Proc Estonian Acad. Sci. Biol., 1994, **43**, 3, 160—172
https://doi.org/10.3176/biol.1994.3.05

DISTRIBUTION AND FROST DAMAGES OF CHINESE POPLAR (*POPULUS SIMONII* CARR.) IN TALLINN (NORTHERN ESTONIA)

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Received February 18, 1994; accepted February 28, 1994

Abstract. The aim of this study is to analyse the historical and present distribution of the Chinese poplar in Tallinn, their age, dimensions and frost damages of trees due to the cold winter in 1986/87.

As 527 trees of the registered 530 turned out to be cultivars of the Chinese poplar (*P. simonii* 'Fastigiata'), it is to them that attention has mostly been paid. Although this cultivar is an acclimatized taxon in Estonia, it still suffers from frost damage in severe winters, and many trees perish.

The most severe winter in recent years was that of 1986/87, when the temperature dropped to —31.4 °C in Tallinn, and more than 1/3 of the trees perished. This research aims to describe perishing of poplars due to frost in relation to types of habitats and dimensions of trees.

Key words: Chinese poplar and its cultivar, distribution, dimensions and frost damages of trees.

INTRODUCTION

As a result of the fact that green areas have been created in towns for centuries, many alien species have become acclimatized in the urban environment. This is especially true for northern towns where some plants of southern origin have turned out to be relatively frost-hardy. But several of them, known as frost-hardy at the first glance, suffer severely from extremal winters when temperatures are very low.

One species that is rather widely distributed in Estonia is Chinese poplar (*Populus simonii*) and its cultivar (*P. simonii* 'Fastigiata') which has been cultivated in Estonia for more than 60 years. As this species is more widely distributed in towns, it has been less damaged during especially cold winters there. Below, the distribution and frost damages of this species in Tallinn will be analysed.

The problem of the frost-hardiness of woody plants is discussed in a number of papers, more thoroughly in the surveys by C. J. Weiser (1970) and J. Levitt (1980).

STUDY AREA, CLIMATE, MATERIAL AND METHODS

Study area. Tallinn is a small city in northern Estonia with an administrative area of 158.3 km² and 443 000 inhabitants (January 1994). The territory is divided into densely and sparsely built-up areas of high and low buildings (about 60%), here called "urban" and "suburban" zones, and a town border zone (non-built-up area), here called "periurban" zone.

Climate. The subject area lies at the northern border of hemiboreal vegetation zones (Ahti et al., 1968). A comparison of 100 European cities showed that Tallinn together with Oslo, Stockholm, Helsinki, St. Petersburg, and Riga belongs to a group treated as the maritime Baltic cold "subclimaton" (Hubalek, Horakova, 1991).

The mean air temperature in Tallinn (1881—1975) is 16.6 °C in July, ranging from 13.0 (1902) to 20.8 °C (1914), and —5.3 °C in January, ranging from 1.2 (1925) to —15.8 °C (1942). But the lowest mean air temperature has been in February (—6.0 °C) which usually is the coldest month of the year (Климат Таллина, 1982). The minimum mean air temperature was registered in February, 1872, (Old Town) when it dropped to —16.2 °C (Tarand, 1975).

A more or less stable cold period lasts for 73 days. The longest cold period (temperature continuously below 0 °C) was in the winter of 1941/42 — 76 days. Within the period from the first autumn day until the last spring day when the air temperature did not rise above 0 °C, there were 13 frosts and 12 thaws (Maanvere, 1976).

The lowest absolute air temperature measured in Tallinn was —32.2 °C (30 December, 1978). Still, the temperature in the Old Town was 5—7 °C warmer (Tarand, 1986). The absolute minimum temperature and mean temperature was low also in the winter of 1986/87, falling to —31.4 °C and —13.8 °C (January, 1987), and in well-known cold winters of 1939/40 and 1941/42 (Fig. 1). The winter of 1986/87 was one of the coldest of recent seven years (Климатологический справочник, 1954; Метеорологический ежемесячник, 1987, 1988, 1989, 1990; date of Institute of Hydrology and Meteorology in 1993).

The mean amount of precipitations in 1891—1975 was 550 mm, ranging from 362 mm (1900 and 1901) to 813 mm (1923) (Климат Таллинна, 1982). Thickness of snow cover ranged in 1920—1982 from 1—2 cm (in winters of poor snow) to 38—45 cm (in snowy winters). The mean height of snow cover of 60 years was 14—16 cm ($\delta = \pm 11$ cm). The maximum height of snow cover was measured in 1941/42: 61 cm (Tarand, 1986).

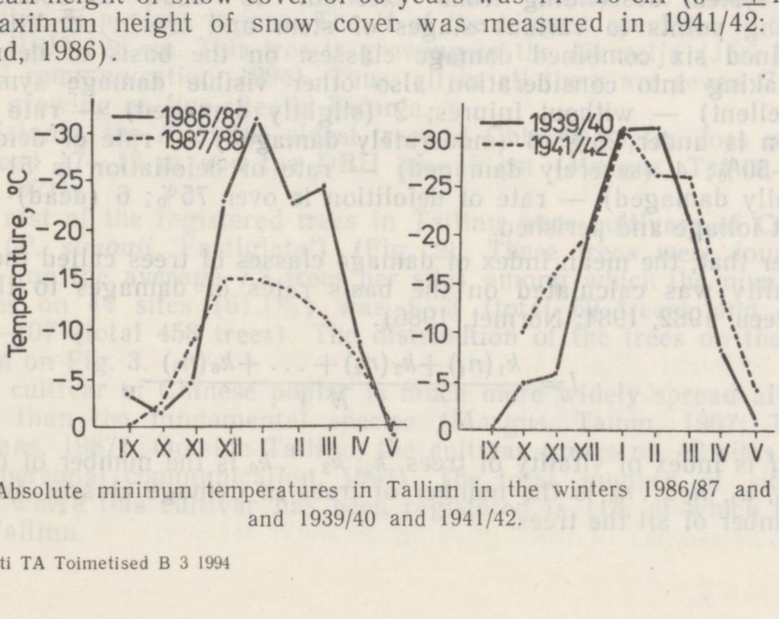

Fig. 1. Absolute minimum temperatures in Tallinn in the winters 1986/87 and 1987/88 and 1939/40 and 1941/42.

It could also be noted about the winters (December-March) going back to 1757 that, by the data of mean air temperatures (Tallinn, Maarjamäe), the warmest winter was in 1960/61 (5 °C) and the coldest in 1928/29 (—11.3 °C). Classification by standard deviations has revealed that 7% of winters are very cold, 23% cold, 39% normal, 26% warm and 5% very warm (Eensaar, Tarand, 1991).

City center is known to be warmer and less humid than the surrounding areas; and certain microclimatic differences can exist due to variations in the topography and distance from the sea (Tarand, 1974, 1986).

The influence of heat-veil on the air temperature is especially strong on frostry days when the cold and dry air near the ground becomes even colder due to an intense and effective emission of rays. The maximum differences between the Old Town and the Ülemiste meteorological station to the south of Tallinn were registered in 1977/79. On 13—14 February, 1977, the differences amounted to 10.9 and 9.8 °C (Tarand, 1986). Route measurements on 18 January 1977 showed a temperature contrast of 6.3 °C (from —10.9 to —14.4 °C) between the western and eastern part of Tallinn, and 0.6 °C (from —13.8 to —14.4 °C) between the northern and southern parts (Климат Таллина, 1982).

Extrapolating the results of episodic measurements in Tallinn according to wind directions and velocities, the average registered intensities of heat-island amounted to 1.6—2.1 °C in winter and 1.0 °C in summer (Tarand, 1986).

Material and methods. In August and September, 1987—1991, all the trees of Chinese poplar growing in Tallinn were registered. During field studies the breast perimeter at the height of 1.3 m (PBH) and the height (*H*) of all the trees were measured. If found necessary, also the diameter (DBH) of the trees was calculated. In addition, sites of trees were registered, insect injuries detected and frost damages of trees estimated.

The sites of trees were grouped by location, functions, character of vegetation and human influence. In a wider sense we can regard them as various types of urban habitats which differ from each other by environmental conditions.

The injures of the trees were rated on a 6-degree scale which is determined by a visual damage picture (Heinrich, Klotz, 1980). The rating system descending from "excellent" to "dead" is obtained by assigning points to various stages of stem and crown condition. We determined six combined damage classes: on the basis of defoliation rate, taking into consideration also other visible damage symptoms. 1 (excellent) — without injures; 2 (slightly damaged) — rate of defoliation is under 25%; 3 (moderately damaged) — rate of defoliation is 26—50%; 4 (severely damaged) — rate of defoliation is 51—75%; 5 (fatally damaged) — rate of defolition is over 75%; 6 (dead) — tree without foliage and perished.

After that, the mean index of damage classes of trees called the index of vitality was calculated on the basis rates of damages to the tree (Алексеев, 1982, 1984; Normet, 1986).

$$I = \frac{k_1(n_1) + k_2(n_2) + \ldots + k_6(n_6)}{N},$$

where I is index of vitality of trees, k_1, $k_2 \ldots k_6$ is the number of damage classes, n_1, $n_2 \ldots n_6$ is the number of trees in damage classes and N is the number of all the trees.

It should also be mentioned that in the assessment of each tree stem and crown the character of environmental stresses is reflected which, in our case, was mainly all the winter stress of 1986/87 and the previous condition of the trees.

In addition, the rutting of tree crowns at a 2-point scale was assessed. Pruned trees were treated separately.

When calculating the phytomass of trees, we proceeded from the volume of single trees found on the basis of their thickness and height, to which the approximate volume of branches and leaves was added (calculated as 20% of trunk volume). Phytomass in dry matter tons was calculated on the basis of the volume weights of the raw mass and dry mass of poplars (0.78 and 0.38 g/cm³, respectively) (content of dry matter 49%) (Rauk, 1986).

Detailed data on the research materials can be found in other papers by the same author (Sander, 1990; Sander, Eensaar, 1990).

RESULTS

History and distribution. By the existing data, Chinese poplar *(Populus simonii* Carr.) came to Estonia in the second half of the 1920s and was more widely distributed by nursery gardens and horticultural institutions in the 1930s (Mathiesen, 1934, 1938). The cultivar of Chinese poplar (*P. simonii* 'Fastigiata') was distributed much more than the species, as can be seen from the sale lists of plants originating from the 1930s.

These trees began to spread also in Tallinn in the 1930s. There exist data from the second half of the 1930s, when most of the trees of that time were planted. Therefore, the oldest Chinese poplars in Tallinn are 55—60 years old (Sander, Eensaar, 1990).

In 1987—1991, 530 trees were registered in Tallinn of which only three were the fundamental species of Chinese poplar. These trees are growing in the garden suburb of Nõmme in two sites and have the following dimensions: 1 — *H* 17.0 m and PBH 88 cm, 2 — 17.7 m and 86 cm, 3 — 23.0 m and 205 cm (Jan. 25, 1994). The latter is the oldest, planted in the 1930s. It is also the largest Chinese poplar in Estonia.

In Finland, the *H* of the largest tree is 25.5 m and PBH 190 cm (Aug. 23, 1988) (Karhu, 1989).

Outside Tallinn other three sites of Chinese poplar are known where the number of poplars is four. The *H* of the biggest specimen is 20.5 m and its PBH 128 cm. This tree is growing in the Järvselja (Jüri Elliku, personal communication, 1994). Thus, all in all there are seven Chinese poplars growing on five sites in Estonia.

In Estonia, the *H* of the oldest trees of Chinese poplar does usually not exceed 17—19 m and the DBH 35—45 cm (Margus, Tamm, 1967; Tamm, 1971).

The rest of the registered trees in Tallinn were cultivars of Chinese poplar (*P. simonii* 'Fastigiata') (Fig. 2). These trees were found on 72 sites (on the average 7.3 trees per site) among which the number of the trees on 44 sites (61.1%) was 1—3 (total 69 trees) and on 28 sites 4—107 (total 458 trees). The distribution of the trees on the sites is shown on Fig. 3.

This cultivar of Chinese poplar is much more widely spread all over Estonia than the fundamental species (Margus, Tamm, 1967; Tamm, 1971; Laas, 1987). Outside Tallinn, the cultivar grows on 42 sites (Jüri Elliku, personal communication, 1994). The total number of sites in Estonia where this cultivar has been registered is 114, of which 63.2% are in Tallinn.

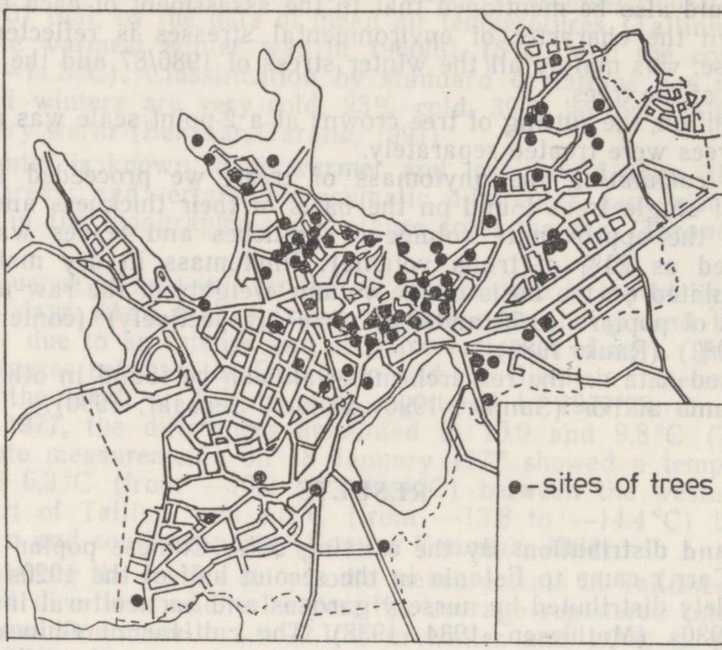

Fig.2. Distribution of sites of Chinese poplar (*Populus simonii* 'Fastigiata') in Tallinn.

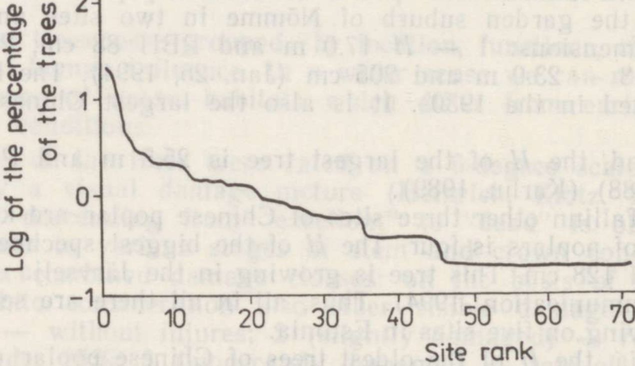

Fig. 3. Number of trees (log %) on sites.

In Helsinki (Finland), which lies to the north of Tallinn, there are only six trees of this cultivar (Karhu, 1986).

The trees registered in Tallinn grow within the boundaries of 11 categories of land use and six types of habitats (Table 1). The greatest number of trees grow at street sides — 172 trees (32.6%), followed by areas of stadiums — 110 trees (20.9%) and parks — 70 trees (13.3%). The total number of trees growing on these areas was 352 (66.8%).

Table 1

Distribution of trees (*P. simonii* 'Fastigiata') in types of urban habitats

Type of habitats	Number of trees		Volume of trees		
	No.	%	m^3	%	Mean, m^3
Parks	70	13.3	110.2	11.9	1.57
Various small greeneries	152	28.8	257.6	27.7	1.70
incl. sports fields (stadiums)	110	20.9	192.1	20.7	1.75
Gardens	15	2.9	39.0	4.2	2.60
Courtyards	76	14.4	235.6	25.3	3.10
Streets	172	32.6	230.5	24.8	1.34
Derelict greeneries and grasslands	42	8.0	57.1	6.1	1.36
Total	527	100	930.0	100	1.76

Dimensions of trees. Of the 527 registered trees, 472 (89.6%) had an unpruned crown, and 55 a pruned crown. The *H* of the smallest unpruned tree was 6 m (a two-branch tree PBH — 30 and 18 cm) and that of the tallest unpruned tree 19.5 m (PBH — 211 cm). It was followed by three trees which were 19.0 m tall (PBH — 190, 202 and 315 cm, respectively) (1987). As a comparison, it could be noted that the *H* of cultivars of Chinese poplar (*P. simonii* 'Fastigiata') in Finland is 8—16 m (Hämet-Ahti et al., 1992). The *H* of the largest tree is 11.25 m and its perimeter 250 cm (Sept. 21, 1988) (Karhu, 1989).

The mean *H* of unpruned trees in Tallinn was to 14.2 m. It was the smallest of street trees (12.5 m) and the greatest of courtyard trees (15.5).

The PBH of the thinnest two-branch tree was 30 and 18 cm (DBH — 10 and 6 cm) and that of the three thickest trees 404, 396 and 380 cm (DBH — 129, 126 and 121 cm). These trees were 15.5, 15.0 and 17.0 m high (1987). As far as we know, they are also the thickest Chinese poplars in Estonia.

The distribution of trees into nine girth and six height classes is shown in Fig. 4.

The volume of trees was 930.0 m^3 (mean volume 1.76 m^3) and biomass 0.276 tons of dry matter. The greatest mean volume (3.12 m^3) was observed for yard trees among which there were also the oldest and the largest trees. Street trees, on the other hand, had the smallest mean volume (1.34 m^3) as they had grown slower and there were more younger trees among them.

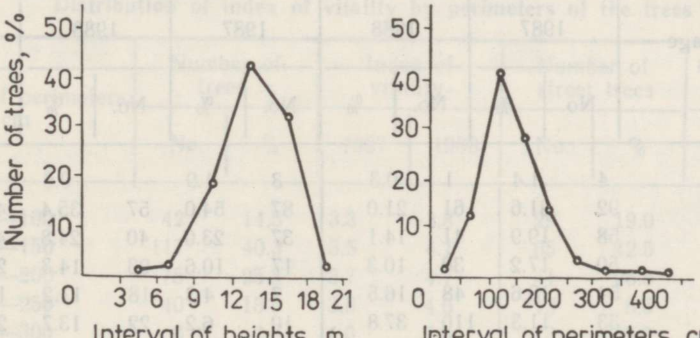

Fig. 4. Number of trees (%) by their height and by the perimeters.

Frost injuries to trees. Although Chinese poplar in Estonia belongs to the second frost hardiness class (Пайвель, 1959) and it is able to endure a temperature down to —36 °C, it has been noted that shoots of these trees suffer from frost in extremely cold winters (Margus, Tamm, 1967). This species may be particularly damaged by early frosts in autumn as the shoots can not lignify in time due to late vegetation (Laas, 1987).

J. Goertz (1938, 1940) considers the cultivar of Chinese poplar (*P. simonii* 'Fastigiata') to be absolutely frost-hardy in the Baltics, mentioning in his first paper that this cultivar occurred abundantly also in southern Finland. V. Veski and A. Niine (1961) consider this cultivar of Chinese poplar more frost-hardy than the species, registering also less frost injures in winter 1955/56.

The state of the Chinese poplar cultivar (*P. simonii* 'Fastigiata') in Estonia was in recent years at the most affected by the cold winter of 1986/87 when the absolute minimum temperature dropped in January to —37.3 °C in Estonia (Narva) and to —31.4 °C in Tallinn. This temperature was low in Tallinn in February (—22.9 °C) and in March (—24.5 °C), too. The mean temperature was in the first two months (1987) —13.8 and —5.5 °C (Метеорологический ежемесячник, 1987). As a result of that frost, a great number of the cultivars of Chinese poplar (*P. simonii* 'Fastigiata') perished in Estonia.

The analysis of poplars damaged in Tallinn is based on their assessment in 1987 (291 trees), 1988 (393 trees) and 1991 (365 trees).

The observations carried out in summer 1987 showed damages on buds, shoots, young and thin branches ones as well as older and thicker. At some places a thin foliage of small leaves appeared on damaged trees at the end of the summer. In most cases, however, there were no signs of recurrence. It was also noticed that trees of a narrower crown, typical of this cultivar, were damaged rather more. Although damages were noticeable both in the case of lateral and top branches, the last were most badly injured. Broom-like branching also occurred quite often.

Condition of trees and changes in them are shown in Table 2 and Fig. 5, revealing the condition of 291 trees after the severe winter of 1986/87 and the relatively mild winter of 1987/88 when absolute minimum air temperature was in January and February —15.5 and —15.3 °C, the mean temperature being —2.6 and —3.1 °C (Метеорологический ежемесячник, 1988).

Table 2

Distribution of trees by frost damage classes

The damage classes	Number of trees									
	1987		1988		1987		1988		1991	
	No.	%	No.	%	No.	%	No.	%	No.	%
1	4	1.4	1	0.3	3	1.9	1	0.6	4	2.5
2	92	31.6	61	21.0	87	54.0	57	35.4	46	28.6
3	58	19.9	41	14.1	37	23.0	40	24.8	44	27.3
4	50	17.2	30	10.3	17	10.6	23	14.3	24	14.9
5	54	18.6	48	16.5	7	4.3	18	11.2	18	11.2
6	33	11.3	110	37.8	10	6.2	22	13.7	25	15.5
Total	291	100	291	100	161	100	161	100	161	100
Index of vitality	3.5	—	4.3	—	2.8	—	3.4	—	3.5	—

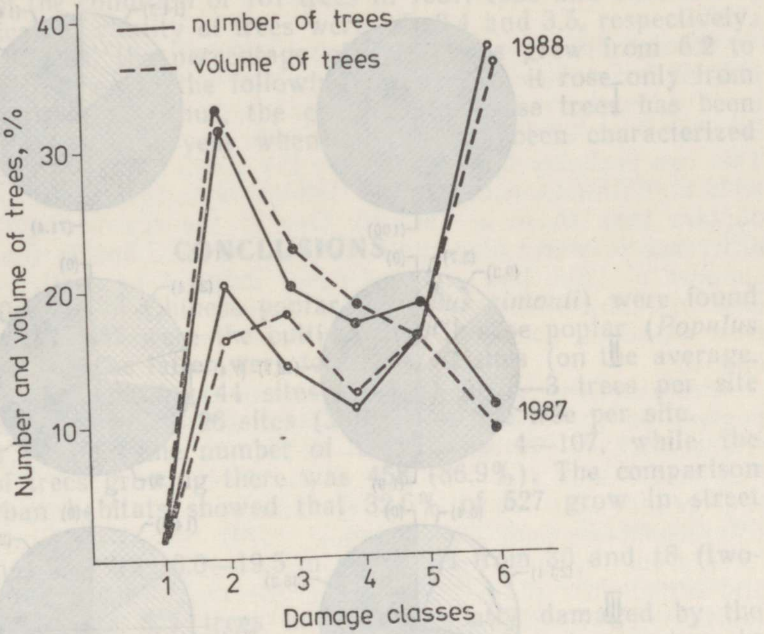

Fig. 5. Number of trees (%) by damage classes in year 1987 and 1988. *1* — excellent, *2* — slightly damaged, *3* — moderately damaged, *4* — severely damaged, *5* — fatally damaged, *6* — dead.

If, in 1987, the index of vitality for 291 trees was 3.5 and the percentage of dead trees was 11..3% (33 trees), then in 1988 the corresponding figures rose up to 4.3 and 37.8% (110 trees) (Table 2).

When comparing the age of trees and types of habitats, we can see that the greatest changes were recorded for the thickest (oldest) and street trees (Table 3; Fig. 6).

It could also be noted that trees pruned in the 1980s were most severely damaged. Their index of vitality was 4.9 and the percentage of dead trees amounted to 69.1%.

During repeated investigations in 1991, 365 trees on 54 sites were registered in Tallinn. Among these, 18.9% were totally damaged (33 trees) and dead (36 trees).

Table 3

Distribution of index of vitality by perimeters of the trees

Interval of perimeters, cm	Number of trees		Index of vitality		Number of street trees		Index of vitality	
	No.	%	1987	1988	No.	%	1987	1988
51—100	42	14,5	3.3	3.8	29	19.0	3.2	3.9
101—150	117	40.3	3.5	4.1	65	42.5	3.8	4.6
151—200	75	25.8	3.7	4.7	41	26.8	4.4	5.4
201—250	40	13.8	3.8	4.6	13	8.5	4.8	5.2
251—300	8	2.8	4.0	5.0	3	2.0	5.3	6.0
301—450	8	2.8	3.1	4.1	2	1.3	3.5	5.5
Total	290	100	3.5	4.3	153	100	4.0	4.8

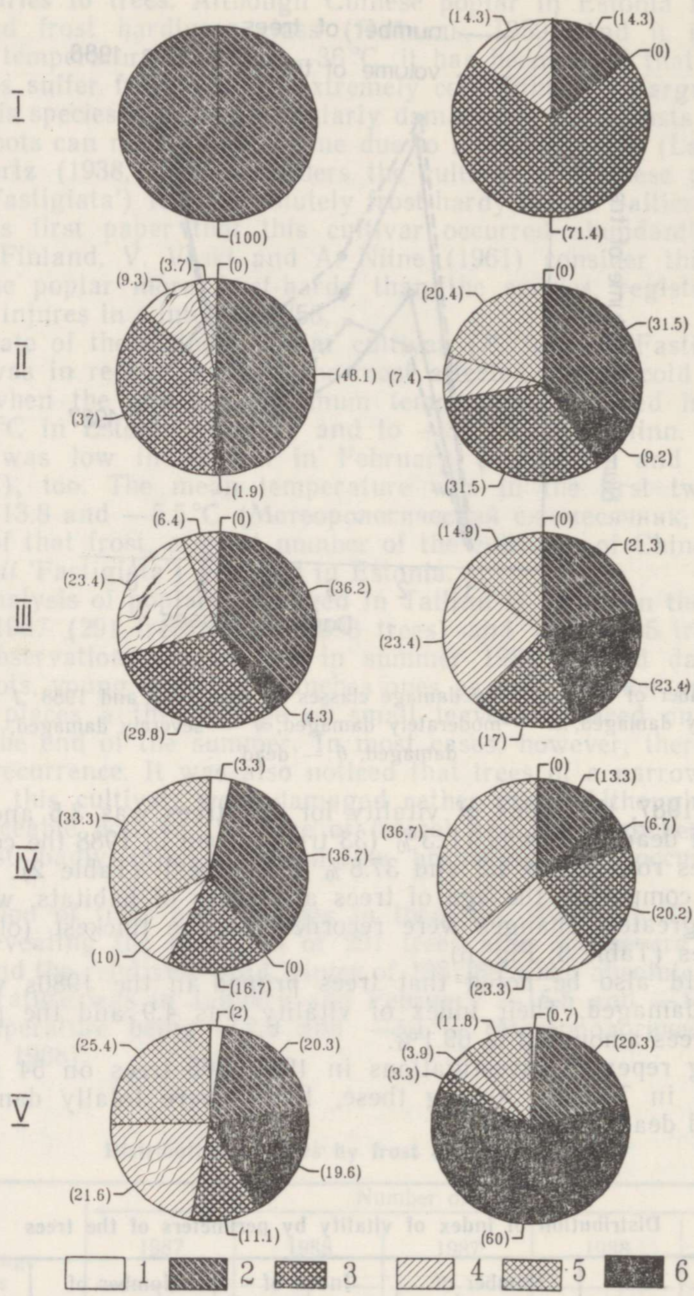

Fig. 6. Number of trees (%) by damage classes (*1* — excellent, *2* — slightly damaged, *3* — moderately damaged, *4* — severely damaged, *5* — fatally damaged, *6* — dead) in types of habitats (I — various small greeneries, II — parks, III — courtyards and gardens, IV — derelict greeneries and grasslands, V — streets) in 1987 (left) and in 1988 (right).

Estimation of the condition of 161 trees in 1987, 1988 and 1991 showed that the indices of vitality of trees were 2.8, 3.4 and 3.5, respectively. If, among those trees, the percentage of dead trees grew from 6.2 to 13.7% in one year, then in the following three years it rose only from 13.7 to 15.5% (Table 2). Thus, the condition of these trees has been stabilizing during the last year when Tallinn has been characterized by a mild winter.

CONCLUSIONS

In 1987, 530 trees of Chinese poplar (*Populus simonii*) were found in Tallinn, of which 527 were the cultivars of Chinese poplar (*Populus simonii* 'Fastigiata'). The latter were found on 72 sites (on the average, 7.3 trees per site), including 44 sites (61.1%) of 1—3 trees per site (totally 69 trees). In case of 26 sites (36.1%) — one tree per site.

On 28 sites (38.9%) the number of trees was 4—107, while the total number of trees growing there was 458 (86.9%). The comparison of different urban habitats showed that 32.6% of 527 grow in street habitats.

The *H* of the trees was 6.0—19.5 m and PBH from 30 and 18 (two-branched tree) to 404 cm.

Unfortunately, these 527 trees had been greatly damaged by the severe winter of 1986/87 when the absolute minimum temperature in Tallinn dropped to —31.4 °C. The frost injures of the trees were rated on a 6-degree scale (from excellent to dead) which showed that by the autumn of 1991, 200 (38.7%) of them were totally damaged (67 trees) and dead (133 trees). 162 trees had also been felled by that time.

It was also found that street trees had been injured most of all. By the end of 1991, 65.7% of the 172 registered trees were either totally damaged (17 trees) and dead (96 trees). But 22.0% of the somewhat older trees of courtyards and gardens were totally damaged and dead (20 trees from 91). This indicates to the fact that bad environmental conditions of street habitats have substantially decreased the resistance of street trees to extremal climatic conditions. Courtyards of old buildings have also appeared to be warmer than other sites (Климат Таллина, 1982).

In addition to damages due to the peculiarities of habitats and the age of trees, their condition was also affected by territorial differences of the urban area due to urban climate. Differences appeared both in the south-north and east-west direction.

By comparing the centre of Tallinn ("heat island") and other districts, we found that the number of perished trees was much larger outside the centre. In this case, the differences were magnified also by the age of the trees which in the centre was greater than in other parts of the city. It is partly due to the climatic conditions, for suburbs are in winter 1.5—3.5 °C colder than the city center (Климат Таллина, 1982).

The comparison of the differences between the east and west showed that the number of perished trees was the greatest in the northeastern part of the city. This is probably so because on severe winter days cold air comes towards us from the east and northeast, as a result of which the heat veil of the city moves to the west and the eastern part is left open for the frost (Tarand, 1986).

The severe winter of 1986/87 damaged cultivars of Chinese poplar (*P. simonii* 'Fastigiata') also outside Estonia. In Finland, which lies to the north of Estonia, nearly all trees perished. Only 19 trees survived, among them one tree in Hango and one in Helsinki, two young trees in Espoo, five trees in Naantali and ten young trees in the nursery garden in Pori (Niilo Karhu, personal communication, 1990; Sander, 1990).

When comparing frost damages of cultivars of Chinese poplar in 1986/87 with those in the severe winter of 1939/40 (Mathiesen, 1940a, b, c) when both local and imported species were greatly damaged, it can be observed that the frost injuries of 1939/40 were much slighter. This can probably be explained by the youth of the trees. It is also possible that climatic conditions of 1986/87 were less favourable for Chinese poplars than those of 1939/40. One of the reasons could also be the difference in water content in the trees which, due to the extremely dry summer of 1939, had in many cases dropped to a minimum. If, in the case of many local and imported species this factor helped to deepen frost damages, then for Chinese poplar this effect could have been the opposite.

Unfortunately we have no data about the frost injures of the Chinese poplars on the severe winter 1978/79 when the absolute minimum air temperature in Tallinn was —32.2 °C in December, in January and February —25.6 and —29.0 °C, respectively. And mean air temperature of December was —9.6 °C, that of January —7.7 °C and February —8.7 °C (Метеорологический ежемесячник, 1979). Probably Cinese poplar suffered from the frost injures, it is known that a number of fruit-trees and ornamental plants in Estonia perished during that cold winter (Jürissaar, 1980, Kerm, 1980).

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HIINA PAPLI (*POPULUS SIMONII* CARR.) LEVIK JA KÜLMAKAHJUSTUSED TALLINNAS

Heldur SANDER

Artiklis on kirjeldatud hiina papli ajaloolist ja praegust levikut ning puude dimensioone Tallinnas. Põhiliigi kõrval on siin enam levinud selle liigi kultivar (*Populus simonii* 'Fastigiata'), mida leidus 1987. aastal 527 puud.

Kuueastmelises skaalas on analüüsitud puude külmakahjustusi, mis põhiliselt tekkisid 1986/87. aasta karmi talve tagajärjel. Seetõttu oli registreeritud puudest 1991. aasta sügiseks alles jäänud 365, millest 18,6% olid surmavalt kahjustunud ja surnud puud.

Võrreldes puid kasvukohtade järgi selgus, et enam said kannatada tänavaäärsed puud ning vähem hoovides ja aedades kasvavad puud.

РАСПРОСТРАНЕНИЕ КИТАЙСКОГО ТОПОЛЯ (*POPULUS SIMONII* CARR.) В ТАЛЛИННЕ И ЕГО МОРОЗОСТОЙКОСТЬ

Хельдур САНДЕР

Дан исторический обзор о распространении китайского тополя в Таллинне. Больше всего в Таллинне встречается культивар китайского тополя (*P. simonii* 'Fastigiata'), которого в 1987 г. насчитывалось 527 деревьев. Для выяснения повреждения деревьев в суровую зиму 1986/87 г. было проведено оценивание их по шестибальной шкале (от здоровых до мертвых), в результате чего было установлено, что к 1991 г. из 527 деревьев сохранилось только 365, причем 18,9% из них были отмирающими или мертвыми. Больше всего пострадали от мороза уличные или старые деревья, деревья, растущие в садах и дворах, сохранились лучше.