	0.0d	0.2	0.0c	0.0
Mean (weighted)	**1.7**	**2.0**	**1.9**	**2.6**	**1.6**	**2.4**	**1.9**	**2.6**	**0.6**	**1.2**

- Scale 0-9
- Values followed by the same letter within a column are not significantly different at p=0.05
- SD-standard deviation

The total proportion of dead trees amounted to 0.3% of the whole sample population. Dead street trees were most frequently observed for A. pseudoplatanus (2.4%).

The variation in species vitality among street and park environments were quite different. For most species, street tree health was more variable than park trees, (Figure 1) and individuals with poor health were more frequent along streets than in parks. *A. platanoides* showed a broad variation in health in both environments. *A. pseudoplatanus* on the other hand was somewhat more homogeneous in parks. Among the individuals of *A. hippocastanum* there was a broad variation of health on streets, but little variation in parks. This species had a higher percentage of individuals in the seven to nine general impression range. *Acer* spp. *B. pendula*, *T. platyphyllos*, and *T.* x *vulgaris* on the other hand were relatively homogeneous and got high scores in both environments. In all species, individuals that were well adapted to the street environment were registered.

P. avium, *S. intermedia*, *T.* x *euchlora* and *T. cordata* were homogeneous in adaptation to both environments. Poor health and extensive leaf injury were registered only in situations with extremely poor growth conditions. *Q. robur* 'Fastigiata' clones exhibited considerable variation in growth and health mostly due to pest attack.

Leaf necrosis. In parks there was little foliar damage on surveyed trees. Among street trees there was 57% visible leaf necrosis. Severe damage (7-9) was registered on 13% of the trees while 30% were moderately damaged (1-3). *A. platanoides* and *A. pseudoplatanus* were severely injured and had the highest proportion of leaf injured trees. As much as 86% and 83% of *A. platanoides* and *A. pseudoplatanus*, respectively, were significantly injured. Small yellowish leaves and leaf edge necrosis was common on these species. Just over 70% of the *A. hippocastanum* individuals had visible leaf injury. Heavy necrosis on leaf edges and small necrotic leaves were frequent on this species too, but variation within this species was greater. Some individuals of this species had no leaf scorch and were of excellent health. Species of *B. pendula*, *P. avium*, *S. intermedia*, and *Tilia* spp. exhibited no leaf injury. *Q. robur* 'Fastigiata' was totally free of foliar damage. *Tilia* spp. and *S. intermedia* leaf injury was observed only on extremely poor areas for tree growth.

The mean values of leaf scorch showed only a minor variation from 1989 to 1992, with some reduction in 1993 (Table 3). *A. pseudoplatanus* and *A. hippocastanum* had the most severe foliar damage, while *B. pendula* and *Tilia* spp. got the lowest leaf injury score in all years.

P. avium and *S. intermedia* showed minor leaf injury (mean 0.4) in 1990 and no leaf injury in other

Table 4. Street tree attack by insects and mites from 1989 to 1993.

Species	1989 Mean	1989 SD	1990 Mean	1990 SD	1991 Mean	1991 SD	1992 Mean	1992 SD	1993 Mean	1993 SD
A. platanoides	1.4c	1.6	0.9d	1.0	0.1b	0.3	0.3c	0.8	0.0d	0.0
A. pseudoplatanus	2.1b	0.9	2.5c	1.0	0.0b	0.0	0.1c	0.3	1.0c	1.0
A. hippocastanum	0.2d	0.7	0.0e	0.0	0.0b	0.0	0.0c	0.0	0.0d	0.0
B. pendula	0.2d	0.7	0.6d	1.4	0.1b	0.4	0.0c	0.0	0.0d	0.0
T. platyphyllos	4.3a	1.4	6.8a	1.7	2.2a	1.6	2.5a	1.7	4.1a	2.0
T. x vulgaris	4.0a	1.3	4.6b	2.4	2.1a	1.0	1.7b	1.1	2.9b	1.7
Mean (weighted)	**1.8**	**2.0**	**2.2**	**2.8**	**0.7**	**1.2**	**0.8**	**1.3**	**2.2**	**2.2**

- Scale 0-9
- Values followed by the same letter within a column are not significantly different at p=0.05
- SD-standard deviation

years of the survey period. *Q. robur* 'Fastigiata' foliar damage (mean 0.1) was noticed only in 1991. *T.* x *euchlora* and *T. cordata* had no leaf injury at all.

The degree of leaf injury varied during the growing season for all species. Symptoms were more severe in September than in June. *A. platanoides, A. pseudoplatanus,* and *A. hippocastanum* showed the highest percentage of injured trees in September. *B. pendula* and *Tilia* spp. showed no symptom during the course of the summer.

Attack by insects and mites. For some species the attack by insects and/or mites varied between the two environments. Forty-seven percent of the trees were attacked by insects and mites. Severe attacks were observed in 15% of the street trees but only in 1% of the park trees. *A. platanoides*, *A. pseudoplatanus*, and *A. hippocastanum* were more severely attacked in park environments than on streets (Table 2). Among the other species there were no significant differences between the two environments.

T. platyphyllos and *T.* x *vulgaris* had the heaviest pest attack of all species along streets and *T. platyphyllos* were significantly more injured than *T.* x *vulgaris*. *A. hippocastanum* and *B. pendula* exhibited only minor attacks (Table 2 and 4). Pest attack on *A. platanoides* and *A. pseudoplatanus* varied from year to year. *T. cordata* and *Tilia* x *euchlora* had minor attacks in all years.

Q. robur 'Fastigiata' was attacked by pests in the years of 1990 and 1991, but had no attacks in 1992 and 1993. *P. avium* was attacked only in 1990 and *S. intermedia* had no attack at all during the survey period. There was a significant interaction between species and year of survey.

The following insects and/or mites were found on the species: *A. platanoides - cicada* (Empoasca), *A. pseudoplatanus* - aphids and cottony maple scale (*Aceria pseudoplatani*), *A. hippocastanum* - cicada, *B. pendula* - aphids, *P. avium* - aphids, *Q. robur* 'Fastigiata' - dwarf aphids in the family of *Phylloxera* along streets and aphids in parks, *S. intermedia* - cicada, *Tilia* spp. - linden spider-mite (*Eotetranychus telarius*).

Nearly 100% of the linden trees were attacked in both environments. The heaviest attack by linden spider-mite on *T. platyphyllos* and *T.* x *vulgaris* was recorded on streets trees. While as much as 43% of the street trees suffered from severe attacks, only 5% of the park trees were attacked. Severe attack of linden spider-mite on trees situated along streets caused leafdrop by the end of June.

Dieback of twigs and branches. Dieback of twigs and branches varied between the park and street environment, as well as among the observed species. Dieback was more extensive in street trees than in park trees (Table 2), and it

Table 5. Contents of foliar elements in leaves from *A. platanoides*, *A. hippocastanum*, and *Tilia* spp. in the street and park environment (1991).

	g/kg dry wt.					mg/kg dry wt.			
	N	P	K	Na	Mg	Cl	Pb	Fe	Cd
STREET TREES:									
A. platanoides	16.8c	2.0a	17.6a	0.3b	1.9b	8.6b	8.6b	193.3b	0.10a
A. hippocastanum	19.0b	1.7a	14.9ab	4.9a	2.2b	13.5a	6.0b	281.7b	0.03b
Tilia spp.	24.2a	1.8a	12.5b	0.9b	3.7a	6.1b	11.2a	474.4a	0.05b
PARK TREES:									
A. platanoides	19.8b	1.5a	10.2a	0.2a	2.1b	2.6a	1.7b	120.7b	0.08a
A. hippocastanum	25.2a	2.0a	11.1a	0.2a	2.9b	1.3b	2.6a	221.0a	0.03b
Tilia spp.	27.8a	1.7a	10.2a	0.2a	4.0a	2.5a	2.8a	211.7a	0.04b

- Values followed by the same letter within a column are not significantly different at p=0.05.

was especially pronounced on *A. platanoides* and *A. pseudoplatanus*. The other species had negligible dieback. Dieback varied from year to year but there was no general tendency of increasing dieback during the survey period.

Stem injury. Most stem injuries were located on the lowest part of the tree. The injuries occurred as an open wound into the xylem and in some cases had caused serious decay. Stem injury on street trees was extremely frequent. In Oslo 49% had visible stem injury and 2.2% of the trees exhibited severe stem injury with little chance to become restored. In most cases injuries were caused by vehicles. In some areas newly planted young trees had stem injuries caused by the protection stand around the stem.

Chemical analysis of leaves and soil. The chemical contents of leaves varied with type of environment, species, and individuals within a species. The foliar content of K, Mg, Fe, Pb, Na, and Cl were significantly higher in street trees than park trees. The content of N, P, S, and Cd were not significantly different between the two environments. The concentration of Na increased from June to July becoming constant in late summer. Both the Cl and Fe content in leaves increased throughout the growing season.

There were significant differences among *A. platanoides, A. hippocastanum*, and *Tilia* spp. (*T. platyphyllos* and *T.* x *vulgaris*) street trees with respect to the content of N, K, Na, Mg, Cl, and content of Fe and Cd (Table 5). A. hippocastanum had the highest contents of Na and Cl, while the *Tilia* spp. had the highest contents of Pb and Fe. There were no differences between the two species of *Tilia*.

An increased content of Na was noted in *A. platanoides, A. pseudoplatanus*, and *A. hippocastanum*, averaging 0.01% of dry weight. Leaves of *A. hippocastanum* had a significantly lower content of Cl (7.3 g/kg) in June than the other months (14.2 g/kg). *A. platanoides, A. pseudoplatanus*, and *Tilia* spp. showed the lowest Cl content in June.

The chloride content in leaves of *A. hippocastanum* correlated closely with the leaf injury score (Figure 2). The highest content was found in the most severely injured leaves. There were no significant difference in Cl between leaves with slight necrosis and leaves with no visible symptoms. The content of Cl in *A. hippocastanum* leaves was significantly higher on the sunnier eastern side (19.0 g/kg), than on the shadow side (12.4 g/kg) of the street. The content of Cl seem to have an even distribution in the whole crown.

Table 6. pH and chemical contents (mg/l dry weight) in soil collected along streets and parks in the Oslo center.

	pH	Pb	K-AL	Mg-AL	Ca-AL	Na-AL	P-AL
Streets	7.2	181	212	185	6727	77	192
Parks	6.4	71	270	161	2985	22	128

- Mean content of the year 1989 and 1990

The Na content also increased with increasing leaf injury. Severely injured and moderately injured leaves had significantly higher content of Na than those with minor damage.

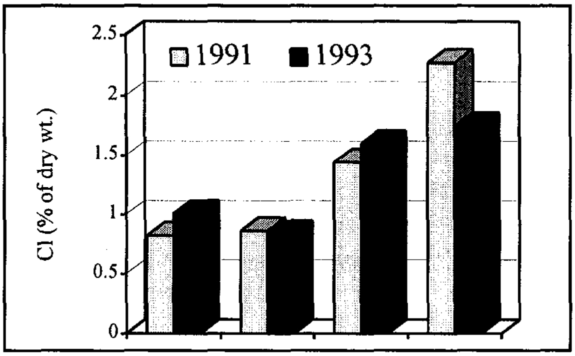
The soil concentration of Pb, Mg, Ca, Na, and P were higher along streets than in parks, but the content of K was higher in parks (Table 6). pH was significantly higher along streets than in parks, averaging 7.2. The concentration of P, K, Mg, and Ca were good for plant growth. Lead concentration was relatively high along streets, averaging 3.5 times higher than in parks.

Discussion

The study of the trees in Oslo center revealed significant differences in health status between park and street trees, as well as variation within species along streets. All species suffered from different stresses expressed by susceptibility to certain environmental stress factors. Limited street tree diversity may reflect a well planned tree planting system in which only the best adapted species are chosen, but is not the case in Oslo. Species composition is rather a result of tradition. This tradition has so far not ensured that the less suitable species be taken out of use.

Some species along streets in this study have very large crown volume at mature age, producing problems in narrow streets. To reduce the need for pruning and to avoid stem injuries, smaller or columnar trees are preferred. *Q. robur* 'Fastigiata' has such a suitable growth form. This study implies that choice of tree species for urban areas should be based on the need for both aerial and soil space, as well as tolerance to urban pollutants.

Tilia spp. was the most vigorous and frequently used tree species in Oslo center. Reduced vitality and severe leaf injury were observed only in the most unfavorable places, such as small traffic



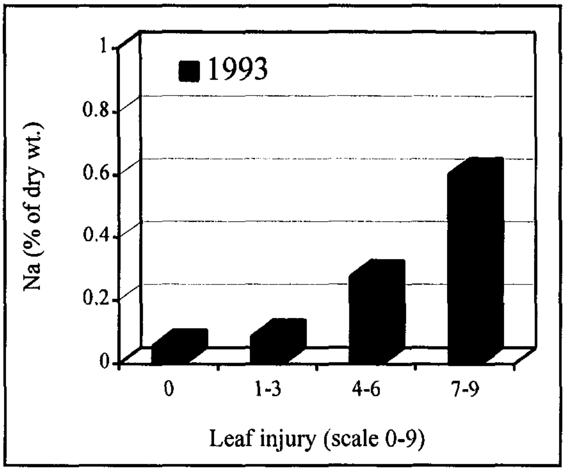


Figure 2. Foliar contents of chloride and sodium (percent of dry weight) in *A. hippocastanum* among different injury groups. Mean value of samples from two months in 1991, and four months in 1993.

islands. Attack by linden spider-mite were frequent, and may represent a serious weakening. *Acer* spp. and *B. pendula* were less tolerant of the street environment than *Tilia* spp. Beatty & Heckman (2) found these three genera to be the most tolerant of extreme urban conditions, while Petersen & Eckstein (23) concluded that the *Tilia* spp. and *Acer* spp. were among the most sensitive of nine tree species in Hamburg, Germany. *Tilia* spp. lost some of its popularity in London because of honey dew drip and its large size (17). We noted little honey dew drip, but *Tilia* tree size was sometimes unacceptable because of lack of space. In general this genus seems to be well fitted to the street environment. The *B. pendula* individuals along streets gave a good general impression and did not seem to be strongly affected by stress factors.

A. platanoides and *A. pseudoplatanus* expressed the lowest vitality of the surveyed species. There was a significant relationship between content of chloride in leaves, leaf injury, and degree of dieback of twigs and branches. Extensive application of de-icing salt are implicated. A number of investigators have reported similar negative effects of soil salts on tree health (21, 33, 38). Berrang et al. (1) found that soil salt was the most critical factor relating to poor tree health. This corresponds with the observations on *Acer* spp. in Oslo, but no other genera showed a relationship between leaf injury and dieback of twigs and branches. Since de-icing salt is usually defined as a main cause of street urban tree decline, one might expect gradually increasing dieback of twigs and branches. However, no such correlation was found in our study.

The clear relationship between degree of leaf injury and content of chloride in the leaves corresponds well with the studies of Dirr (4), Holmes (10), Holmes & Baker (11), and Shaw & Hodson (28). The content of sodium was not as well correlated to leaf injury as the chloride content. Elevated sodium levels were reached only in severely damaged leaves. Holmes & Baker (11) also found that sodium content is generally lower and more variable than chloride content.

De-icing salts have probably lead to a rapid weakening of *A. hippocastanum* individuals. *A. hippocastanum* appears to be intermediate in its ability to tolerate the sodium and chloride of de-icing salt. Similar observations have been made by Sanda (26).

Our study indicates that a considerable part of variation in decline may be related to genetic differences among individuals, and that the differences in fitness is more pronounced under harsh street conditions.

Tilia spp. are the most homogeneous adapted species in both park and street environments, while individuals of *Acer* spp. exhibited the most heterogeneous adaptation. Both species of the genus *Acer* showed great differences in health between the street and park environment. *A. pseudoplatanus* was the most heterogeneous species of this genus. Within these species there are some individuals which are more tolerant to the street environment than others. These individuals should be evaluated further and tested as a seed source for suitable street trees. The wide variability within *A. hippocastanum* may also reflect a genetic potential for selecting well adapted seed sources. Among the individuals of *B. pendula* and *Tilia* spp. there were small variations in vitality. There may be somewhat less potential for selection in these species.

The severity of insect or mite attacks were different between the two environments. *A. pseudoplatanus, B. pendula* and *Tilia* spp. suffered the most heavy attacks in street environments. Braun & Flückiger (3), Dohmen (5), and Kropczynska et al. (15) similarly found increased attack of aphids and linden spider-mites on trees exposed to stress factors such as air pollution, drought, and de-icing salts. Linden spider-mite severity was determined to be serious since populations were high. The long term effect of repeated attack is a weakening of the tree system. This tendency of greater attack among stressed trees appeared not to be true for *Acer* spp. and *A. hippocastanum*, as they suffered from the severest attacks in park environments.

Injury on the tree stem contributed to a reduction in vigor. To reduce this problem, methods of protection must be developed. Putting resources into the selection and production of well adapted street trees is almost meaningless unless protection from stem injury is also achieved.

The soil pH along streets were higher than urban park soils. This may represent a contributing factor to the reduction of tree health along streets. According to Messenger (18) and Ware (37) soil alkalinity, caused by calcium carbonate ($CaCO_3$) in pavement and de-icing salts, is commonly a limiting factor for the growth of urban trees. High soil pH may represent a long term problem even if precipitation pH is quite low.

The bulk density or compaction of the soil was not studied in Oslo center. This factor could be another serious restriction to tree vitality by inhibiting root development (24) or by causing mineral and water deficiencies (36, 40).

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Résumé. Une évaluation sur cinq ans de la condition des arbres dans la ville d'Oslo en Norvège a été réalisée à partir de 807 arbres de rues et de 436 de parcs. La condition de l'arbre, sa vigueur et les causes possibles de dépérissement ont été évaluées pour chaque individu. Les arbres de rues ont une santé plus faible, présentent plus fréquemment des problèmes de parasites et comportent des brûlures foliaires plus sévères que les arbres de parcs. Les symptômes fréquents sur les arbres de rues sont de petites feuilles chlorotiques, des nécroses, des blessures aux troncs, des ramilles et des branches mortes, et la présence de parasites. *Tilia platyphyllos* and *Tilia* x *vulgaris* sont les espèces les plus performantes parmi les arbres de rues, suivies par *Aesculus hippocastanum* et *Betula pendula*. *Acer platanoides* et *Acer pseudoplatanus* ont été jugés les moins bonnes, et, dans plusieurs cas, souffraient de sévères dépérissements. Les contraintes les plus critiques sur la santé des arbres de rues sont le sel de déglaçage, les blessures aux troncs par manque d'espace de croissance, les parasites et le pH élevé du sol.

Zussammenfassung. In Oslo, Norwegen wurde eine fünfjährige Überprüfung der Baumgesundheit an 807 Strassen- und 436 Parkbäumen durchgeführt. Für jeden Baum wurde die Gesundheit, Vitalität und mögliche Gründe für ein Absterben untersucht. Die Strassenbäume hatten eine geringere Vitalität, häufigeren Insektenbefall und mehr ernste Blatterkrankungen als Parkbäume. Häufige Symptome an Strassenbäumen waren schmale, chlorotische Blätter, Stammverletzungen, tote Zweige und Äste und Schadinsekten. *Tilia platyphyllos* und *Tilia* x *vulgaris* erwiesen sich als die gesündesten unter den Strassenbäumen, gefolgt von *Aesculus hippocastaneum* und *Betula pendula. Acer platanoides* und *Acer pseudoplatanus* wurden als schlechteste Bäume eingestuft und litten in vielen Fällen an massiven Absterbeerscheinungen. Die meisten ernsthaften Schadenskomponenten bie Strassenbäumen waren Streusaliz, Stammschäden wegen zu klein bemessener Standräume, Schadinsekten und hoher Boden-pH.