Variation in common lime (*Tilia x europaea* L.) in Swedish Gardens of the 17th and 18th centuries

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Cover illustration:
Malmvik Manor, west of Stockholm, from Suecia Antiqua et Hodierna by Erik Dahlberg. In the middle of the yard is the renowned Malmvik lime, planted in 1618. This is the earliest documented planting of common lime in Sweden. A last fragment of the tree fell in a severe storm in 1999. A few years later a young plant, propagated from the original one, could be replanted by the author at Malmvik.

All photographs in this thesis by the author unless otherwise stated.

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ABSTRACT

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Trees of common lime (*Tilia x europaea* L.) have been planted in Swedish gardens and urban landscapes since at least the beginning of the 17th century. This is in accordance with the situation in most other European countries. The trees were initially imported from the Netherlands but later domestic production was started. The domestic material was collectively known as 'Dutch lime' even when propagated in Sweden. To understand the variation in common lime in Swedish gardens, the methods of propagation in the 17th and 18th centuries were investigated using contemporary textbooks and other references. Propagation by layering was the most important method, while seed propagation was used during the second half of the 18th century.

The lime material planted in Sweden during the 17th and 18th centuries was found to constitute a number of unnamed clones and one single seed strain, all of which are included in the concept 'Dutch lime'.

Based on the information obtained, a system of classification was developed which also covers more recent introductions of common limes. The extensive variation found within the taxon *Tilia x europaea* L. is divided into six clonal groups, one of which also contains a single seed strain planted in Swedish gardens before 1800. The classification system proved to be useful in practice as a tool for identification of different varieties of common lime. It was found that the different groups react differently to pruning practices, which is of significance when choosing methods for restoration of old lime tree plantings.

A separate study was made of the oldest recorded planting of common lime in Sweden. By combining knowledge of lime biology and garden history in an interdisciplinary way, it was possible to chart and interpret the development of this particular single tree during its 381-year history at Malmvik Manor near Stockholm.

Key words: *Tilia x europaea* L., classification, clone, Dutch lime, garden history, propagation, pruning, seed strain.

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LIST OF PAPERS

PAPERS I - IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

INTRODUCTION

The studies included in this thesis were prompted by two questions addressed to the author in the mid-1990s when working as an extension officer at the Swedish University of Agricultural Sciences at Alnarp.

Mrs. Lena Löfgren Upsäll, landscape architect of historic gardens at the National Property Board of Sweden, posed the first question, asking for advice regarding the identity of the lime trees (mostly of common lime, *Tilia x europaea* L.) in the avenues of the baroque garden at the Royal Palace at Drottningholm near Stockholm. The first trees in these avenues were planted in 1684. Later the author was involved in the different issues preparatory to the restoration of these avenues.

The second question was raised by Mr. Perola Fritzon, at that time tree expert at the Parks Department in Stockholm. He asked for advice on how the extensive variation in common lime (*Tilia x europaea* L.) he could observe in plantings of the last three centuries, in parks and streets in Stockholm, should be interpreted.

In order to answer these questions, I carried out a preliminary study of general textbooks in botany and dendrology. However, the results were disappointing and the correlation between the characteristics of the trees observed at Drottningholm and in Stockholm and the descriptions in the textbooks consulted proved to be inconsistent. The next step was therefore to obtain a deeper understanding of the variation in common lime.

Interest in the diversity of cultivated plants has increased markedly during recent decades. There are a number of reasons for this. The equivalent rise in interest in the preservation and restoration of historic gardens has increased the demand for a more detailed knowledge of the plant material used during the various garden style epochs. This is articulated in the Florence Charter (Mosser & Teyssot, 2000, p. 530) formulated by ICOMOS (International Council On Monuments and Sites) and IFLA (International Federation of Landscape Architects) and first presented in 1982 as an addendum to the Venice Charter. This charter requests for example an investigation of the origin and identity of the material used in historic gardens. '*Those species of trees, shrubs, plants and flowers to be replaced periodically must be selected with regard for established and recognized practice in each botanical and horticultural region, and with the aim to determine the species initially grown and to preserve them.*' (Florence Charter, Art. 12).

The same kind of request, but from a different point of view, has been addressed by the authorities responsible for preserving biodiversity. During the first years after the Rio summit in 1992, the Swedish authorities focused

on biodiversity in wild species and natural habitats, the exception being the efforts to preserve genotypes of agricultural and horticultural crops made by NGB (Nordic Gene Bank) since 1979. However, for some years more interest has been focused on domestic or cultivated biodiversity (Swedish Biodiversity Centre, 2000). From the perspective of conservation of domesticated diversity, old plantings of trees and shrubs are of great interest but current knowledge is limited regarding the origin, history and taxonomic status of these old trees and shrubs. Restricted research has been conducted in this field from both a biological and a historic point of view.

Trees of common lime (*Tilia x europaea* L.) have been planted in Swedish gardens for architectural purposes since at least the beginning of the 17th century. At the end of this century, trees of common lime were frequently chosen when planting avenues in gardens of the baroque style (Couch, 1992).

Many of the limes planted during the 17th and 18th centuries have survived until today but are often in need of restoration or replacement. Guidelines on this are given in the Florence Charter.

The material of common lime planted in Swedish and in other European countries was collectively known as '*Dutch lime*' and the equivalents in other languages (Dezailler d´Argenville, 1709; Evelyn, 1776; Jaques & van der Horst, 1988). Even when domestic propagation and production of common limes began in Sweden, the results were still referred to as '*holländsk lind*' (*'Dutch lime*'; Anon., 1777; Ackermann 1807). It is striking that the concept '*Dutch lime*' could embrace the extensive morphological variation of common lime found in Swedish gardens.

In addition to exhibiting morphological variations, the different types of common lime also respond differently to pruning methods. This is important to consider in planning the restoration or reconstruction of historic gardens. Genetic differences may at least partly explain these differences.

Trees of common lime planted in Swedish gardens during the 17th and 18th centuries were generally propagated by layering (Fig. 1). During the second half of the 18th century, propagation by seed was also used. This is the reason why most of the trees from that time found in Sweden are of clones of common lime. In a study of the common lime planted during the same period in England, Pigott (1992) found that the trees of common lime could be referred to two clones or possibly two groups of very similar clones. Classification into clonal groups of historical trees of common lime in other European countries might be used as a tool to select appropriate methods and clones for reconstruction of historical common lime plantings.

Figure 1. Propagation by mound layering of common lime in a modern German nursery (Baumschulen Lappen in Nettetal-Kaldenkirchen). Trees propagated in this way were used for replanting some parts of the baroque avenues at The Royal Palace of Drottningholm. The principles are probably very similar to those practised during the 17th and 18th centuries.

The aim of this study was to investigate the origin, development and morphology of common lime trees planted in Sweden during the 17th and 18th centuries. Specific objectives were to:

- Investigate how these limes were propagated, vegetatively or by seed.
- Classify the diversity of common lime (*Tilia x europaea L.)* into clonal groups.
- Describe the variation in common lime planted in Sweden during the 17th and 18th centuries.
- Trace the history, growth and development of a common lime tree that was planted in 1618 and died in 1999.

These objectives are interlaced with the origin and the etymology of common lime. Thus it was deemed appropriate to first describe the origin, etymology and taxonomy of lime in general, and common lime in particular, using an interdisciplinary approach. This description was also intended to provide important background information for the studies of classification and variation in common lime (Papers II and III)

TAXONOMY, HISTORY AND ETYMOLOGY OF COMMON LIME

Taxonomy and morphology

The genus *Tilia* belongs to the family *Tiliaceae*, comprising some 40 genera. All of them except *Tilia* and one species of *Grewia* are tropical or subtropical (de Jong, 1992). The limes belong to all the temperate latitudes of the northern hemisphere except north-west America and the Himalayas (Bean, 1980). At present, about 35 species are recognized in the genus (de Jong, 1992).

The present work only deals with the European species *Tilia cordata* Mill. (small-leaved lime), *T. platyphyllos* Scop. (large-leaved lime) and, in particular the hybrid between these, *T. x europaea* L. (common lime). They were all treated by Carl von Linné as a single species (*Tilia europaea* L.) in *Species Plantarum* (1753). Later, Miller (1768) described the small-leaved lime with the epithet *T. cordata* Mill. and Scopoli (1771) the large-leaved lime as *T. platyphyllos* Scop. Both names have been questioned because the lack of type specimens. A proposal to preserve the universally used names *T. cordata* and *T. platyphyllos* was made by Pigott (1997), who presented neotypes of both species. Since it seems probable that Linnaeus founded his description of *T. europaea* on material of common lime, Pigott and Sell (1995) proposed that this epithet should be used for that taxon. The chromosome number of the two parental species and their hybrid is 82. In this study, several thousands of lime trees planted during the 17th and 18th century were investigated. All but a very few of them were of common lime.

The most recent monograph on *Tilia* dates back no later than the beginning of the 20th century. In his '*Monographie der Gattung Tilia*' (Monograph on the genus *Tilia*), Engler (1909) distinguished 25 species, five of which are now considered to be synonymous with other species (de Jong, 1992). Jones (1968), in his revision of the American limes, reduced the number of species on this continent from fifteen to three.

Taxonomy of lime is difficult to study due to the minor and varying expression of morphological characters separating the species. Scheller wrote (1972, p. 8); '*As easy as the lime genus is delimited from other genera, as difficult is the delimitation of the species therein. The reason for this is mainly the variation in the different morphological characters. Many of them vary in their expression and therefore one often has to use the expressions more or less or mostly. Only the sum of all characters may give a definitive classification of the different species*'. Scheller (*op. cit.*) made no distinction between the different groups or clones of common lime (*Tilia x europaea* L). Scheller's statement is underlined by the observations made

Table 1. Overview of morphological characters of common lime and its parents. This overview is partly based on information from Pigott (1969, 1992) and Scheller (1972).

Trait	***T. platyphyllos***	***T. x europaea***	***T. cordata***
Hairiness of shoot	Many hairs	Few hairs	No hairs
Number of visible bud-scales	2	3	3
Exposition of leaves in the crown canopy during late summer and early autumn[1)]	No exposition of the lower surface	Varying between the different clonal groups, in trees of clonal groups C, D and E they are exposed	The lower surfaces are exposed
Shape of the leaf	Convex	Flat	Flat to concave
Leaf, upper surface	Glabrous to hairy	Glabrous to hairy	Glabrous
Leaf, lower surface	Green, both on and between veins with many, simple, whitish hairs	Greyish to yellowish-green, variable frequency of simple, double and stellate hairs	Bluish-green, glabrous except tufts of brownish hairs in the angles of the main veins
Third order veins on the lower surface	Clearly visible	More or less visible	Not visible (sunken in the lamina)
Inflorescence	Pendulous	Pendulous to slightly protruding	Protruding and often held above the bract
Number of flowers	2-5	3-10	4-10
Tenacity of mature fruits	Woody, difficult to break between fingers	Rather easily broken between fingers	Easily broken between fingers

[1)]In the outer canopy of trees of *Tilia cordata, T. tomentosa* Moench and of some of the clonal groups of *T. x europaea*, in late summer and early autumn, the petioles of the leaves are twisted and or the laminas are folded and thus the lower surfaces are exposed. This phenomenon seems to be more pronounced during periods of drought (Fig. 2).

in the studies included in the present thesis. The leaf characters may vary within the twig, between adjacent twigs in the same position, between twigs from different levels in the crown and between twigs more or less exposed to the sun. This is the reason why samples have to be collected following a strict procedure (Pigott, 1992). A further complication is that most trees included

Figure 2. The foliage of the common lime at the church in Overpelt in north-eastern Belgium. This tree belong to clonal group E (Paper II). Some leaves are exposing their lower lamina.

in the investigation are old, sometimes planted more than 300 years ago, and have been subject to different pruning practices.

The trees of *Tilia* species are normally large or medium-sized. In Europe, *Tilia cordata* and *T. platyphyllos* can reach 40 metres in height in the wild. The tallest trees of common lime found by the author in Sweden have reached 35 metres (at Lyckås garden in the province of Småland). The shape of the trunk in cross-section is very variable. In some types of common lime it is circular, even in old trees, while in others it is irregular with broad ridges. The development of hemispherical bosses or burls is very frequent on trunks of common lime. The bark is generally light grey with fissures varying in depth and shape.

Young trees of small-leaved and large-leaved lime and their hybrid, the common lime, normally develop a central leader. When pollarded for agricultural or architectural purposes, the dominance of the central leader is lost. When such trees are allowed to grow freely again they develop a candelabra crown architecture, which has often been regarded as typical for trees of common lime. On the other hand, most, if not all, types of common lime initially

develop a strong leader, which can be seen when a sprout is allowed to develop from a stump. This character may have been one reason why the common lime became the preferred tree for baroque avenues. Architects and gardeners favoured the development of a straight trunk during the baroque era (Dezailler d´Argenville, 1709).

The shape of the crown varies between narrow and very broad. The branches of the second order vary from upright to almost horizontal. The twigs in the crown canopy are normally descending. The colour of the extension of current year shoots varies from red over brownish-yellow, emerald green to brownish-grey. The expression of those colours is strongly influenced by the position and type of the shoot. The colour is stronger in shoots exposed to the sun. The colour is more obvious on long shoots on recently pollarded trees and becomes brighter during spring.

The leaves are alternate, and arranged in two rows on the branches. They are generally heart-shaped at the base and with a serrate margin. An important character is the sheen or lustre of the upper surface of the lamina. In trees of Crimean lime (clonal group F) the lamina is very lustrous, in trees of clonal group A it has a matt sheen resembling that of oilcloth and in trees of clonal group C it is dull. Those differences are lost in herbarium specimens. This underlines the importance of studying the material when fresh. A character that has been mostly overlooked in previous studies is the exposure of the brighter lower surface of the lamina in the outer canopy. This exposure is caused by the twisting of the leaf petiole and to some extent by the folding of the leaf. This phenomenon starts in late summer, when it is easily observed, and seems to be stronger during periods of drought. It is typical of the species *Tilia cordata* and *T. tomentosa* (silver lime), which occur naturally in south-eastern Europe. It is not found in *T. platyphyllos*, but it is typical of some clonal groups of common lime (Paper II). The foliage of trees belonging to one of the clonal groups is often infested with an unidentified fungus (probably *Cercospora microsora*) causing black spots.

The flowers are produced on the shoots of the current year, in axillary, slender, long-stalked cymes. One of the most characteristic features of the genus is the large, membranous bract, several cm long, to whose midrib the lower part (sometimes more than half) of the main inflorescence stalk is united, thus giving an appearance of developing directly from the centre of the bract. The flowers are very uniform throughout the genus, and are not diagnostic to differentiate species (Bean, 1980). The date of flowering is quite variable between the species. The first to flower is *Tilia platyphyllos*, followed by *T. x europaea* and *T.*

cordata. Later still is *Tilia tomentosa* of south-eastern Europe and also very late is the Crimean lime (*Tilia x europaea* 'Euchlora'). The different flowering dates of *Tilia cordata* and *T. platyphyllos* may play a role as a reproductive barrier between the two species. The number of flowers in the cyme is quite variable both within and between the species. Scheller (1972) has presented a list of the number of flowers in the cyme of the most common species. For *Tilia cordata* he gives an interval of 4-10. However, in the present study cymes with 20-25 flowers were observed in both wild and cultivated trees in Sweden.

The fruits are nut-like, with up to three seeds, with a thick or thinnish, downy, ribbed or smooth shell. The thickness varies between the species. It is normally not possible to crush the mature fruits of *Tilia platyphyllos* between the fingers, whereas those of *Tilia cordata* are easily crushed. The fruits of common lime resemble those of the latter species.

Taxonomy and morphology of common lime

There is considerable confusion regarding the proper Latin epithet for common lime. The view of Pigott & Sell (1995) that *Tilia x europaea* L. is the correct name for this taxon is accepted in this study. In 1813, Hayne described a new lime species, *T. vulgaris* Hayne. It was demonstrated by Pigott & Sell (1995) that Hayne founded the description on material of clonal group A (Paper II) of common lime but even earlier the name *T. x vulgaris* was used for common lime (Krüssmann, 1962). In 1824, de Candolle described a new lime species, *T. intermedia* DC, which was also based on material of common lime, and this epithet is currently used in German textbooks and nursery catalogues (Zander, 2002). Thus all three epithets, *Tilia x europaea*, *T x vulgaris* and *T. x intermedia*, are used simultaneously, which is confusing and may lead to the situation that trees of common lime, imported to Sweden from the Netherlands via Germany, may have three different names during their journey. Another species described by Koch (1867) is *T. hollandica,* now considered a synonym for common lime. This epithet is only found in older references.

In historic references, limes are often referred to as large-leaved. In James's translation (1712, p. 141) of the influential French work '*La théorie et pratique du jardinage*' published by Dezailler d´Argenville in 1709, the following sentence can be quoted '*There is a Kind of it* [lime] *call´d the Dutch lime, which is most esteemed, because of its large Leaves…'.* Since almost all clones and seed strains of common lime have leaves smaller than those of large-leaved lime (*Tilia platyphyllos*), it seems that they were being compared to those of small-leaved lime *(Tilia cordata).*

It is striking that the rather large morphological variation in common lime found by the author in Swedish gardens of the 17th and 18th century could be embraced by the term '*Dutch lime*'. One possible explanation is that the trees normally seen by nurserymen or gardeners in the 17th and 18th century were either rather young or subject to regular pruning. This may have prevented the expression of the adult phase, thus concealing differences in character that become more obvious in trees that have been allowed to grow free for a period of time.

Lime history

The cultural heritage of lime is very significant. Lime trees have also been used for several purposes, *e.g.* for a long time, lime was very important as a source of fodder for cattle. In many areas, for example in northern Belgium, the Netherlands and in German-speaking areas, it played a major role in pre-Christian mythology. Later, it became one of the most common trees in gardens of all eras of European garden history.

Ever since man became a stationary farmer, the lime has been an important tree in forest meadows. The foliage was harvested by pollarding in summer, dried and used as leaf-hay as supplementary fodder for cows and other domesticated animals during winter (Slotte, 2000). In some parts of Sweden this tradition continued until World War II (Emanuelsson & Bergendorff, 1996). The tradition of pollarding trees for agricultural purposes may have influenced the techniques and tools used when lime trees in gardens of the renaissance and baroque styles were pruned. The lime has also been important as a source for production of fibres and bast, utilized in string or rope. This is the reason why lime is called basswood in North America.

In northern Belgium, the Netherlands and some parts of the German-speaking areas, in prehistoric time and later, lime was used extensively as a village tree. These trees were usually planted in the market place in villages and were part of pre-Christian mythology. The majority of these trees were probably felled when the areas were Christianised, but they were still quite frequent until the 19th century. Today only a very limited number remain and in general these trees are not trained in the original way. This is discussed further on page 19 of this thesis.

Lime wood is soft and therefore of minor importance as timber. It possesses particular properties that explain why it has been used for several quite

Figure 3. Altar-piece carved in lime wood from about 1470/80 AD, belonging to the Historical Museum of Basel, Switzerland.

specific purposes. The softness makes it easy to carve and the wood normally does not crack when dried. Therefore it has been used extensively as a material for wooden sculptures, particularly in altarpieces, due to its resistance to woodworm (Fig. 3). Because lime wood has often been used in religious contexts, it has been called *lignum sanctum (*holy wood; Wiepking, 1963). It was the preferred material during the golden era of German renaissance sculptors, including the famous master Tilman Riemenschneider (Baxandall, 1995).

Lime trees have played a major role as an architectural element in gardens and urban landscapes in Sweden and other European countries at least during the past four centuries. During most of the 17th century, limes were planted individually or in small numbers, although towards the end of the 17th and in

the first half of the 18th century there was extensive planting of limes in large numbers in gardens of the baroque style. Later, lime was also an important tree in gardens of the English landscape style. The use of lime trees as an architectural element during the 17th and 18th century is the very foundation for this thesis. In some areas in Sweden, especially in Scania, the southernmost province, and in the provinces surrounding Lake Mälaren, gardens containing lime trees from this era are very common. In most gardens the lime plantings date back to the end of the 17th and of the first half of the 18th century. One of the reasons for this was the political and economic power of Sweden during this period. The Swedish King elevated a number of officers who served in the Swedish army during the Thirty Year War to the nobility. The new noblemen often built castles and manor houses and surrounded them by gardens of the baroque style. Many of these are depicted in the topographical work *Suecia Antiqua et Hodierna (*Dahlbergh 1899). Even though the illustrations may have glorified the real situation, they illustrate the extensive creation of new gardens or garden aspects. An illustration made in 1763 of a fairly new lime avenue at Ulriksdal Castle near Stockholm shows many interesting aspects (Fig. 4). The role of the avenue as a social arena is obvious and the way the young limes were pruned and staked is quite visible.

Many of the lime plantings that are now some 250-300 years old still contain large numbers of the original trees. The fashion of planting lime trees in gardens was imported to Sweden from continental Europe, but in many other countries the old lime tree plantings have disappeared. During war times, the trees were cut down for fuel or were otherwise affected by war activities. In countries such as the Netherlands, several of the old mansions have been altered or destroyed due to urbanisation. Other gardens have been changed by owners wishing to follow contemporary garden styles.

The Swedish history is quite different. The country did not suffer from the great wars during the 20th century. The manors built during the era when Sweden was a great power are in many cases situated in areas that are still quite rural. Many of the Swedish manor gardens were not changed as radically as in other European countries. Thus, the conditions for preservation of the original lime tree plantings have been quite favourable in Sweden. This has led to one of the hypotheses for this study, namely that Sweden may have preserved a diversity in imported lime trees which is greater than in the original countries, *i.e.* those from which we once imported the trees.

The fact that so many of the original lime tree plantings are still in good condition after up to 300 years is an example of the capacity of limes, and

Figure 4. Oil-painting made by the Swedish artist Sevenbom in 1763. It depict a fairly young avenue of common lime at Ulriksdal Castle. Photo: Statens Konstmuséer.

especially of common limes, to endure different pruning practices. As stated by Stritzke (1994), these trees were regularly pruned for a number of years. Then their crowns were kept at a certain level in order to fit an architectural concept, for example to allow a view over the baroque gardens from the rooms in the *corps de logie* where guests were entertained. When the baroque style lost its importance, the lime trees were often left to grow free or pollarded at longer intervals. During the 20th century, the lime avenues in many gardens have been restored using radical pruning practices, with varying results. In some gardens the limes have survived and developed new crowns at a lower level, while in others the trees are weakened or have died. There is a great need for improved knowledge of how the pruning practices should be executed in a restoration process.

In some gardens tree vitality is very low, which sometimes results in the need for replanting. The background for this is complex and probably an

interaction between the reaction of pruning of the specific clone (clones) and the site properties, such as type of soil and weed competition.

Origin of common lime

Wild trees of common lime have been reported from a number of European areas where the two parents, *Tilia cordala* and *T. platyphyllos*, have a current or historic distribution, such as the Alps, the Pyrenees and Poland (Pigott, 1991), Denmark (Wicksell & Christensen, 1999), Germany (Hegi, 1954), Lithuania and Ukraine (Jaccard & Frey, 1927), the Netherlands (Maes, 1990) and Sweden (Fries, 1945).

Pigott (1991, p. 1182) states that '*Pollen grains that have the exine pattern of* Tilia cordata *on one side and that of* T. platyphyllos *on the other are produced by trees which are morphologically intermediate in other respects or otherwise appear to be* T. cordata *(Andrew, 1971). This type of pollen is present in post-glacial deposits at 5500 B.C. and from the Hoxnian interglacial. This suggests that hybridisation is not exclusively a consequence of human disruption of woodlands'*. Thus, hybridisation seems to have started relatively soon after the two parental species reached their present distribution in north-western Europe.

Although the evidence is limited, it seems that the origin of the imported Swedish material of common lime is the Netherlands (Pigott, 1992) and adjacent areas in northern Belgium and north-western Germany. This view is supported by the fact that three clones of common lime found in Sweden by the author (Paper III) matched three very old trees found near Deventer in central Netherlands, at Sambeek in south-eastern Netherlands and at Weelde in northern Belgium, respectively.

Two of those trees (in Sambeek and in Weelde) seem to have played a role as village limes.

Village limes

There is a long tradition of planting lime trees in villages in the Low Countries and in parts of the German-speaking areas. These trees are called *dorplinden* in Dutch and *Dorflinden* in German (village limes) (Fig. 5). They were sacred to the goddess Freja who was the patron of love, fertility, justice and trade. A number of activities took place at or near those trees, such as weddings and festivals, hence the German expression *Tanzlinde*, markets and law sessions, hence the German expression *Gerichtlinde* (justice lime). When the Low Countries were Christianised in the 7th and 8th centuries, many village trees were felled (Lukács-Graus, 2000). However, in some areas people protested and some village trees

Figure 5. A very impressive and old tree of common lime at Westerlo in northern Belgium, trained as a village lime. This particular clone has not yet been found in Sweden.

were saved. The fact that the tradition of village limes was also adopted in Christianity may have saved some trees. Thus there are examples of old lime trees connected with worship of the Virgin Mary (*Marialinde* in German).

Some trees have survived for a long time or have also been replaced by their offspring. An interesting example is presented in a print from 1620, used as an illustration in Paper I, showing the market place of Oirschot in south-eastern Netherlands. In the print, one mature and one young village lime are illustrated, the latter possibly being a kind of successor. The earliest reference to the oldest tree at Oirschot dates back to 1337 (Maes, 1996). This indicates that a particular clone may have been used locally over a long period. In the German-speaking areas, the remaining village trees are usually large-leaved limes (Goerss, 1981; Pigott, 1992), whereas in the Low Countries they are most often of common lime (Maes, 1990). Since the few existing village limes still show a great variation, they may once have represented an extensive genetic diversity. The variation in common lime in Swedish gardens of the 17th and 18th centuries is possibly a reflection of the original diversity. These village trees may have originated as seedlings or layerings from wild limes. If they are descended

from natural stands, now extinct, the village limes may represent a genetic diversity of *Tilia* in the Netherlands, and adjacent areas, now completely or almost completely lost in the wild.

The great number of village trees once present has also been reduced due to the extensive urbanisation of large areas of north-western Europe. Many old lime trees also disappeared in the 20th century. Maes & van Vuure (1989) provide the following examples: In 1916, two old limes in the market place in Eindhoven were felled and were found to measure 240 and 600 cm respectively in trunk circumference. A very big lime in Kadier en Keer in the Netherlands was felled in 1932 due to widening of the nearby street. In 1994, one of the most renowned of the Dutch village trees, that in Tilburg, was felled for the same reason. However, the genotype of this tree was saved, since a root of the old tree was replanted and generated adventitious shoots (Lukács-Graus, 2000).

In a survey of the biggest limes in the Netherlands, Maes and van Vuure (1989) found 52 trees with a stem circumference of 450 cm or more. Three of these were *Tilia cordata*, nine *T. platyphyllos* and 40 *T. x europaea*. Of the 11 limes with a stem circumference of 600 cm or more, one was *T. platyphyllos* and the others *T. x europaea.* According to Maes (1990), the oldest lime in the Netherlands is the tree of common lime at Sambeek, mentioned above, with a trunk circumference at breast height of 820 cm. This tree was found by the author to belong to clonal group E (Paper III).

In 1911, Chalon (cited by Badouin, de Spoelberch & van Mulder 1992) found 87 big lime trees in a survey of big trees in Belgium. During a more recent survey carried by these authors in the period 1987-92, they found only 54 of these trees still alive. One of the most impressive and skilfully maintained contemporary village limes is that at Westerlo in northern Belgium (Fig. 5). This tree is of a clone of common lime, not yet found in Sweden.

In what is now Germany, most big lime trees with a history as village limes are large-leaved lime (*Tilia platyphyllos*). In the German districts of Meiningen and Hildeshausen, which contain 113 villages, 83 village trees of lime still existed in the 19th century (Schaubach, 1889, *cit*. Wiepking, 1963). One of the most impressive German village trees is the lime at Schlenklengsfeld, which is believed to have been planted in 760 AD (Goerss, 1981). Every second year, a dance festival is held when the lime is in flower. Of the trees still alive, the one in Heede is of a remarkable size, with a trunk circumference at breast height of about 17 m (Maes, 1990). One of the most well documented German village trees, now lost, was that at Neuenstadt planted in 1325 (Hegi, 1954). The existence of this tree was well known among European botanists

and dendrologists of the 19th century and it was mentioned by Loudon in his Arboretum et fruticetum Britannicum. To quote from his work: '*The branches extend to nearly 100 ft. on each side of the trunk, and they are supported by 108 pillars, some of which are of wood, and some of stone; there is a place of entertainment formed in the head of the tree, which is ascended to by a flight of steps. In the hollows of the branches, earth has been placed, and gooseberry bushes planted, which bear fruit, which is sold to visitors*' (Loudon, 1854, vol. 1, p. 372). The history of this tree until 1887 was investigated by the famous German plant physiologist Robert Caspary (Caspary, 1887;Fig 6 a and b). A Swedish garden journalist visited the place in 1922 and found the tree in a rather miserable state. The crown was then supported by 100 posts, 88 made of stone and 12 of wood and covered an area of 1.2-1.3 hectares. Some of the lower branches were missing and the lower canopy was partly replaced by a number of younger trees of small-leaved lime. The journalist was told that in 1647 when the Swedish army was searching for fuel, they heeded the pleas of local inhabitants, spared the tree and instead used window frames and apple trees from the surrounding orchards (Anonymus, 1922). Fig. 7 shows the 'landscape' under the crown of the lime at Neuenstadt. The old lime tree at Neuenstadt was finally destroyed during an Allied air raid in May 1945, at the very end of World War II (Wiepking, 1963).

In the Nordic countries, there is no evidence of a tradition of village limes. An exception was an old lime tree that seemed to have been maintained in the village lime tradition, which once grew on the Danish estate Boller (Fig. 8) in southern Jutland. This tree was estimated to have been planted in the 15th century and fell in the severe storm of 1902. The trunk circumference at breast height was then 5.6 metres and the crown, supported by 42 iron posts, was 28 metres in diameter (Becker, 1920). The Malmvik lime (Paper IV) was trained in the same way as a village lime.

Propagation and trade of common lime

An important factor in understanding the variation in common lime found in Swedish gardens is their propagation. Paper I presents evidence supporting the view that vegetative propagation by layering was the dominant method used during the 17th and 18th century (Fig. 1). The main reason for this seems to have been the climatic conditions during most of that period, which prevented the development of the lime seed. The cool and rainy climate known as 'the Little Ice Age' is estimated to have lasted between ca. 1430 and 1850 (Pfister, 1977). During

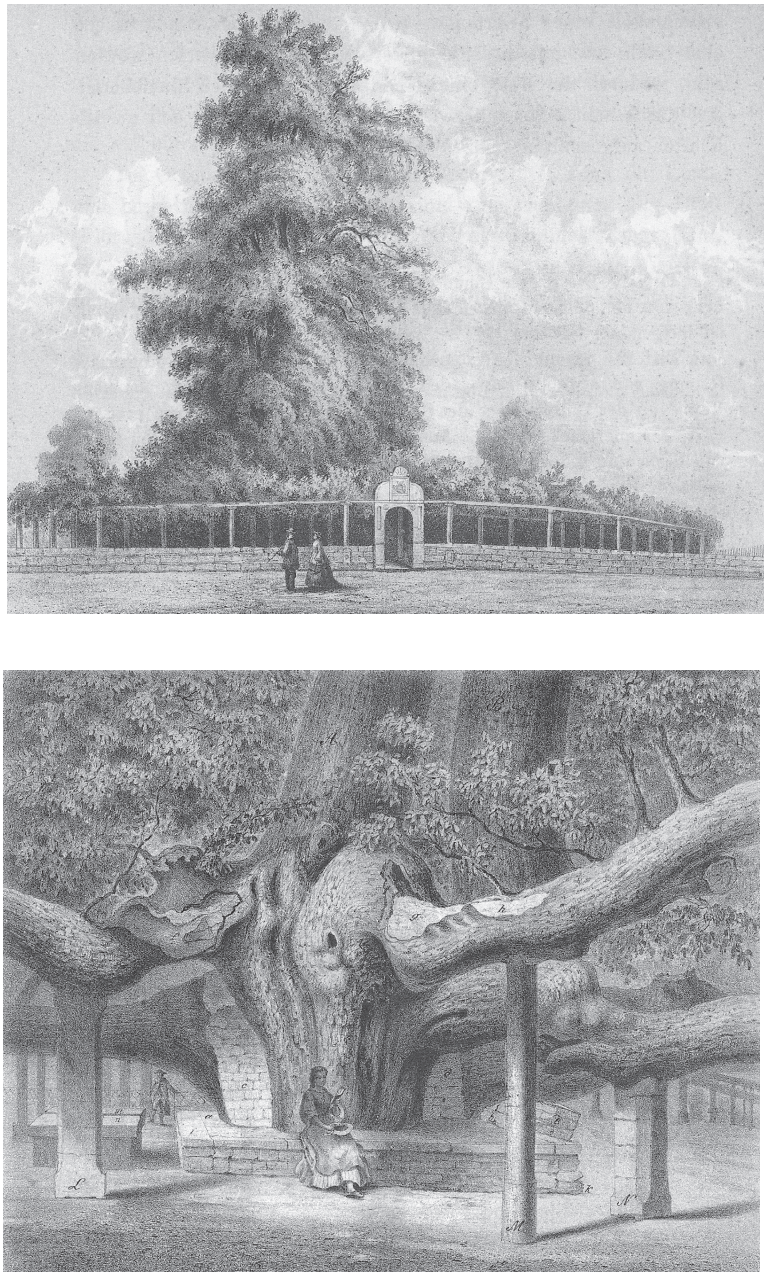

Figure 6 a and b. In 1887 Robert Caspary published a paper, including two drawings, of the famous lime tree at Neuenstadt. Above the lime from outside, below a part of the impressive trunk.

Figure 7. A photo of the 'landscape' under the canopy of the Neuenstadt lime. Photo from Wiepking (1963).

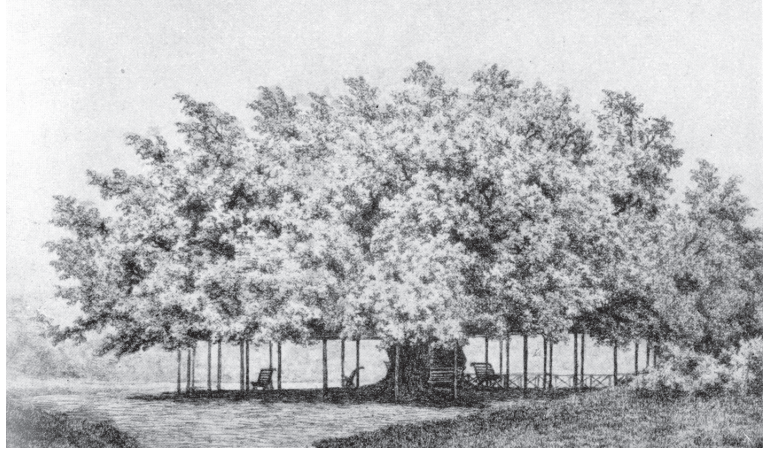

Figure 8. The lime at the Danish estate of Boller in mid-Jutland. It was trained in same fashion as a village lime. In 1844 it is said that the Danish King had a dinner for 180 guests under the canopy. It has been estimated that the lime was planted in the 14th century (Becker, 1920).

the second half of the 18th century the climate became less harsh, which made possible the full development of lime seeds. Seed propagation was a more rational way of propagation and coincided with a great demand for trees of 'Dutch lime'. The methods used when propagating common lime are reflected in the plantings in Swedish gardens. In a planting of vegetatively propagated trees, one clone or a number of clones are rather easily identified. When the trees are propagated by seed the variation is more difficult to identify due to the small differences between the individual trees.

As described in Paper IV, the first recorded import and planting of common lime to Sweden was made in 1618, when Erik Larsson, later elevated to the nobility as Erik von der Linde, brought a sapling of lime from the Netherlands to Sweden where he planted it at what was destined to be his manor at Malmvik, west of Stockholm. This tree became very famous and probably inspired other citizens to plant lime trees. Many of them were planted at '*malmgårdar*', small farms used as summer residences by wealthy citizens, then situated outside the old city of Stockholm. Some of these lime trees are still alive. An interesting example is found at Groens Malmgård in southern Stockholm and in the surrounding gardens. This was founded in 1670 by Christian Horleman, a Dutch gardener appointed by the King as the keeper of Kungsträdgården ('*The King's Garden*') in the centre of Stockholm. His garden was later bought by a Dutch merchant and finally by another Dutchman, Verner Groen, after which the place got its name (Lindberg, 2002). At Groens Malmgård there is an old lime tree, probably planted at the end of the 17th century. The tree is of a clone described in Paper III (clonal group A, clone no. 6) and is distinguished by *e.g.* the brownish-yellow colour of the long shoots. In the surrounding gardens, trees of the same clone are found. They seem to have been planted during the 18th century until the end of the 19th century. This may be interpreted as follows. The first tree was probably imported from the Netherlands by some of the early proprietors. Later, this tree was utilized as a mother tree for local propagation and production of trees planted in the neighbouring gardens.

No direct link has been identified between a clone of common lime planted in Sweden during the 17th and 18th centuries and a particular nursery or garden in the Netherlands. There is, however, one example of indirect evidence pointing to a certain district in the Netherlands as a source of lime trees imported to Sweden. During the second half of the 18th century, vast numbers of trees were imported by Hans Ramel, baron at the Övedskloster Castle in Scania in southern Sweden. No records of this have been found but there are still

thousands of trees of common lime of the seed strain belonging to clonal group C (Paper II) to be found on the many properties that belonged to him. A report by his friend Erik Gustaf Lidbeck (Törje, 1973), one of Carl von Linné's pupils, tells us that on one occasion 4 000 trees, most of them probably limes, were imported to Övedskloster from the Netherlands. Trees of the same seed strain have been found by the author in Haarlem in the Netherlands, in the avenues of Spanjaardlaan ('*Spaniard's Lane*') and Kleine Houtweg ('*Little Forest Walk*'). In Denmark Christensen (1981) has found documents of an import of lime trees, probably of the same seed strain, to the garden at The Royal Palace of Fredensborg from two Dutch nurseries, namely Johannes Krebs and Johannes Rosenkrantz. They were both situated at Haarlem (Kuijlen, Oldenburg-Ebbers & Wijnands, 1983). Haarlem was a very suitable location for nurseries because many different kinds of soils (sand, clay *etc*.), which could accommodate the various cultures of *e.g*. lime trees, fruit trees and bulbs, were found within a limited area (Oldenburger-Ebbers, 1998).

Etymology

The genus name *Tilia* is probably derived from the Greek word 'tilos' which means thread or plant fibre, alluding to the bast. The Greek word for lime is *philyra* (Corneliuson, 1997). Another derivation is proposed by Henriksson (1911). He suggested that *Tilia* is derived from the Greek word 'ptilon' which means a wing and alludes to the bract of the inflorescence.

The Old Norse word for lime is *lind* (Svenska Akademiens ordbok, 2004). It is derived from the Germanic word *lindi*, which means a tree from which wicker wood or bast can be obtained. The lime as a source for bast is the background of the American common name for the genus, which is *basswood* (Bean, 1980).

In Old Swedish, the word *linn* was used for lime. It is significant because it is the origin of the family name Linnaeus (later von Linné). In the late 17th century Nils Ingemarsson, then a student of theology at Växjö in the province of Småland, changed his family name to Linnaeus. He was inspired by a large small-leaved lime, with three trunks, growing near his home on the farm Jonsboda in the same province. Two brothers, Carl and Sven Tiliander, relatives of Linnaeus, took their family name after the same tree, while some other relatives probably took their family name Lindelius after their home on the farm Linnegård (Lindberg, 1956/57). The male line of all three families ended during the

17th and 18th centuries, and according to the myth this was connected with the falling down of the three main trunks of the Jonsboda lime. Today Linnaeus´s lime is still alive and has developed new trunks from sprouts.

The tradition in Sweden of changing family name started at the turn of the 17th century. Before that time, family names in the lower classes often ended in *-son* or *-dotter* (-son or -daughter). When the new tradition started, family names associated with lime became very popular. In a recent study, Lindqvist (2000) found that the 19 most common Swedish family names of today end in *-son* (*e.g*. Bengtsson). The next most common were Lindberg as number 20, Lindström as 21, Lindkvist as 22 and Lindgren as 23. Of persons with a family name starting with a tree name, 441 of 1000 began with Lind-. Another testimony to the significance of the lime in people's mind is the frequent use of lime in folk songs and in poetry, as underlined by Geijer & Afzelius (1880). In a poem by one of the leading Swedish poets from the era of national romanticism, the lime plays an important role (Rydberg, 1891).

The use of the word *lind* (lime) in place-names in Sweden such as *Lindesberg*, *Lindhult* and *Lindholmen* is interesting and quite frequent. The reason is generally regarded to be a current or historic presence of lime trees at or near those places. This is similar to the situation in other countries, even in Eastern Europe. The Slavonic name for lime is *lipa*. This is the background of the name of the German city of Leipzig.

MATERIALS AND METHODS

An interdisciplinary approach was used to study the origin, growth and development of trees of common lime planted in Sweden during the 17th and 18th centuries. Texts and illustrations from contemporary references dealing with gardens and architecture were analysed with a dendrologist's/botanist's perspective. Thousands of old trees were examined during field studies, with the historical perspective in mind. Historic lime trees in other parts of Europe, mainly the Netherlands, Flanders and some examples in Germany and England were also visited.

The survey of limes planted in Swedish gardens of the 17th and 18th centuries was started in 1995. Most plantings of common lime were found in the province of Scania in southern Sweden and in the provinces adjacent to Lake Mälaren. These areas are characterized by rich agricultural landscapes, with a high concentration of manors and castles, often containing trees of common lime from the period. The gardens containing lime plantings were found partly by studying books on architectural history and garden history (Dahlbergh, 1899; Karling, 1931) and partly by field studies. The latter were very effective during wintertime when trees of common lime can be identified at quite some distance, even from a passing car, due to their characteristic crown architecture.

The historic practice of pruning means that it is almost never possible to describe the natural crown architecture of the different clones (Fig. 9). Most trees from this period have been pollarded or pruned according to the principles of the baroque era (Dezailler d´Argenville, 1709; Stritzke, 1994) and have later been subjected to maintenance regimes varying from almost total neglect to pruning at some intervals. Sometimes a lime planting has been subjected to a radical restoration of the crowns, with varying results. When left to grow freely, the crowns of common lime often develop three or more main branches rising vertically from the lapsed pollard (Read, 2000). As already mentioned this has led to the incorrect conclusion that trees of common lime are characterized by candelabra crown architecture. On the contrary most, if not all, types of common lime, when allowed to grow without pruning, develop a strong central leader. In the present study, this was observed in a number of trees planted at the end of the 18th century that have never been pollarded or heavily pruned. For the entire material described in this thesis (Paper III), a potential height is mentioned as a range, for example 25-30 m, which may be reached under Swedish conditions.

In 1998 the molecular method of RAPD was used in an effort to discriminate a number of clones. The results was, however, not reproducible and the results were never published.

Figure 9. Lime avenues at Sturehov Castle south-west of Stockholm. The trees were pollarded in 1958 but are in very good condition. Due to the regular pruning, it is very difficult to identify the clone. Most trees belong to clonal group C.

*Propagation of common lime (*Tilia x europaea *L.) planted in Swedish gardens of the 17th and 18th centuries*

In order understand the morphological variation found in some plantings of common lime from the second half of the 18th century, a study was made of historic and modern textbooks and references. The character of this variation was of a kind that could only be explained if propagation by seed had been used. In order understand when and why the different propagation methods, mainly by layering and by seed, were used during this period, references dealing with the climate in Europe during this period were also consulted.

*Classification of cultivated common lime (*Tilia x europaea *L.)*

Two studies were carried out by the author. The first of these was a study of the limes planted in Swedish gardens of the 17th and 18th centuries in the areas

mentioned above. The great majority of these trees belong to the taxon *Tilia x europaea*, represented by a number of clones and one seed strain (Paper II). The foundation for this was the work of Pigott (1992). In order to get a broader reference material, some old Dutch and Belgian lime trees were also examined. In a second study, plantings from the 19th and 20th centuries were studied. They were most often found in gardens of the English landscape style, in streets and squares and in cemeteries. About 300 plantings representing more than 15 000 trees were included in the studies. The material was studied both fresh and as herbarium specimens. The samples were preferably taken when trees of common lime were starting to flower and the leaves were fully developed, up until the end of August. They were collected from the lower part of the crown, preferably 2-5 m above the ground and exposed to the sun. However, this was sometimes not possible to achieve when the distance between trees was small and the planting orientated in a more or less north-south direction.

Scions were taken during early winter from representative trees and grafted at the research nursery at Alnarp.

The main characters that were observed in order to divide the studied trees in clonal groups are:

- Shape of the base of the leaf lamina
- Sheen or lustre of upper leaf lamina
- Length of the petiole
- Shape of the fruit
- Position of the cyme
- Shape of the floral bract

*Variation in common lime (*Tilia x europaea *L.) planted in Swedish gardens of the 17th and 18th centuries*

The procedure mentioned for the previous study was followed but restricted to plantings of the 17th and 18th centuries. When a planting was identified, an overview was made in order to find the variation caused by a mixture of clones and, sometimes, by the trees being seed-propagated. Representative trees were then identified and samples taken during summer and studied fresh and as herbarium specimens. Due to the varying age of the crown, the samples had to

be selected carefully. Some trees had not been pruned for over a century, while others were recently pollarded. Thus the samples, if possible, were taken from twigs containing short shoots, 40-80 mm in length. In many trees it was not possible to find longer shoots in the reachable part of the crown, due to low vigour of the tree. As stated above, it is of great importance to study the samples when they are fresh. Otherwise some important characters like the sheen or lustre and the micromorphology of the upper lamina may soon be lost when the leaves are dried.

Photos were taken using negative film (Fuji Superia 200 ASA). Scions were taken from some particularly interesting trees during wintertime. The scions were preferably collected from long, epicormic shoots found at the trunk. They were grafted at the research nursery on the Alnarp campus. Later, the young plants were planted in the field at the nursery, where observations of *e.g.* the phenology were made. This proved to provide valuable extra information, and was used for example to discriminate the very similar clones of clonal group E.

About 250 plantings of common lime, in the areas mentioned above, were visited several times during a period of six years. These plantings represent in all more than 10 000 trees.

*The Malmvik lime. A historical and biological analysis of the oldest documented planting of common lime (*Tilia x europaea *L.) in Sweden*

When the studies of common lime in Swedish gardens included in this thesis started, the oldest living tree of that taxon was, as mentioned before, found at Malmvik manor near Stockholm. A number of references dealing with the development this tree were identified and analysed. They were related to the properties of this particular clone of common lime, in Sweden only found at Malmvik. Scions from the tree were collected and grafted in 1997. One plant of the resulting grafts was planted at Malmvik in 2002, a few years after the original tree fell in a storm.

RESULTS

*Propagation of trees of common lime (*Tilia x europaea *L.) planted in Swedish gardens of the 17th and 18th centuries (Paper I)*

Through studies of historic and modern references, it was possible to present an overview of how the common lime was propagated in the 17th and 18th centuries. For most of the period propagation by layering was the dominant method. The two main methods of propagation by layering were found to be simple layering and mound layering. In the Netherlands, this procedure would normally take only one year but in Sweden it took twice that time or more. Propagation by seed seems to have played an increasing role during the second half of the 18th century.

The used propagation methods may be explained by the fact that during 17th and 18th centuries the climate was generally characterized by cool and rainy summers and cold winters. This coincided with the period called the Little Ice Age, which lasted between 1430 and 1850 AD. During the second half of the 18th century the climate gradually became warmer, which allowed the lime seed to ripe and be viable again. This is in agreement with observations made during the field studies of plantings from seed-propagated trees from 1770 and on.

*Classification of cultivated common lime (*Tilia x europaea *L.); (Paper II)*

An analysis of the trees of common lime planted in Swedish gardens showed that the clones and seed strains could be divided into six groups (Table 2). This is an extension of the work of Pigott (1992). To cover the Swedish material, it was necessary to develop a more extensive system by adding three new clonal groups, C, D and E (Paper II). In order to cover the variation in the Swedish material, a slight extension of Pigott´s definition of his clonal group A was necessary. This allowed all the historic limes found in Swedish gardens to be covered. In the present thesis Pigott´s entity clonal group is used, although a seed strain is included in clonal group C. By defining a further group, F, covering the variation in Crimean lime, the new system comprises six entities. This system covers all types of common lime found in Sweden planted from the early 17th century until today and provides an overview of the variation in common lime. It also allows for identification in the field with no other instruments than the naked eye.

When studying trees of common lime in England planted during the 17th and 18th centuries, Pigott (1992) found many of them to belong to clonal group B. It was not possible to find trees in Swedish gardens of the same period that belong to this group with certainty.

From preliminary observations, it was possible to conclude that the system presented in this paper (Paper II) seems also to cover the variation in common lime in other countries in Central and Northern Europe.

Table 2 (Paper II) shows an overview of the periods when trees of common lime representing the different clonal groups were planted in Swedish gardens. Trees of clonal group A seem to have been the most common choice over the whole period. This may at least partly be explained by the generally prolific production of basal shoots at the base of the trunk in trees of clones belonging to this group. This was an advantage when layering was chosen as the propagation method.

The proposed system for classification of common lime into six clonal groups was tested in practice on both students at the Swedish University of Agricultural Sciences Alnarp and on professional people attending training courses. During courses in 2003 and 2004, the students were able to identify all clones of common lime in the contemporary nursery assortment using this classification system as a tool. In all, about 200 persons have tested the system. The results prove that the system is rather easy to understand and to use as an instrument in practice for identification of different varieties of common lime. This is an important aspect of the research.

*Variation in common lime (*Tilia x europaea *L.) planted in Swedish gardens of the 17th and 18th centuries (Paper III)*

The study of the limes in Swedish gardens of the 17th and 18th gardens showed a wider morphological variation than earlier anticipated. Almost all of the limes were found to belong to the common lime complex. Only a few dozen small-leaved limes and two trees of large-leaved lime, planted before 1800, were found. The variation in the common lime complex consists of a number of clones and one seed strain belonging to four of the six clonal groups mentioned in Paper II. Members of all the four groups are represented in gardens of the 17th and 18th centuries. While the use of members of group A and C has continued until the present day, the use of trees of group D and E seems to have ended before 1900. An overview of when the trees from the clonal groups were used in Swedish gardens is shown in Table 2. (Paper II).

Table 2. Overview over the periods when trees representing the different clonal groups have been planted in Swedish gardens. The presence of trees of clonal group B is not yet confirmed.

Clonal group	17th century	18th century	19th century	20th century	21st century
A	———	———	———	———	
B			---------- ?		
C	———	———	———	———	
D	———	———	———		
E	———	———	———		
F				———	

Table 3. Overview over the clonal groups of common lime (see Paper II)

Clonal group	Defined by	Frequency in Swedish gardens of 17th and18th centuries	Type tree in Sweden	Popular name	Cultivars
A[1]	Pigott (1992)	Very frequent	Gustav II Adolf's lime, Svartsjö Palace	Pallida group	Koningslinde, Pallida, Wratslaviensis
B	Pigott (1992)	Absent	None identified	Hatfield Tall group	No known
C[2]	Bengtsson (Paper II)	Frequent	A tree at Sjöö Castle	Zwarte Linde group	Zwarte Linde
D	Bengtsson (Paper II)	Rare	A tree at the Royal Palace of Ulriksdal	Ulriksdal group	None known
E	Bengtsson (Paper II)	Rare	A tree at Grönsöö Castle	Malmvik group	None known
F	Bengtsson (Paper II)	Absent	A tree at Ribbingska hospital, Lund	Crimea lime group	Euchlora, Frigg, Laurelhurst, Redmond

[1]) Slightly modified in this paper
[2]) A few seed strains are included in this group

*The Malmvik lime – an analysis of the oldest recorded planting of common lime (*Tilia x europaea *L.) in Sweden (Paper IV)*

This lime was imported from the Netherlands and planted at Malmvik Manor near Stockholm in the year 1618. From early illustrations it can be concluded that the lime was trained in the same way as the old village limes, which von der Linde most probably became acquainted with during his travels in the Netherlands. The Malmvik lime was probably once the most famous tree in Sweden. This, and the fact that von der Linde was a well-known person in Stockholm and a good friend of the Swedish King, may have played an important part in the increasing interest in planting limes, especially Dutch limes, that took place in and near Stockholm.

It was possible to link the history of this particular lime with the special properties connected with the type of common lime belonging to clonal group E as described in Paper III. Based on a biological understanding of the development during the life cycles of different kinds of lime and cultural studies of how the old village limes were shaped and maintained in *e.g.* Dutch villages, it was possible to obtain a deeper understanding of the special Malmvik tree in a garden history context.

DISCUSSIONS AND CONCLUSIONS

In an international perspective, Sweden has a large number of plantings of lime, particularly of common lime, from the 17th and 18th centuries. The early idea that they represented a more extensive variation than anticipated was shown to be true in this study. Many of these trees are still alive and as a consequence of the increasing interest in the maintenance and restoration of historic gardens, the demand for more taxonomic knowledge of these trees is also increasing.

The main result of this study is a partly new, partly broadened system for general classification and identification of common lime (*Tilia x europaea* L.), which can be used in the biological sciences and modern landscaping, and as a tool for determining the authenticity of historic lime trees. The study revealed hitherto unknown diversity in the taxon common lime in Sweden. The concentration of different varieties in geographically limited areas is probably not to be found in any other country in Europe. In order to maintain this diversity of common lime, efforts ought to be made to develop methods of enhancing a prolonged life span of these trees. These methods should include better pruning techniques and also better knowledge of how to maintain site properties important for the survival of old lime trees.

The classification system presented in this study proved to be a tool that can be used in practice for identification of the variation in common lime on clonal level. This is important for the development of new plantings, but especially for restoring historic lime tree plantings in accordance with the Florence Charter. When authentic plant material is not available for a restoration project, the classification system can provide guidelines of how to chose trees as similar as possible to the original ones.

Studying the cultural context in which common limes have been used for centuries proved to be a very rich source of knowledge about how the lime trees have been used and trained to fulfil their cultural functions. Combining this cultural knowledge with biological knowledge, mainly from the taxonomical and morphological sciences, was also quite fruitful. In particular, the historical studies were an invaluable help in creating both the geographical and the historical maps used for the classification of lime trees. The cultural landscape in which these lime plantings were found also acted as a kind of mind map, which was used as an important support for the scientific orientation in the very diverse world of common lime. Without these maps, the real map and the mental map, the investigation of lime trees carried out in this study would have been very difficult. In addition, the classification of common limes,

combined with an understanding of the biology of the life span of limes, provided a deeper understanding of some aspects of the use of lime trees in garden history. To conclude, the interdisciplinary approach adopted in this study proved to provide new possibilities in research.

The results indicate the need for further research. Among the most interesting issues, the following ought to have priority:

- A comparison of the variation in common lime in different countries should be executed. The differences between the common lime used in England and Sweden indicate that there might be greater regional variations than anticipated.
- A careful study of the oldest cultivated limes, preferably of common lime, still alive in Europe should be carried out urgently since they seem to be mother trees for the variation found in gardens.
- In order to extend the longevity of cultivated lime trees, pruning practices should be developed and refined. This is needed because observations made in this study indicate that similar or identical pruning practices have given very varying results in the survival and further development of different trees.
- The use of interdisciplinary research in garden history, combining historical methods with biological methods, needs to be further developed
- DNA techniques as a tool for characterizing the genetic variation in common lime need further development. The RAPD method tested here was inadequate especially regarding the possibility of obtaining reproducible results.

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