RESEARCH ON STREET TREE PLANTING PRACTICES IN THE NETHERLANDS

by Jitze Kopinga
Research Institute for Forestry and Landscape Planning ‘De Dorschkamp”
Wageningen, The Netherlands

ABSTRACT.--Research focusing on the problems of planting and maintaining street trees in the Netherlands started in the second half of the 1960’s and since then has mainly concentrated on problems concerning the growing site. On the basis of these studies a working party of researchers recently developed recommendations for the design of a planting hole. These are presented. The provision of water and nutrients in accordance with chemical and physiological properties of the original soil and of the planting pit material is discussed.

INTRODUCTION

Research on the establishment and maintenance of tree plantings in the urban environment in The Netherlands is carried out by the research departments of the Municipal Plantation Services of certain large cities, a few private services, and by a handful of scientists working at research stations that, with one exception, are under the aegis of the Ministry of Agriculture and Food. The research conducted by the municipalities primarily concerns practical problems of mainteance. The private services work on specific problems that require custom-made answers. Scientists at the research stations try to establish the scientific basis of the solutions to some of the problems encountered in the establishment and mainteance of trees.

Although the various researchers work independently and in different organizations, the dialogue is good. They are like a small club in which the people are well aware of each other’s work and can readily contact each other if necessary. Discussions about current problems, how they should be tackled, and the design and results of research frequently take place during the meetings of two working parties: the Intermunicipal Study Group on Tree Mainteance (ISB) and the Study Commission for Research on Trees in an Urban Environment (OBIS). City arborists from Amsterdam, Rotterdam, Harlem, The Hague, and Utrecht, together with researchers and consultants from government institutes make up the ISB. All research institutes that deal with amenity tree problems are represented on OBIS.

This paper presents a picture of the origin of the scientific research on street trees in the Netherlands and of some currently-held views and opinions.

HISTORY

In the Netherlands, research into the problems of planting and maintaining street trees is comparatively recent. There is a tradition of research on tree nursery production, fruit production and silviculture, but this research was mainly aimed at increasing the production and quality of the crop and was focused on specific cultural problems.

Although many of the resulting findings could subsequently be applied to the management of city trees, problems that were specific to the latter remained outside the scope of research. This situation changed, however, in the second half of the 1960’s, when a large number of street trees died because of “poisoning” from natural gas.

The reason for this was the switch from coal gas to natural gas. Because the natural gas was much drier than coal gas, the lead-and-rope connections between the pipe elements of the gas distribution network dried out, causing gas leaks into the surrounding soil. The damage was great, some towns losing more than 20% of their street trees, and the need of a solution to the problem was urgent.

The Society of Officers of Municipal Plantation Services (VHB) therefore set up a working party consisting of a number of researchers and representatives of gas boards and plantation services, which was charged with studying the gas problems. This working party was called the Committee for the Study of the Influence of Natural Gas on Plants (SIAB). It managed to reveal the extent of the problem and the mechanisms that made natural gas cause damage to trees. In addition, it developed recommendations and methods for limiting or preventing any deleterious consequences arising from of the presence of natural gas in the soil.

To give an example: it was discovered that the cause of the damage was the lack of oxygen in the soil. This was partly caused by the oxygen being replaced by the gas, but was largely the result of the gas in the soil being consumed by bacteria that oxidized the gas and thereby removed oxygen from the soil (Adamse et al, 1972: Hoeks, 1971, 1972). This explained why small gas leaks were generally not detected during the routine examinations made by the gas boards. During these examinations the gas content of the open air above the pipes is ascertained, using a kind of “sniffer.” If a small leak was present, however, the gas had usually been converted before it reached the surface. Subsequently, it also became clear that the chance of detecting gas was greater during the winter than during the summer, because the methane consuming bacteria are less active at lower temperatures (Figure 1).

When the SIAB was disbanded after publishing its last report in 1972, it was clear to the VHB that the street trees were not only suffering from damage caused by natural gas. Many more factors that were not fully understood were found to be adversely affecting tree growth. Therefore, the VHB insisted that research on street trees be continued at various institutes and set up the OBIS working party, Studiecommission on Trees in an Urban Environment, in 1973.

OBIS RESEARCH TOPICS

The following is a list of the research institutes that have been involved in the OBIS activities over the years, and the aspects of street tree problems that are being or have been studied:

ICW - Institute for Land and Water Management Research.

* Moisture conditions in the soil in relation to the transpiration from trees, infiltration of rain water, horizontal and vertical water movement, and water use by trees.
* Oxygen conditions in the soil as affected by gas diffusion through pavements, vertical and horizontal diffusion, and oxygen consumtion by tree roots and soil micro-flora.
* Effects of soil compaction on the root development of trees.

STIBOKA - Soil Survey Institute.

* Suitability of various soils and soil types for the growth of trees, and the effects of disturbances such as changes in bulk density (compaction), waterlogging, and draining on the patterns of root development.

IB - Institute for Soil Fertility.

* Root penetration capacity of several tree species.
* The influence of the location of several nutrient elements in the soil and their accessibility to tree roots.
* The suitability of sewage sludge as a growing substrate for street trees.

RIJP - Ijsselmeer Polders Development Authority.

* The effects of various methods of soil improvement on the growth and development of several woody ornamentals.

RBL “De Dorschkamp” - Research Institute for Forestry and Landscape Planning.

* Reactions of trees to wounding.
* Growth and development of trees on artifically made soils and substrates, such as refuse land-fills, harbour and sewage sludge dumps (supply of nutrition elements, problems caused by heavy metals).

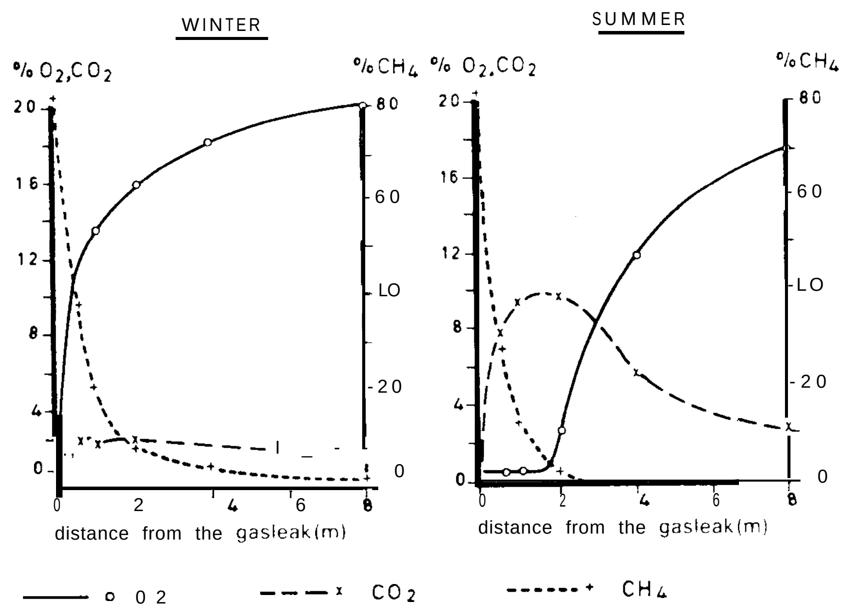

Figure. 1. The influence of the season on the composition of soil air around an artifical gas leak of 25 L/h (Hoeks, 1971).

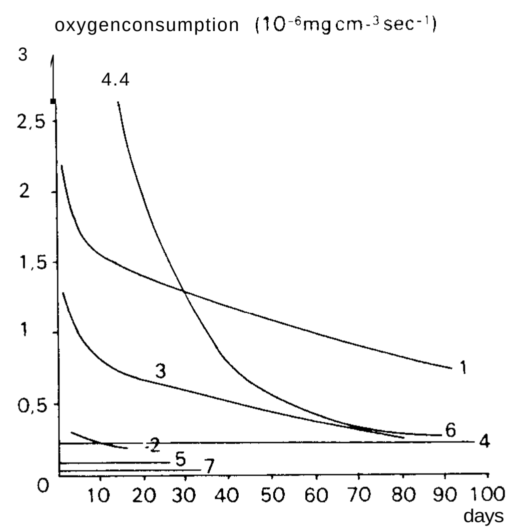

Figure 2. Oxygen consumption of various mixtures of lime containing sand and organic matter from different origins (to a final organic matter content of 5%), when used as filling of a planting hole (after: Couenberg, 1983).

1 = “stabilized” sewage sludge;
2 = mixture 1, after 550 days in an aerobic planting hole;
3 = top soil of a meadow on peat soil;
4 = mixture 3, after a storage of three years in a depot;
5 = consumption when 4% per year of the organic matter of a matured mixture oxidizes;
6 = mixture 4, with an addition of 1% of organic fertilizer (8.7.7. NPK);
7 = normal consumption by tree roots in a one meter thick layer of soil (100 mg oxygen/m2 per hour).

* The influence of soil pH on tree growth.
* The influence of de-icing salt on tree growth.
* Diagnosis of tree disorders (chemical and physical aspects of the soil as well as phytopathological and entomological aspects of the tree).
* Ascertaining the suitability of tree species and their cultivars for an urban environment.

PBSG - Experiment Station for Nursery Stock and Urban Greenery.

* Backgrounds to the establishment of street trees (reasons why trees fail or succeed in establishing.

SOME RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Space does not permit a detailed consideration of all the findings that have come to light during the existence of OBIS, but some of them are worth mentioning in the scope of this fifth technical symposium of METRIA.

* Pavements of concrete slabs and bricks need not necessarily limit tree growth. These are generally not the bottleneck in the downward diffusion of oxygen that is necessary for the normal functioning of tree roots (Bakker, ICW, pers. comm.).

* When there is a contiguous pavement of asphalt, concrete, or large slabs with plugged joints, or when there are oxygen demanding processes in the soil other than those of the tree roots, the use of ventilation systems is highly recommended (Couenberg, 1983; see also Figure 2).

* Unpaved surfaces can also inhibit oxygen transport considerably when they are wet or compacted.

* To avoid any undesired effects of oxygen depletion when carrying out soil improvements or when filling a planting hole, the soil that is used must always be well matured.

* Soil mixtures of lime-containing sand with an organic matter percentage of 4-5% (w/w) allow good tree growth and satisfy the demands of the road-building engineers.

* In smaller planting holes (of between 1 to 4 cubic m), horizontal diffussion of oxygen from the surrounding soil often exceed the vertical diffusion through the overlying pavement. When vertical oxygen transport through adjacent pavements is possible, it is preferable to design the planting hole for the maximum surface area to be along the side contiguous with the adjacent pavement, i.e. the hole should be oblong rather than square or circular.

* The distance the oxygen has to diffuse should not be too great. When no ventilation systems are present, the planting hole should never be more than 1 meter deep.

* Planting holes should be filled with material that contains at least 15% (v/v) air in the spring. An air volume of 20-25% is even better.

* The oxygen supply through ventilation pipes in which the air can circulate can be more than ten times higher than the supply through vertical pipes containing stagnant air.

* Diagnosis of salt damage to trees can best be confirmed by leaf analyses. If only soil sampling is possible, the determination of the so-called "C-value" (the degree of chloride concentration in the actual soil moisture), is to be preferred above the determination of the electrical conductivity (EC-l 5, or ECe).

* When a tree is completely dependent on rainwater for its water supply, in the conditions prevailing in the Netherlands, this tree will need about 3/4 cubic meters of rootable soil per square meter of crown projection to meet its demand for water (Bakker, 1983). This model applies to a tree with a more or less "normal" shape and with a Leaf Area Index of about 4 (Bakker, pers. comm.). Though this recommendation still requires further refinement, it does indicate dimensions that are similar to those derived from research on Dutch elm and roadside plantations of Heidemij poplar (Schoenfeld, 1975; Schoenfeld and Van den Burg, 1984, Figure 3), and calculations based on the nitrogen demands of trees (Van den Burg, RBL, pers. comm.).

CALCULATING THE DIMENSIONS OF THE PLANTING HOLE.

In the Netherlands, urban forestry is sometimes typified as one of the soft sectors of the public services. This might be because it still is impossible to evaluate urban forestry in hard cash, so that no cost-benefit analysis can be made. Therefore it is difficult, if not impossible for the plantation services to support their claims for "underground space" with real technical and financial data. This is in contrast with the other branches of the public sector such as the utility services, for whom this is no problem. This too often means that when decisions are being made on assigning the available space undergound , the plantation services have been unable to participate in the discussion on an equal footing.

To meet the needs for more data about the space required for acceptable tree growth, and because the utility services are not unwilling to cooperate when they are spoken to in a "language" that they understand, research was begun to produce estimates of the physical requirements for urban trees. This research showed that, provided that the circumstances and soil conditions of

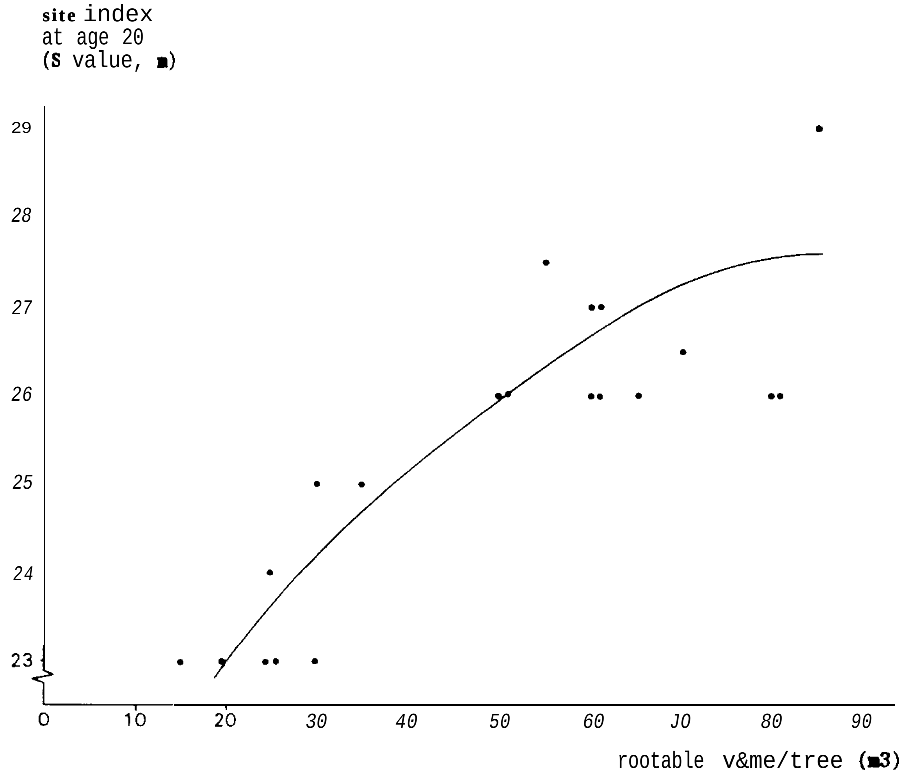

Figure 3. Relationship between volume of rooted soil and site index of 'Heidemij' popular at age 20 (Schoenfeld and Van den Burg, 1984).

the site are known, it is possible to estimate the minimum planting-hole dimensions that are required to ensure acceptable growth.

To illustrate this, some tables are presented below showing the various factors that should be taken into consideration, together with some sample calculations.

THE ANNUAL AMOUNT OF RAIN WATER INFILTRATING THROUGH VARIOUS PAVEMENTS (derived from: Bebelaar and Bakker, 1981; Bakker, ICW, pers. comm.).

pavement	dimensions (cmxcmxcm)	joint space (%)	infiltration rate (mm/h)	infiltrated amount per growing season (mm)
slabs	60x60x7	0.6	0.5	77
slabs	30X30X5	1.1	0.9	112
bricks	20x10x10	5.1	3.5	252
bricks	10x10x10	7.1	5.5	284
vent. slabs	60x60x7	1.9	1.9	196
vent slabs	30X30X5	5.6	3.0	238
pet-f. bricks	20X20X10	30:o	7.5	298

PERCENTAGE OF THE PRECIPITATION THAT INFILTRATES THROUGH A SLAB-PAVEMENT AT VARIOUS INFILTRATION RATES. (source: Bebelaar and Bakker, 1981).

	Infiltration rate (mm per hour)									
period	0, 33	1	2	3	4	5	6	8	10	20
May 1 -Oct. 1	16	37	58	68	75	79	82	86	89	95
Oct. l-May 1	25	54	79	88	93	95	97	98	99	100
year through	20	46	69	79	84	88	88	92	94	98

THE AMOUNT OF AVAILABLE WATER (LITERS/M^3) IN ROOTABLE SOIL. (derived from: Wopereis, 1981; and Bakker, ICW, pers. comm.).

soil type	Wopereis, 1981	Bakker
humus-poor dune sand	70	—
fine sand (without loam)	150	—

humus-rich sand (without loam)	190	—
humus-rich sand (loamy)	240	100-300
very humus-rich sand (loamy)	260	
sandy clay	220	
light clay	160	150-300
heavy clay	140	
peat	—	400-600
street sand (moderately coarse, no humus	—	ca. 65
tree pit soil (2% org. matter)	---	ca. 100
tree pit soil (5% org. matter	---	ca. 150

THE DISTANCE (IN CM) FROM THE WATER TABLE AT WHICH CAPILLARY WATER GIVES WATER SUPPLIES OF 2,3, OR 5 MM (= UM2) PER DAY. (source: Wopereis, 1981).

soil type	---------water transport----------		
	2 mm/day	3 mm/day	5 mm/day
clay-poor marine sand	45 cm	40 cm	30 cm
light loamy cover sand	105 cm	100 cm	80 cm
heavy loamy cover sand	160 cm	145 cm	120 cm
supply (L/m2) over 150 days	300	450	750

CALCULATING THE DIMENSIONS OF THE PLANTING HOLE

To ascertain whether a certain planting hole is sufficiently large for a tree to grow, given an existing or expected situation, one has to know the following:

a. the storage capacity of the planting-pit material
b. the annual amount of precipitation
c. the amount of the precipitation that infiltrates through the pavement or that runs off the pavement
d. the drainage of superfluous infiltrated rainwater (this is the total infiltrated water minus the maximum reserve of water the planting-pit material can hold)
e. the capillary supply from the water table
f. the evaporation of water through the pavement
g. the transpiration from the tree.

A street tree transpires about 1.5 to 2 times as much as a forest tree, which on average transpires about 500 mm/year. This is about the same as the open water evaporation during an average summer in the Netherlands. So an average street tree has a potential transpiration of 750 mm/year (Bakker, 1983). This figure for transpiration is sufficient for the tree's potential growth. The question, however, is whether this amount is necessary for street trees.

Pot experiments carried out formerly by the ICW could not provide sufficient information on this. The trees took up all the water they were given and then wilted, from one day to the next. Therefore, for the time being, estimates must be taken from silvicultural research. These show that the growth of trees is regarded as being acceptable when the actual growth is 40% of the potential growth. For more or less drought-resistant trees, this implies that the actual transpiration may be lowered to 75% of the potential transpiration (Bakker, 1983). Again, it must be emphasized that this is based on the Dutch climate, in which there is generally a reasonable alteration between wet and dry periods during the growing season, so that trees do not need to cope with prolonged drought.

SAMPLE CALCULATION (source: Dept. TBO, Beplantingsdienst Amsterdam, 1981)

Consider a tree with a crown diameter of 8 m (its crown projection will be about 50 m^2), which has been planted in a hole 6.3 x 0.6 m filled with soil that contains 5% (w/w) organic matter (this will have a water storage capacity of about 150 L/m^3), in a pavement of ventilated slabs (Infiltration Rate = 5.6 mm/hr), over a water table 1 m below the surface.

The question is, do these circumstances offer enough possibilities for tree growth?

The reserve of water will be taken to be 0 at the end of the growing season (October). The amount that infiltrates during the winter period (until May l) is 28O x 18L = 504OL.

If about 45 mm evaporates through the pavement during this period, 5040 - (45 x 18) L infiltration water will remain. This is sufficient to replenish the storage capacity of the planting hole to its maximum (V-max - 1620 L). The superfluous water (2610 L) will percolate downwards.

In the growing season (May until October) the evaporation of water from the tree could be 1.5 x 500 x 50 L = 37500 L.

In the situation described here, the capillary supply from the water table is 500 x 18 L = 27000 L. The infiltrated precipitation is 5040 L. The loss of water by evaporation through the pavement is not incorporated into the calculation, as this will mainly be used up in the tree's transpiration. The stock of water is 1520 L. This gives an available amount of water of 33660 L.

Although there is a deficit of 3840 L, the ratio of actual/potential transpiration is 0.9, which means that 90% of the tree's demand for water can be met. This is still far beyond the 75% that is considered to be an acceptable level.

Though in the situation described, 2610 L of water is lost in the winter period, it has the advantage that the planting hole is frequently flushed, this minimizes the chance of an unacceptable build-up of salts in the soil. For this reason, it is also regarded as undesirable to make the planting hole dimensions so large that all the precipitation can be stored.

CALCULATING THE DIMENSIONS OF THE PLANTING HOLE ON THE BASIS OF THE NITROGEN SUPPLY OF TREES. (source: Van den Burg, RBL, pers. comm.).

The calculation of the minimum dimensions of a planting hole on the basis of the water demand of a tree is just one of the approximations possible. A similar exercise can also be performed on the basis of the N-supply.

The needed data include:

* the quality of organic matter (expressed as C/N ratio)
* the amount of organic matter (expressed as total N)
- an estimate of the N mineralization in the soil
* the weight per volume (bulk density) of the soil

SAMPLE CALCULATION

A tree with a crown projection of 100 m^2 requires N uptake of about 400 g N per growing season. These data are derived from silvicultural research.

Because about half of the mineralized N does not become available to the tree (it is washed out by rain, denitrified or fixed by micro-organisms), approximately 800 g N must be mineralized. About 1300 kg organic matter with a C/N ratio of 20 will cover the demands of the tree. When the soil present contains 5% (w/w) organic matter, this implies that 26000 kg of soil must be accessible to the tree roots.

With a soil bulk density of about 1 kg/dm^3 (this is often exceeded in city soils, where values of 1.3 - 1.5 kg/dm^3 are encountered (Wopereis, 1981), one comes to a planting hole volume of 20-25 cubic meter.

It should be noted that the example is given only to indicate the order of magnitude one should bear in mind when designing a planting hole. For a more exact calculation, more data must be known about factors such as N mineralization and fixation and the leaching of nitrogen in city soils. Furthermore, it must be realized that organic matter will be the only source of nitrogen and will be consumed gradually. How long the initial reserve will provide enough nitrogen still remains a major question.

EPILOGUE

When one starts calculating with the data presented above, it soon becomes evident that in many urban situations the desired dimensions are not practical. Whether it is still justified to plant a tree in these kinds of situations is a dilemma that cannot be resolved simply. It is unpredictable, for example, whether the tree roots will be able to escape out of the planting hole and tap another source of nutrients and water. It is also obvious that the dimensions could be smaller if the tree is to be watered and fertilized artificially, although it is questionable how long this will remain possible both technically and financially. Just consider the manpower requirements during long periods of drought. These possibilities, however, will be different from one situation to the other.

There is also the question of what may be regarded as “acceptable” growth. Some people, for example, might tolerate anything as long as the tree does not die; others would desire a tree that is able to develop to full natural size and will keep its amenity value for a long period. Furthermore, some tree species will thrive better than others in urban situations because of their adaptability to unfavorable circumstances.

To discover how far a tree’s adaptability to the urban environment can be stretched, research by the OBIS working party in the Netherlands is continuing.

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