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An archaeobotanical view on the history of the Uppsala Linnaeus Garden and the Garden of the Academy of Turku

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Garden history in academic gardens can be studied both from written and drawn sources, such as lists of plants and old maps. Another possibility is archaeobotanical analyses carried out in gardens. The aim of this study was to test archaeobotanical macrofossil analysis as a method in Uppsala Linnaeus Garden, founded in 1655 by Olof Rudbeck the Elder, and the former garden of Turku Academy, founded in 1757 by Pehr Kalm. The literature provided historical contexts of the gardens. For the archaeobotanical study in the Uppsala and Turku gardens, macrofossil sampling was carried out from the soil with a sampler and a total of 75 soil samples were collected from six different pits in Uppsala and from seven in Turku. Samples were floated and sieved, and macrofossil plant remains were identified. Pollen analysis was carried out from nine subsamples from Uppsala. Six macrofossil samples were dated with AMS-radiocarbon method. Altogether 839 macrofossils and 61 plant taxa were found. Pollen grains from 42 different taxa were discovered, but only four of them in greater numbers. Spores of ferns, moss and fungi were also present in pollen samples. Abundant macrofossil species were in Uppsala *Chelidonium majus* (116 seeds) and in Turku *Chenopodium album* (58 seeds), *Plantago major* (51), *Polygonum aviculare* (53) and *Spergula arvensis* (83). Interesting species were *Chenopodium hybridum* (47 seeds from Uppsala, four from Turku), found in the *Hortus Rudbeckianus,* listing species grown in Uppsala by Rudbeck and in the *Hortus Linnaeanus*, listing plants cultivated in Uppsala during the Linnean period; *Datura stramonium* (five seeds from Uppsala), also in both the *Hortus Rudbeckianus* and the *Hortus Linnaeanus*, and also on Kalm's list of plants cultivated in Turku; and *Sambucus racemosa* / *S. canadensis* (23 seeds from Turku), found in the *Hortus Linnaeanus* and on Kalm's list. Pollen grains of the group Asteraceae, which contains garden plants, were found in seven soil samples in Uppsala Garden. In addition, chips of wood and charred wood, small animal bones, and fish scales and bones were found in both gardens referring to soil improvement and indicating gardening. Fungal spores that grow on animal dung could indicate manure and thus gardening as well. Sampling in the garden sites gained information of plants and gardening that would not have been discovered without this study due to the improbability of excavations at the sites. The results could be interpreted as an example of macrofossil assemblages typical of garden sites. Although the macrofossil material found in both gardens was relatively scarce, some equivalent taxa were discovered. However, these could not alone allow a conclusion of strong connection between the gardens, but since the proof of the affiliation exists in the literature, the similarities in the macrofossil materials of the gardens can be attributed to their close relations. By combining macrofossil and pollen analyses and with application of AMS-radiocarbon dates the study was able to collect more knowledge of the garden sites than through macrofossil studies alone. In investigations of garden soil, even more multidisciplinary approach with addition of methods, such as chemical analyses of soil, and analyses of insect remains and phytoliths, could probably gain more extensive evidence of past gardens.

Keywords: botanic garden, garden plants, macrofossils, pollen, Olof Rudbeck the Elder, Pehr Kalm, University garden, Åbo

Introduction

Academic gardens in the early modern Sweden and Finland played an important role in the development of botany, gardening and horticulture in these northern latitudes. Enthusiastic and learned people had the need and the opportunity to create gardens for scientific purposes, but also for experimental and economical use (Ruoff 2001a, Martinsson & Ryman 2007). Botanic gardens and people who ran them were in a key position in introducing new plant species to Sweden and Finland, species that had been brought from the New World to Europe from 1492 onwards. Through academic gardens, new plants and cultivation practices, i.e. new garden culture, was able to spread, first to noblemen and their manor gardens, then to parsonages and later to common people too. The advance of botany and economy was visualized and became concrete in academic gardens and in people who established these gardens and operated in them (Ruoff 2001a, Martinsson 2007).

Old botanic gardens were perhaps first herb gardens for medical education, before the precise botanical approach, developing from old medicinal gardens (Ruoff 2001a, Hobhouse 2004). One of the European pioneers was founded in 1590: the botanic garden of the University of Leiden in the Netherlands (Hobhouse 2004). Leiden, where botany was at a high level already in the 17th century, had remarkable influence on botanists and the development of Swedish and Finnish botanic gardens (Kari 1940, Martinsson & Ryman 2007). The 'hortus botanicus' of Leiden was a treasury to European medical and botanical scientists, Dutch ships bringing plants never seen before from the New World and Asia (Morton 1999, Ruoff 2001a). The University of Uppsala was founded in 1477, while the Academy of Turku (Åbo in Swedish) was founded in 1640 and their botanic gardens were established in the 17th century. Both of these universities were located in Sweden (Turku is nowadays in Finland), and had close connections via scholars, especially botanists from the 1670s onwards (Martinsson & Ryman 2007).

The history of botany and garden history in academic gardens can be studied on the basis of written and drawn sources, such as letters, reports, account books, plant lists of gardens, and old maps and plans. Research of art history, history of landscape architecture, and archaeology can be involved. However, an additional possibility is archaeobotanical studies carried out in gardens with macrofossil analyses of garden soil.

The aim of this study was to test whether archaeobotany could shed light on the history of the Uppsala University and Turku Academy botanic gardens. As the importance of these gardens is known from the literature, and as the history of this kind of gardens has a tight connection to the plants themselves, I attempted to find remains of plants through archaeobotanical analyses from the soil of the gardens. I applied such methods in a context where it was possible to compare the results of archaeobotanical analyses to what is known about the flora of the sites on the basis of historical sources, the lists of plant species cultivated in the gardens. Since no archaeological excavation took place in the gardens, sampling for macrofossil analyses was carried out from the soil with a sampler. I aimed to compare the possible macrofossil finds to the plants mentioned in the literature, and to test the sampling method I used, with the application of AMS-radiocarbon dates of macrofossils.

Material and methods

Study sites

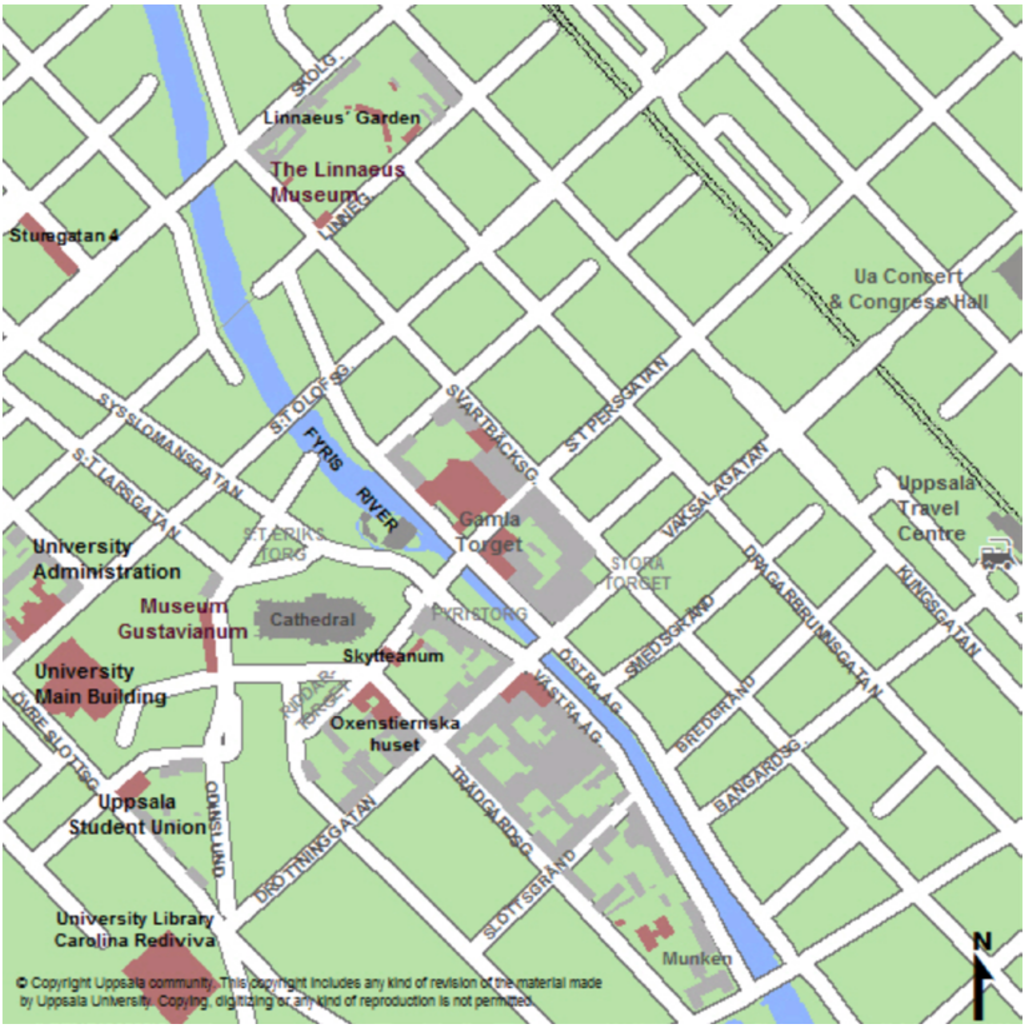
The Linnaeus Garden

The Linnaeus Garden in Uppsala, Sweden (the location: 59°51'45"N 17°38'04"E; present address Svartbäcksgatan 27; in the border of southboreal and hemiboreal vegetation zones) was at the time of its establishment the northernmost academic 'hortus botanicus' in the world and the first one in Sweden (Martinsson & Ryman 2007; Fig. 1). **Olof Rudbeck the Elder (1630–1702)**, a professor of medicine and a botanist, established this botanic garden of Uppsala University in 1655 (Martinsson & Ryman 2007; Fig. 2). Rudbeck had studied botany in Leiden, from where he imported and ordered 800 plant taxa to Uppsala Garden. Rudbeck succeeded in his botanical and horticultural experiment of cultivating South European plants in the north (Martinsson & Ry-

Fig. 1. Uppsala and Turku (Åbo in Swedish) in Sweden of that time, and in present Finland, in Fennoscandia, North Europe.

man 2007). Uppsala Garden expanded to its final size in 1662 (Martinsson & Ryman 2007). In the same year, 1702, when Olof Rudbeck the Elder died, the garden was destroyed in a fire that raged in Uppsala (Martinsson & Ryman 2007). From this starting point, **Olof Rudbeck the Younger (1660–1740)**, who now became responsible of the garden as the director for the next 39 years, could not create as great a garden as his father. Only after **Carl Linnaeus (1707–1778)** was appointed the professor of medicine and the head of the botanic garden in Uppsala University in 1741, the botanic garden developed into one of the best

▼ Fig. 2. The map of Uppsala showing the location of the Linnaeus Garden (59°51′45″N 17°38′04″E; Svartbäcksgatan27). Copyright Uppsala kommun.



of its time (Morton 1999, Martinsson 2007). **Carl Linnaeus filius (1741–1783)** became the director of the botanic garden after Linnaeus the Elder, and then **Carl Peter Thunberg (1743–1828)** in 1785 (Lundqvist & Moberg 1993). The garden became packed with plants, and the location was not the best for gardening, and as a consequence a new botanic garden was constructed to a part of the Uppsala Castle Garden, the transfer continuing from 1787 to 1802 (Martinsson 2007, Martinsson & Ryman 2007). The area of the old garden was made into a German style park, and in the 1920s the Swedish Linnaeus Society (Svenska Linnésällskapet) reconstructed it as it was in Linnaeus' time, and as it still is (Martinsson 2007).

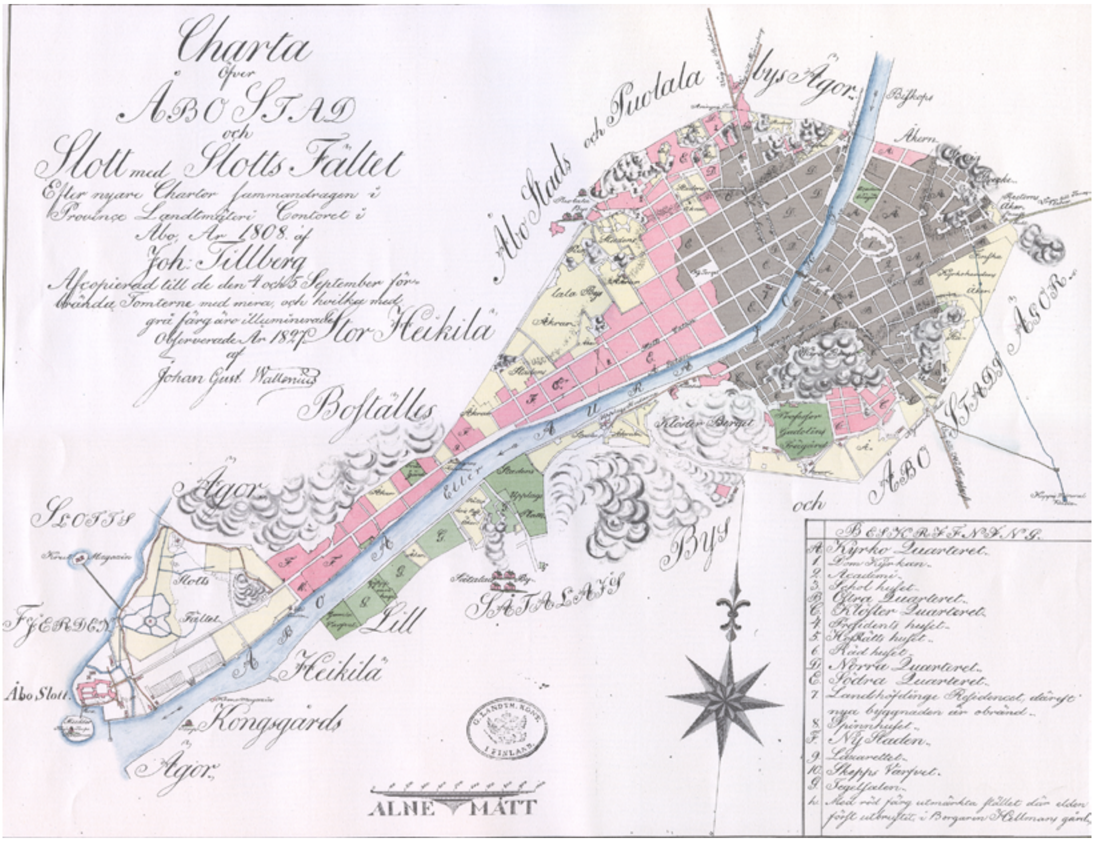
The comprehensive enumerations of plants cultivated in Uppsala Garden reveal the remarkable range of plants that Rudbeck managed to grow in his garden, approximately 2500 taxa and 1500 at species level (Martinsson & Ryman 2007). These are the *Hortus Upsaliensis* of Olof Rudbeck the Elder (1666) and the *Hortus Rudbeckianus*, which connects data from four of Rudbeck's catalogues and some other records of plants grown in Uppsala Garden in Rudbeck's time (1655–1702) (Martinsson & Ryman 2007). Further, the *Hortus Upsaliensis* of Carl Linnaeus (Linné 1745/Fries 1908/Martinsson 2007, Linné 1748) and the *Hortus Linnaeanus*, the catalogues of plants cultivated in Uppsala Garden during the Linnean period (1741–1783), including Linnaeus and his son, demonstrate the collection of plants in that time, 2157 species (Juel 1919).

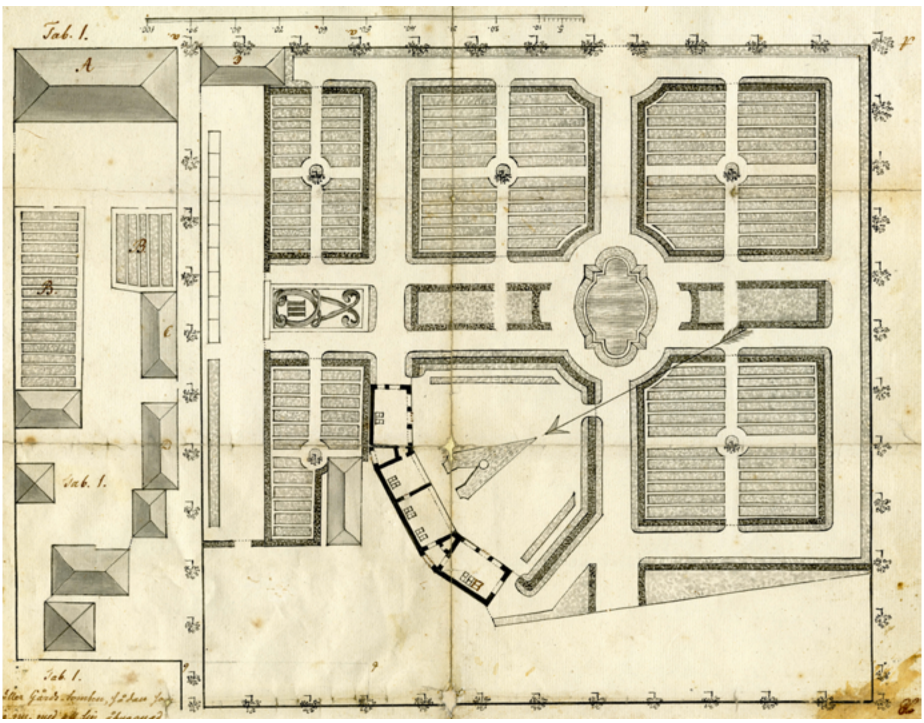
The Garden of the Academy of Turku in Finland

Turku Academy probably had a 'hortus medicus' (called herb garden and cabbage garden in the sources) from the beginning of its existence, even though the position of botany had not stabilized at first (Kari 1940). The first professor of physics and botany in Turku Academy, **Georgius Alanus (1609–1664)** from 1640, may have established a medicinal herb garden, as well as Uppsala University may have had one before the establishment of the botanic garden in 1655 (Kari 1940, Martinsson & Ryman 2007). A garden for medicinal plants was in educational use in Turku Academy at the latest in 1678, in the term of **Elias Tillandz (1640–1693)**, who had studied botany in Uppsala from 1663 onwards under Olof Rudbeck's supervision and became the professor of medicine in 1670 (Klinge et al. 1987, Ruoff 2000). Tillandz soon established a botanical garden close to Academy building. Tillandz's garden deteriorated after he died, and it was in bad condition already in 1702 (Kari 1940, Ruoff 2001a).

Johan Browallius (1707–1755), who was appointed professor of physics and botany in Turku Academy in 1737, brought Linnaeus' teachings to Finland and resurrected the idea of a botanic garden in Turku Academy (Kari 1940). In the period of utilism in Sweden and Finland, when socially relevant and practical research was favoured and the appreciation of natural sciences rose, a professorship of economy was first given to Uppsala University in 1740 (professor Anders Berch), but Turku followed quite soon in 1747 (Niemelä 1998:64). **Pehr Kalm (1716–1779)** was the first professor of economy in Turku Academy in 1747–1779. Kalm was taught botany and natural sciences by Browallius and **Carl Fredric Mennander (1712–1786)**, and later Linnaeus became his mentor (Kerkkonen 1936). In order to find new useful plants to Sweden and Finland, Kalm made an expedition to North America in 1747–1751 as a consequence of baron Sten Bielke's (1709–1753) idea and under Linnaeus' supervision (Kerkkonen 1959).

Turku Academy bought a part of the Willebrand plot in 1750, and also got a part of the old bishop's plot, and to these areas, near the Turku Catherdral and on the shore of the River Aura, the new Botanic Garden of the Academy was founded starting in 1757 (Kari 1940, Klinge et al. 1987; Fig. 1 and 3; the location: 60°27'12"N 22°16'40"E; present address Piispankatu 17). Pehr Kalm and the professor of medicine **Johan Leche (1704–1764)** designed the new garden (Kari 1940, Ruoff 2001a; Fig. 4). In the first years Kalm grew approximately 400 plant species in his gardens, but later the number of species diminished (Kari 1940). In a dissertation defended by Josephus Mollin under supervision of demonstrator in botany, Carl-Niclas Hellenius, are listed 388 plants that had been cultivated in the garden of the Academy of Turku in Kalm's period, though at the time of Kalm's death in 1779 the number of plants was probably only 200 (Hellenius & Mollin 1779, Kerkkonen 1936).





▲ Fig. 3. The map of Turku drawn in 1808 and observed in 1827; Turku Academy Garden (Academic Trä[d] gård) is in green, north from the Catherdral of Turku [No 1]. A photograph of a replica in Turku Museum Centre Archives, original in the National Archives in Finland.

◄ Fig. 4. The map of Turku Academy Garden probably from 1775 (showing the monogram of King Gustav III, who visited Turku in 1775, in plantings). The Finnish Museum of Natural History, Botany Unit.

Relatively comprehensive lists of species cultivated in the garden of the Academy of Turku can be found in the literature concerning Pehr Kalm's planting reports from 1759 and 1768 and Kalm's letters, although these do not include all plants Kalm cultivated, but the ones he particularly paid attention to (Kerkkonen 1936, Kari 1940). Since the sources of such plant lists are scattered and the nomenclature is not current, I gathered the data of 84 different taxa, concerning both the Academy Garden in town and Kalm's other garden in Sipsalo (in present Turku), that Kalm cultivated for different purposes: useful species for manufacture, edible plants, medicinal plants, plants for hedges, ornamental plants and fodder plants (Appendix 1; Kerkkonen 1936, Kari 1940).

Carl-Niclas von Hellens (1745–1820) became the director of the Academy Garden in 1778, later a professor in natural sciences (Enroth & Kukkonen 1999). He had all the plants in the garden dug up, and new plantings were made in scientific order (Ruoff 2001a). Through his work he got the number of species in the garden to increase to over two thousand (Kari 1940, Enroth & Kukkonen 1999). Finland became an autonomous Grand Duchy of Russia in 1809, and Helsinki became its capital in 1812 instead of Turku. After Turku was burnt in the Great Fire in 1827, the Academy, including the Academy Garden, was transferred to Helsinki in 1829. Professor **Carl Reinhold Sahlberg (1779–1860)**, the last director of Turku Academy Garden, moved to Helsinki with the Academy, as many others, and continued his work by establishing a new botanic garden (Enroth & Kukkonen 1999).

Sampling in Uppsala and Turku Garden sites

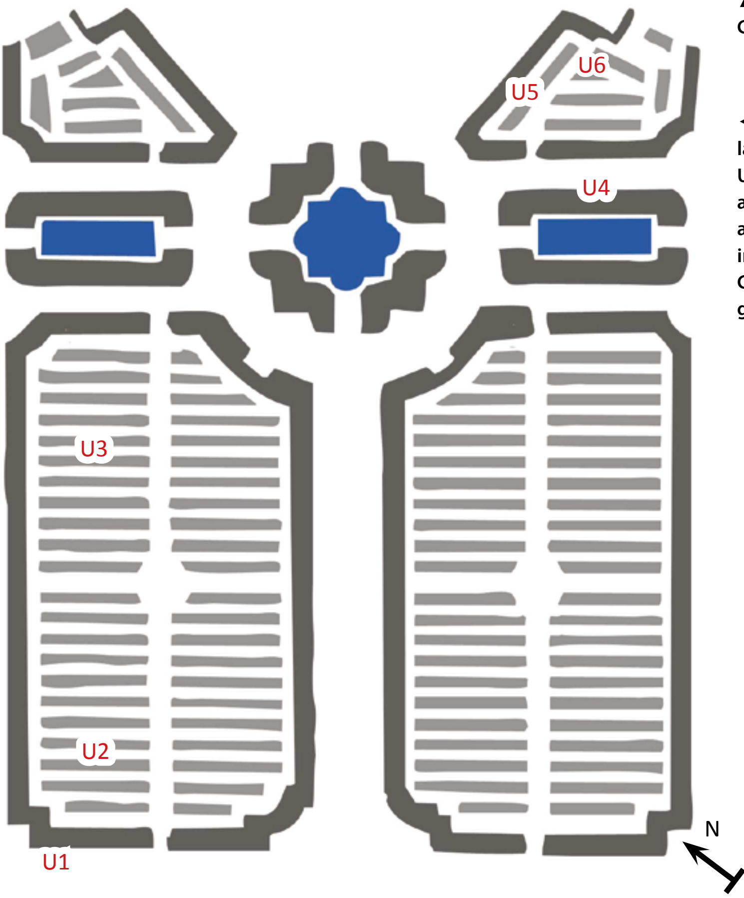
Soil samples were collected in 2008 with an open-ended end-filling sampler (hand auger; Fig. 5), previously tested and found to be feasible in two other gardens in Finland by the author (Alanko et al. 2015, Alanko 2017). Before sampling, the pits were opened with a shovel to move the topmost ground. The sampler was 130 cm in length, thus giving the maximum depth for samples approximately 100 cm. From each sampling pit the samples were collected one by one in vertical series. The sampling method is described in more detail in Alanko et al. (2015).

In Uppsala Linnaeus Garden a total of 34 soil samples were collected from six different pits from three sections of the garden: The Perennial Parterre, on the side of the Marsh Pond, and the Autumn Parterre (Fig. 6). In order to find suitable spots for sampling, the choice of the spots for pits were made after a conversation with a gardener working at the site at the time. Soil samples were approximately 1 litre each, thus containing ca 34 litres of soil in total. Samples in pits varied from one to 11 different levels in one pit. The depth of the samples varied from 15 cm to 100 cm measured from the ground level.

In the former Garden of Turku Academy, a total of 41 soil samples were collected from seven different pits. At least half of the plot of the old Academy Garden has been destroyed by later constructions. Still, on the side of the riverbank, there was less-touched area around an old *Quercus robur*, the so-called Kalm's oak, which may be from the time of the Academy Garden. It is unlikely that soil has been transferred or added considerably around the oak, and thus this was regarded as the most suitable spot for sampling (Fig. 7 and Fig. 8). According to the map of ducts and wires of the present town area, no sewers or cables were underground in the sampling area. In the time of sampling in 2008, the surroundings of the oak were mostly plain grass, but nowadays an exhibition garden for Kalm's memory exists at the site (Fig. 9). Soil samples were approximately 1 litre, thus containing over 40 litre of soil altogether. Most of the samples were collected with a sampler, as in Uppsala, but some of the samples were taken with a small shovel straight to a plastic bag. Samples in pits varied from one level to nine different levels in one pit. The depth of the samples varied from 8 cm to 102 cm measured from the ground level.

In some spots in Turku, thick roots of the oak were in the way preventing sampling straight or deeper down, in some cases big stones had the same effect. In some cases in Uppsala, the soil was too hard to make boreholes. In some spots, pieces of brick were shown in the soil, and deeper down the soil turned clayey especially in Turku, and moist in Uppsala. Both gardens are situated near a river.

▲ **Fig. 5a and 5b. The sampler in Turku Garden site. Photographs Teija Alanko.**



◄ **Fig. 6. The sampling pits in Uppsala Garden. Pit U1 in the bed on the edge, U2 and U3 in the Perennial Parterre, U4 at the edge of the Marsh Pond, and U5 and U6 in the Autumn Parterre. According to the map of the present Linnaeus Garden (http://www.linnaeus.uu.se/tradgardsvandring/indexEng.php).**

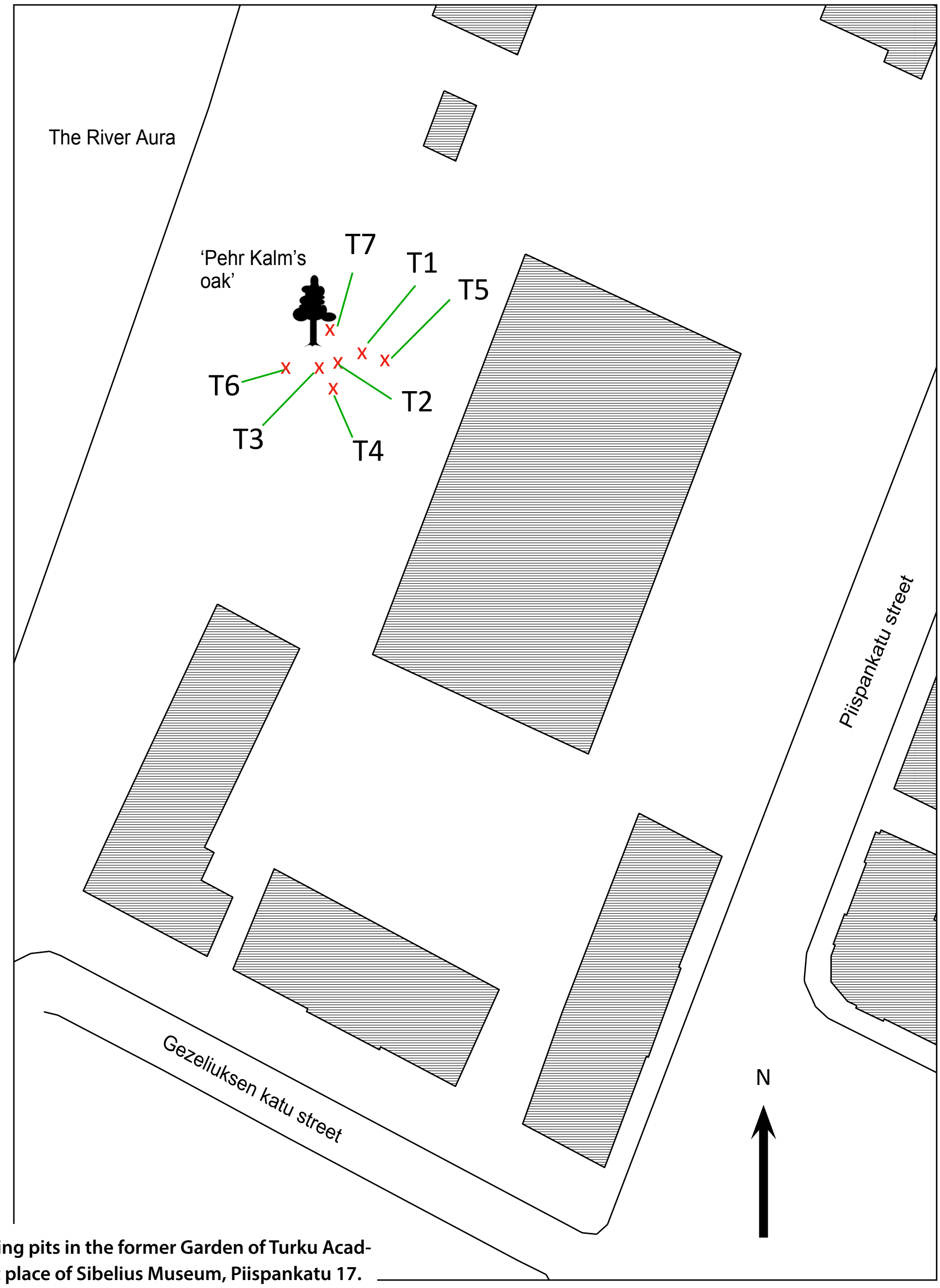


Fig. 7. The sampling pits in the former Garden of Turku Academy. The present place of Sibelius Museum, Piispankatu 17.

Laboratory work

Macrofossil analysis

Soil samples were floated with the complete volume of approximately 1 l of each in a plastic bucket, and the organic material that surfaced was washed under tap water with a 0.250-mm-mesh-size sieve. Part of the samples were floated in a saturated NaCl solution (with H_2O:NaCl ratio of 6:1), which has been a custom in Finland (Núnez & Vuorela 1976, e.g. Vanhanen & Koivisto 2015), and the rest in pure tap water, which has appeared to work as well (e.g. Lempiäinen-Avci 2013). Soil samples that were waiting for laboratory work were stored in a freezer.

Fig. 8a and 8b. Kalm's oak in 2008. Photographs Teija Alanko.

Fig. 9. Present exhibition at the site in 2015. Photogarph Teija Alanko.

From the residual material after flotation, approximately 1–2 dl, macrofossil plant remains, mostly seeds, were picked up, identified and counted with the help of a stereomicroscope, a seed reference collection (Finnish Museum of Natural History, University of Helsinki) and identification literature (Berggren 1969, 1981, Anderberg 1994, Cappers et al. 2006). The botanical nomenclature follows Hämet-Ahti et al. (1998, 2005). Chips of un-charred and charred wood were also partly collected, but not counted in precise numbers or identified. Some of the plant remains were photographed with a microscope camera or with CT scanning and a systems camera.

Un-charred macrofossils were stored in 50 % ethanol (except those seeds that were AMS-dated, which were stored dry). Charred macrofossils were dried and stored dry. In addition to plant macrofossils, also other remains, such as insects, sclerotia of Fungi, small animal bones, and fish scales and bones were collected, identified and stored.

Pollen analysis

Subsamples for pollen analysis were taken from nine soil samples from the Uppsala Linnaeus Garden. The samples that were selected for preparation and analysis of pollen were chosen from such samples, which have already yielded macrofossils and thus were more potential for obtaining pollen as well. These samples were from three different pits and from different layers of depth (pit/layer as follows: U2/1, U2/4, U2/5, U2/6, U4/2, U4/3, U4/4, U4/5, U3/10). Pollen analysis was carried out by Teija Alenius in Archaeology of the Department of Philosophy, History, Culture and Art Studies in the University of Helsinki. The subsamples were prepared according to the procedure suggested in Bennett & Willis (2001). Safranin-stained glycerine was added to the pollen subsamples for staining and mounting. Identification of pollen was based on previous publications (Erdtman et al. 1961, Fægri & Iversen 1989, Moore et al. 1991, Reille 1992, 1995).

AMS-radiocarbon dates

Some dried macrofossils were dated with the AMS-radiocarbon method. Three AMS-radiocarbon dates were measured from three different soil samples from two different pits of Uppsala Garden in the Laboratory of Chronology in the Finnish Museum of Natural History. Three other samples from Uppsala that were sent for dating were unfortunately too small to have enough carbon to complete the dating procedure and thus only a small number of dates were measured in total. Three dates were measured from macrofossils from three different soil samples from one same pit of Turku Garden in the Poznan Radiocarbon Laboratory.

Results

Macrofossils from the Uppsala and Turku gardens

In Uppsala Linnaeus Garden, a total of 322 macrofossil plant remains were found in 34 different soil samples in six different pits. These belonged to 36 different plant taxa, of which 21 were identified to species level, but seven of these with slight uncertainty (Table 1, Appendix 2 and Fig. 10).

In the former garden of Turku Academy, a total of 517 macrofossil plant remains were found in 41 soil samples in seven different pits. These belonged to 47 different plant taxa, of which 24 were identified to species level, but seven of these with slight uncertainty (Table 1, Appendix 3 and Fig. 11).

The two gardens had 22 plant taxa in common. In addition, in Uppsala 15 taxa were found that were not found in Turku, and in Turku 25 taxa were found that were not found in Uppsala. The two gardens combined yielded 839 macrofossil plant remains from 61 different plant taxa. The most abundant species in Uppsala were the old medicinal plant *Chelidonium majus* (greater celandine), with 116 macrofossil seeds, and *Chenopodium hybridum* (sowbane), with 47 seeds. In Turku the most common species were the cultural weeds *Chenopodium album* (fat hen; 58 seeds), *Plantago major* (greater plantain; 51 seeds), *Po-*

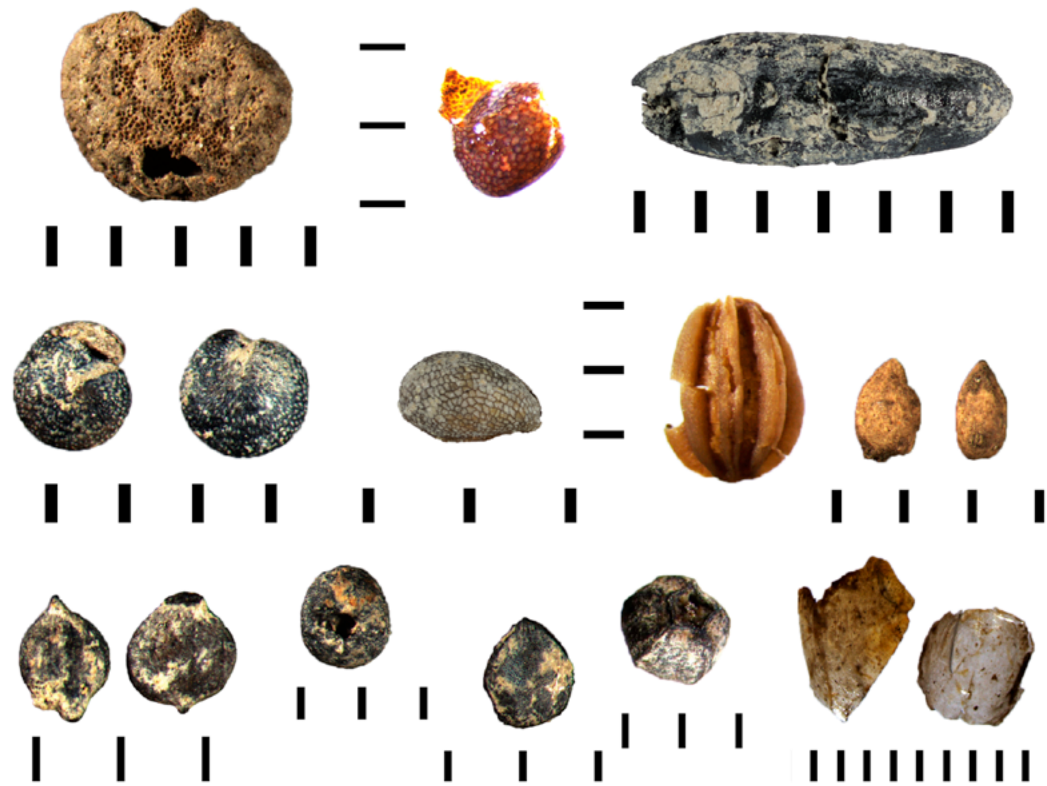


Fig. 10. Some macrofossils found in Uppsala Linnaeus Garden: *Datura stramonium* (number of sample U4/2), *Nicandra physalodes* (U3/6), *Secale cereale* (charred; U4/4), *Chenopodium hybridum* (two seeds; U5/1), *Chelidonium majus* (U4/4), *Aethusa cynapium* (U3/6), *Alchemilla* sp. (two seeds; U4/2), *Carex* sp. (two charred seeds; U3/10), *Galium* cf. *spurium* (charred; U3/10), *Ranunculus* cf. *repens* (charred; U3/10), indet. charred receptacle, and fish scales. Every macrofossil taxon has its own scale bar, a gap between each column is always 1 mm. Photos Santeri Vanhanen and Pekka Malinen, image editing Seppo Alanko.

lygonum aviculare (swine-grass; 53 seeds), and *Spergula arvensis* (corn spurrey; 83 seeds).

Noteworthy species were the medicinal and ornamental *Datura stramonium* (thorn apple; five seeds from Uppsala), the ornamental *Nicandra physalodes* (apple-of-Peru; one seed from Uppsala), the cultural weed *Aethusa cynapium* (fool's parsley; two seeds from Uppsala and six from Turku), and the useful plant *Sambucus racemosa* / *S. canadensis* (red-berried elder / American elderberry; 23 seeds from Turku). In both gardens an unexpected species was *Scrophularia auriculata* (water figwort), in Uppsala with 5 seeds and in Turku with 29 seeds, although the identification was slightly uncertain, and it might be almost as well *Verbascum lychnitis* (white mullein), which has a quite similar seed, but more probably *S. auriculata*. The samples of both gardens also yielded undefined plant material, and chips of wood and charred wood. Chips of charred wood were obtained from every pit in both gardens. Chips of wood were also present in almost every pit. Although these did not occur in high amounts, they were very typical in samples defining the character of the soil.

Pollen from Uppsala Garden

Very low amounts of pollen were found in the subsamples of Uppsala Garden. A total of 306, 243, 250, 73, 270, 188 and 247 pollen grains and

Table 1. The results of macrofossil analyses from Uppsala Linnaeus Garden and Turku Academy Garden.

Plant macrofossils from Uppsala Linneaus Garden and Turku Academy Garden																
Pits U1 to U6 from Uppsala, Pits T1 to T7 from Turku. All samples approx 1 litre and collected with a sampler or with a small shovel																
PIT	**U1**	**U2**	**U3**	**U4**	**U5**	**U6**	**U TOTAL**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T TOTAL**	**BOTH TOTAL**
Number of samles in the pit	1	7	11	5	5	5	**34**	5	1	9	4	7	7	8	**41**	**75**
Depth below ground (cm)	27-34	15-59	8-96.	27-72	40-100	37-78	**15-100**	45-83	22-32	24-90	14-65	41-89	8-62.	31-102	**8-102**	**8-108**
Species and other taxa in alphabetical order in groups of use and ecology with number of seeds, fruits, diaspores																
Garden plants and Useful plants																
Aquilegia vulgaris													2		**2**	
Cerealia charred		1*	1*				**2**									
Chelidonium majus	10	7	12+1*	85		1	**116**			5			9	1	**15**	
Datura stramonium			1	4			**5**									
Fragaria vesca		1					**1**				2		2		**4**	
Fragaria vesca/F. moschata														1	**1**	
Hyoscyamus niger			1				**1**			1					**1**	
Nicandra physalodes			1				**1**									
Rubus idaeus	1	2					**3**						1		**1**	
Rubus sp.		4					**4**						1		**1**	
Salvia sp.												1*			**1**	
Sambucus racemosa/S. nigra ssp. *canadensis*											2	1	18	2	**23**	
Secale cereale				1*			**1**									
Cultural weeds																
Aethusa cynapium			2				**2**				2		4		**6**	
Ajuga pyramidalis/reptans/genevensis											1		1		**2**	
Alchemilla sp.				4			**4**									
Apiaceae		1			1		**2**						5		**5**	
Atriplex cf. *hortensis*			1				**1**									
Atriplex sp.												1			**1**	
Cerastium sp.											2				**2**	
Chenopodium album		2	9	1	1		**13**			1	9	2	43	3	**58**	
Chenopodium glaucum/rubrum													1		**1**	
Chenopodium hybridum		6	29	1	9	2	**47**				1	1	2		**4**	
Chenopodium sp.	1	2	30	2	2	2	**39**				4	5	5	1	**15**	
Fallopia convolvulus											1		1		**2**	
Fumaria officinalis											1		1		**2**	
Galeopsis cf. *speciosa*													2		**2**	
Galium cf. *spurium*			1*				**1**									
Galium sp.													1		**1**	
Lamium sp.						1	**1**						1		**1**	
Persicaria sp.													1		**1**	
Plantago major										1	3	9	9	29	**51**	
Polygonum aviculare								3		17	2	9	21	1	**53**	
Potentilla sp.				1			**1**						1		**1**	
Prunella vulgaris				2			**2**									
Ranunculus cf. *acris*			1				**1**									
Ranunculus repens			5*				**5**									
Rumex sp.										1	1				**2**	
Scrophularia cf. *auriculata*						5	**5**	1		6		13	8	1	**29**	
Spergula arvensis									1	1	60		20	1	**83**	
Stellaria media			2*				**2**					5		8	**13**	
Trifolium cf. *campestre*			1				**1**									
Trifolium repens												1			**1**	
Urtica sp.													4		**4**	
Meadow plants																
Myosotis sp.													2		**2**	
Poa sp.										8			10		**18**	
Poa sp./Poaceae					1*		**1**			6	2	1		12	**21**	
Poaceae	3		2+1*	2*		1	**9**				1		5	1	**7**	
Stellaria cf. *graminea*														1	**1**	
Viola sp./cf. *hirta*/cf. *odorata*				2			**2**							2	**2**	
Viola sp.											1		7	1	**9**	
Wetland plants																
Carex cf. *nigra*			1*				**1**									
Carex sp. distigmatae			2*				**2**			2*	1		1		**4**	
Carex sp. tristigmatae		1		1*			**2**									
Empetrum nigrum											1				**1**	
Juncus sp.		2					**2**			1	2		6		**9**	
Veronica cf. *scutellata*/cf. *officinalis*											2				**2**	
Trees and shrubs																
Betula cf. *pubescens*				1			**1**									
Betula sp.				1			**1**							1	**1**	
Picea abies charred needle		1*	2*	3*	1*		**7**			1*		2*		1*	**4**	
Pinaceae scales of cones	1			1			**2**		1	1	4	2	2	5	**15**	
Indet.	1	8	13	5	1	2	**30**	5		2	4	5	13	3	**32**	
cf. receptacle					1*		**1**									
Number of macrofossils	17	38	119	117	17	14	**322**	9	2	54	109	58	210	75	**517**	**839**
Number of taxa	5	12	20	16	6	7	**36**	2	2	14	22	15	33	19	**47**	**61**

Table 1. cont.

PIT	U1	U2	U3	U4	U5	U6	U TOTAL	T1	T2	T3	T4	T5	T6	T7	T TOTAL	
Number of samles in the pit	1	7	11	5	5	5	**34**	5	1	9	4	7	7	8	**41**	
Depth below ground (cm)	27-34	15-59	8-96,	27-72	40-100	37-78	**15-100**	45-83	22-32	24-90	14-65	41-89	8-62,	31-102	**8-102**	
Other remains																
Wood		x	x	x	x	x		x		x	x	x	x	x		
Charred wood	x	x	xx	xx	x	x		x	x	x	x	x	x	x		
Plant material	xxx	x	x	xx	x	x		x	x	x	x	x	x	x		
Fungi, sclerotium		x	x	x	x	x				x	x	x	x	x		
Crushed brick	x	x	x	x	x	x		x	x	x	x	x	x	x		
Teleostei, scale, vertebra		x	x	x	x	x				x	x	x	x	x		
Insecta/Hexapoda	x	x	x	xx		x		x		x	x	x	x	x		
Lumbricus terrestris pod			x					x		x	x		x			
Small bones		x	x	x	x	x				x	x	x	x	x		
Bryophyta	x															
* charred																
x=some, xx=quite a lot, xxx= much																

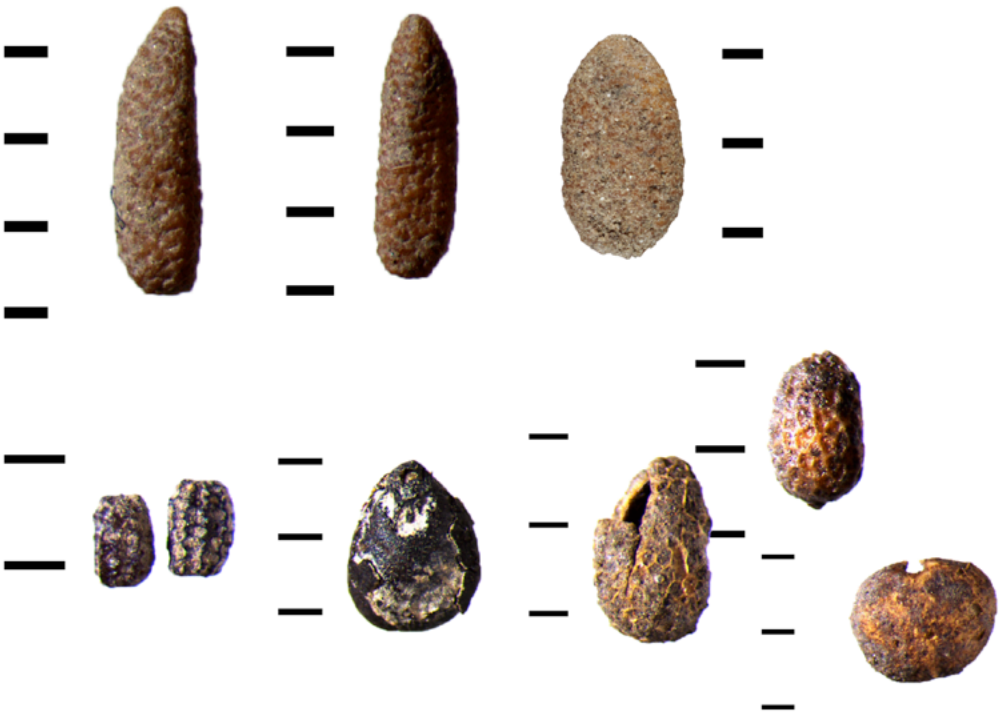


Fig. 11. Some macrofossils found in the former Garden of Turku Academy: *Sambucus* cf. *canadensis* (two seeds; number of sample T5/2), *Sambucus racemosa* (T4/1a), *Scrophularia auriculata* (two seeds; T6/3), *Salvia* sp. (T5/2), *Ajuga* sp. (T4/1a), *Ajuga* sp. (T6/3), *Fumaria officinalis* (T6/3). Every macrofossil taxon has its own scale bar, a gap between each column is always 1 mm. Photos Santeri Vanhanen and Pekka Malinen, image editing Seppo Alanko.

were counted from samples U2/1, U2/4, U2/5, U2/6, U3/10, U4/2 and U4/3, respectively. Two of the analysed samples did not show any pollen (U4/4, U4/5). Pollen grains from 38 different plant taxa were discovered, but only four of them in greater numbers: *Pinus*, *Betula*, Poaceae and Cichoriaceae (Table 2). Percentage values of the total pollen sum of each sample varied between different pits with *Pinus* from 28 % to 67%, with *Betula* from 1% to 17%, with Poaceae from 7% to 16%, and with Cichoriaceae from 8% to 53%. The pollen types were arranged in six groups (Cerealia, Herbs, Grasses and sedges, Noble deciduous trees, Broad leaved trees, and Coniferous trees) so that the pattern of the assemblages of pollen in each sample was illustrated (Fig.12). Spores of ferns, moss and fungi were also present in the samples (Table 2).

Table 2. Number of pollen grains and spores of each taxa found in seven soil samples in Uppsala Garden.

Soil sample	U2/1	U2/4	U2/5	U2/6	U3/10	U4/2	U4/3
Picea	2	1	1		10	6	6
Pinus	150	69	69	29	119	129	132
Betula	52	12	3	1	11	11	18
Alnus	12	2	1		12	1	7
Populus		1					1
Ulmus	3	1			2		
Tilia	2	3	1		2	1	1
Quercus	7						1
Acer					1		
Corylus	5	2			4		
Salix	3				1		
Juniperus			1		2	1	3
Calluna					1		
Cyperaceae	1	11	1	1	9	3	3
Poaceae	25	37	34	6	25	18	17
Artemisia	1						
Apiaceae	1	1	4	1	2		
Filipendula	2	1	2		2		
Urtica			1				
Chenopodiaceae	2	1		2	5		7
Plantago_major_media			1				
Plantago_lanceolata					1		
Ranunculaceae		1			1		
Galium					2	1	
Asteraceae	2	2	11		1		3
Cichoriaceae	28	87	109	30	51	15	38
*Alchemilla_t_*		1	3				
Campanula	1						
*Potentilla_t_*	1						
Brassicaceae	1	3	3				3
Caryophyllaceae		2		1	4	2	3
Fabaceae	1	3	1				2
Gentiana			1				
Polygonum	1			1			
Rubus					1		
Hordeum	2	1	2	1	1		2
Secale	1		1				
Fagopyrum tataricum		1					
Equisetum	1						
Polypodium	9	14	8	9	10	6	8
Sphagnum		14	6	3	16	6	13
*Lycopodium_undiff_*		1	1	2	1	1	4
Pteridium		5					2
Gelasinospora		1	2				
Sporormiella	1						
Sordaria	4	35	47	6	11		15
Podospora			3				1
Gelasinospora, type 1	1						
Trees	216	85	74	30	152	147	164
Noble	17	6	1		9	1	2
Shrubs	3		1		4	1	3
Herbs	70	152	174	43	105	39	78
Pollen sum	306	243	250	73	270	188	247

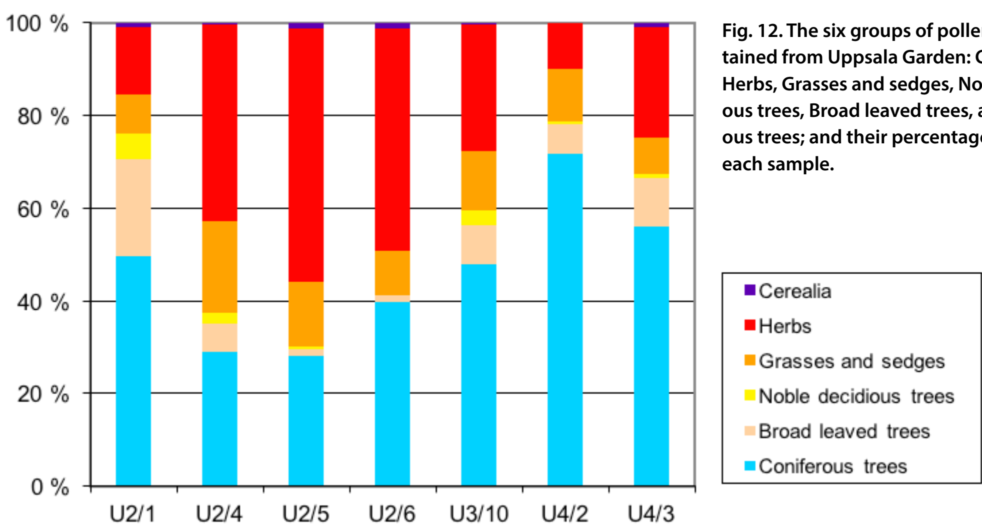


Fig. 12. The six groups of pollen types obtained from Uppsala Garden: Cerealia, Herbs, Grasses and sedges, Noble deciduous trees, Broad leaved trees, and Coniferous trees; and their percentage values in each sample.

Table 3. Radiocarbon dates obtained from the macrofossils of Uppsala Linnaeus Garden and the former garden of Turku Academy. Calibration data: Intcal13 (Bronk-Ramsey 2009, Reimer et al 2013).

Lab. code	Pit, sample, depth below ground (cm)	Material	^{14}C age BP	Cal age, prob. 48.8% - 68.2%	Cal age, prob. 95.4%
Hela-3757	U4, U4/2, 39-45 cm	*Datura stramonium*	209 ± 27	AD 1735–1810 (48.8%)	AD 1645–present
Hela-3515	U4, U4/4, 55-65 cm	*Secale cereale*, charred grain	348 ± 40	AD 1480–1635 (68.2%)	AD 1455–1640
Hela-3755	U3, U3/10, 79-88 cm	Charred seeds	445 ± 25	AD 1430–1455 (68.2%)	AD 1420–1475
Poz-76626	T6, T6/1, 8-13 cm	*Sambucus racemosa*	modern		
Poz-76627	T6, T6/2, 20-32 cm	*Sambucus racemosa*	modern		
Poz-76628	T6, T6/3, 32-40 cm	*Sambucus racemosa*	modern		

Other remains

Other remains than plant macrofossils were also obtained from the soil samples. Crushed brick, small animal bones, remains of insects, and fish scales and bones were found in both gardens (Table 1). Although fish remains that were present in almost every pit in both gardens did not occur in high amounts, they were very typical in samples defining the character of the soil.

AMS-radiocarbon dates from the Uppsala and Turku gardens

AMS-radiocarbon dates from Uppsala Garden resulted in calibrated calendar years of AD 1420-1475 (Hela-3755), AD 1455-1640 (Hela-3515) and AD 1645-present (Hela-3757) with the probability of 95.4% (Table 3). AMS-dates from Turku Garden (Poz-76626-76628) appeared to be modern on the grounds of containing more ^{14}C than the 'modern standard' 100 pMC (in the samples 122.34 ± 0.38 pMC, 156.83 ± 0.43 pMC, 108.1 ± 0.3 pMC, respectively) (Table 3).

Discussion

Plants in the Uppsala and Turku gardens

In many archaeobotanical studies in Finland, and elsewhere too, commonly found cultural weed is *Chenopodium album* (fat hen) (e.g. Lempiäinen 1989, Påhlsson 1991, Vuorela et al. 1996, Nurmenniemi 1999, Lempiäinen-Avci 2015a, 2015b). It was also found in Uppsala, but more abundant was *Chenopodium hybridum* (sowbane), which has not been usually found in previous macrofossil studies in Fennoscandia. *Chenopodium hybridum* is in the *Hortus Linnaeanus,* which lists the plants cultivated in the botanic garden of Uppsala University during the Linnean period (in 1741–1783, including Linnaeus and his son; Juel 1919:27), and also, as an introduction of Olof Rudbeck senior, in the *Hortus Rudbeckianus*, listing species that were grown in Uppsala garden by Rudbeck (in 1655–1702; Martinsson & Ryman 2007:49). Hence, it is probable that these macrofossils originate from the plantings of the botanic garden of the 17th and 18th centuries.

Chenopodium hybridum provides a weak link between the Uppsala and Turku gardens. The species was found in relatively large numbers in Uppsala. In Turku, only four seeds were found, but still these may be the only macrofossil finds of this species in Finland. *Chenopodium hybridum* is native to Europe, nowadays a common garden weed up to Scandinavia, and regarded as a neophyte in Finland (i.e. introduced after the early 17th century; Uotila & Suominen 1976, Hämet-Ahti et al. 1998). In the 19th century it was found especially in gardens in towns and often in parsonages and manors in southwest Finland, and now it appears rarely in gardens, harbours and railways in southern parts of Finland (Uotila & Suominen 1976, Hämet-Ahti et al. 1998). This suggests strongly that it eiher has been cultivated in gardens or it has been a garden weed. Because the funds for the operation of Turku Academy Garden were very limited and the procurement of seeds was difficult, Carl Linnaeus sent seeds to Turku to Pehr Kalm repeatedly, and Kalm also received seeds from professors Johan Leche and Pehr Adrian Gadd (Kari 1940). Linnaeus might have sent seeds of this species to Kalm on purpose or by accident, since he used to send seeds of different species mixed up in an envelope, and thus *C. hybridum* could have been only a weed too (Ruoff 1991). Either way, in addition to the exchange of knowledge between the Uppsala and Turku gardens, based on teacher-student-relationships of Olof Rudbeck and Elias Tillandz, and Carl Linnaeus with Johan Browallius, Carl Fredrik Mennander, Pehr Kalm and Carl von Hellens, exchange of plant material occurred too, at least from Uppsala to Turku. In addition, another cultural weed, *Aethusa cynapium* (fool's parsley), which is regarded as an indicator of old settlements, was found as macrofossil both in Uppsala and Turku. It can be found in the *Hortus Rudbeckianus* too (Martinsson & Ryman 2007:54).

Datura stramonium (thorn apple), which was found as macrofossil in Uppsala, is an old and very poisonous medicinal plant. It was growing in Uppsala Garden already in Rudbeck senior's time in 1658, and was probably introduced to Sweden by him (Martinsson & Ryman 2007:197). It is in the *Hortus Rudbeckianus* under the name *Datura Turcarum fl. albo*, referring to the white-flowered variety, and marked as an ornamental plant and not yet as a medicinal one (Martinsson & Ryman 2007:197). Macrofossils of *D. stramonium* have been found earlier in Sweden in at least two sites in a 17th century context in Norrköping and Nyköping (Heimdahl 2014). These may have originated from Rudbeck's introduction or the plant may have come to Sweden several times through different routes. In Denmark the species was mentioned for the first time in 1647 (Lange 1994:111). In the *Hortus Linnaeanus* the species is under the name *Datura stramonium* L., described in 1748 by Linnaeus (Juel 1919:92). Pehr Kalm also grew a *Datura* species, presumably *D. stramonium,* in his experimental gardens in Turku in 1768 (Kari 1940). According to Hellenius & Mollin (1779), *D. stramonium* was cultivated in Turku Academy Garden in the end of Kalm's term, although it was not found in this study as a macrofossil. *Datura stramonium* is native to North America and belongs to the same Solanaceae family (nightshades) as *Hyoscyamus niger* (henbane), which was found in both Uppsala and Turku with one seed from each.

The AMS-radiocarbon date from the seed of *Datura stramonium* from the pit U4 at the edge of the Marsh Pond in Uppsala Garden (Hela-3757), indicate the cultivation of the species in the Linnean period or after that. In addition to seeds of *D. stramonium*, the soil sample also included seeds of *Chelidonium majus* (greater celandine), *Alchemilla* sp. (lady's mantle) and *Prunella vulgaris* (self-heal). The dated charred grain of *Secale cereale* (Hela-3515), from the same pit than the dated *D. stramonium,* from deeper sample with the age cal AD 1455-1640, suggests the former use of the plot. The grain may have originated for example from household waste, before Rudbeck senior established his garden. Of the other macrofossil species in this deeper sample, *C. majus* might have been cultivated and used before Rudbeck's time, but *D. stramonium*, which was probably introduced by Rudbeck, would not be as old as the dated cereal grain. However, the dated *S. cereale* in the sample suggests that *D. stramonium* may be from the 17th century. Four seeds of *C. majus* were found in a sample deeper than the dated *S. cereale* (65-72cm below ground), which indicates that these seeds may be even older than the grain of *S. cereale*.

Charred seeds of *Carex* sp. (sedge), *Galium* cf. *spurium* (false cleavers), *Stellaria media* (common chickweed) and *Ranunculus* cf. *repens* (creeping buttercup) from the pit U3 in the Perennial Parterre in Uppsala Garden, were AMS-dated (Hela-3755) and resulted in cal AD 1420-1475 demonstrating the time before the actual garden. The same soil sample also included *H. niger*, *C. album* and *C. hybridum*. All the species in the sample are regarded as cultural weeds associated to human activity and thus indicating settlement in the area in the late Middle Age period, except maybe *C. hybridum*. *Stellaria media* and *H. niger* have also been useful plants and may have been cultivated on purpose.

Nicandra physalodes (apple-of-Peru; family Solanaceae), with one macrofossil seed from Uppsala, was described by Linnaeus in 1753 with the name *Atropa physalodes* in his *Species Plantarum* (Linné 1753:181). *Nicandra physalodes* is native to Peru. It is poisonous and nowadays used as an ornamental plant. The species is in the

Hortus Linnaeanus (Juel 1919:92), but not yet in the *Hortus Rudbeckianus* (Martinsson & Ryman 2007). *Datura stramonium* and *N. physalodes* are examples of new introductions from the New World that were taken into cultivation in botanic gardens in Europe in the 17th and 18th centuries. Macrofossils of both of these species most probably derive from Rudbeck's and Linnaeus' time.

Seeds of species of Solanaceae, such as *D. stramonium, H. niger* and *N. physalodes,* may preserve well uncharred in garden soil because of their poisonous alkaloids. Toxic substances may prevent animals or invertebrates consuming these seeds or even resist decomposition. Another similar macrofossil study from garden soil of a 18th century garden in Finland (Alanko 2017) showed the same tendency of the preservation of uncharred seeds with alkaloids or other poisonous chemical compounds. Plants containing toxins found in the other study were for example *D. stramonium, C. majus, H. niger, Sambucus racemosa* (red-berried elder) and *Solanum dulcamara* (woody nightshade).

Scrophularia auriculata (water figwort) was found both in Uppsala and Turku. The species is in the *Hortus Linnaeanus*, with the synonym *Scrophularia aquatica*. However, another species with a quite similar seed, and with which the identification could be mixed, *Verbascum lychnitis* (white mullein), is also in Linnaeus' plant list (Juel 1919:95). In the Turku material, the macrofossil of *S. auriculata* is definitely of garden origin, since it does not grow wild in Finland, and probably the seeds from Uppsala derive from garden cultivation too, although the species is common in Western Europe. Still, if the seeds were *V. lychnitis* after all, due to a slightly uncertain identification, this species has also most probably been cultivated in the gardens on purpose. In Finland, the plant is not native but a neophyte, and appears only rarely as an escapee (Hämet-Ahti et al. 1998).

Cichoriaceae (or subfamily Cichorioideae of Asteraceae) is a group containing garden plants, and thus the pollen grains of this group that were found have some significance in these results. Cichoriaceae was found in all the seven soil samples that contained pollen in Uppsala Garden. In the *Hortus Rudbeckianus*, 44 different plant taxa belonging to Cichorioideae are itemized (Martinsson & Ryman:70-81), and in the *Hortus Linnaeanus* 40 different taxa (Juel 1919:105-114). This refers to quite wide cultivation of the subfamily in Uppsala Garden, and thus the derivation of Cichorioideae pollen from this garden cultivation. Although some of the Cichoriaceae pollen may have originated from weeds rather than from cultivated plants, e.g. *Taraxacum officinale* (dandelion) and *Leontodon autumnalis* (autumn hawkbit), these two, for example, were also grown on purpose in Rudbeck's period (Martinsson & Ryman 2007:76, 80).

Although not a wide range of garden plants was found in the Turku Garden site as macrofossils, according to Kerkkonen (1936) and Kari (1940), Pehr Kalm's letters and planting reports (from 1759 and 1768) form a list of species cultivated for different purposes in the garden of Turku Academy (Appendix 1). In addition, Hellenius & Mollin (1779) has listed plants that were cultivated in the Academy Garden in Kalm's period. Hence, the literature may reveal plants that could be found as macrofossils by demonstrating which plants of Kalm's introductions survived in Finland, perhaps producing seeds, and which did not germinate at all but could have left the sowed seeds in the ground.

The *Sambucus* seeds found in Turku are noteworthy, because Pehr Kalm brought a *Sambucus* species from North America with him, then called *S. americana*, but now classified as *S. canadensis* (American elderberry; Ruoff 2001b, Catalogue of Life 2016). Kalm reported that he cultivated *S. canadensis* and *S. nigra* in his experimental gardens in Sipsalo and/or in Turku Academy Garden for medicinal purposes, and although he tried them for hedges too, they appeared to be unsuitable (Kerkkonen 1936; Appendix 1). In the end of Kalm's term, three *Sambucus* species were cultivated in the Academy Garden, *S. ebulus, S. canadensis* and *S. nigra* (Hellenius & Mollin 1779). To his friend Carl Fredrik Nordenberg, Kalm gave seeds of *S. americana* in 1751 among over a hundred species, and Nordenberg probably tried to cultivate it in his garden in Frugård Manor in Uusimaa in southern Finland (Blåfield et al. 1998; Ruoff 2001b). *S. nigra* can be found in the *Hortus Rudbeckianus*, but not *S. racemosa* (Martinsson & Ryman 2007:44). In the *Hortus Linnaeanus* all three, *S. nigra*, *S. racemosa* and

S. canadensis are listed, the two latter from 1753 (Juel 1919:98-99). The question is, can macrofossil seeds of these three different taxa be definitely distinguished and identified. Perhaps all macrofossil finds from Finland that are identified as *S. racemosa* are not absolutely certain, and some of them could be *S. nigra* or *S. canadensis*. Radiocarbon dates from *Sambucus* seeds from one pit in Turku Garden (Poz-76626-76628) appeared to be modern, containing more ^{14}C than the 'modern standard', which occurred in the environment only after 1953 (because of atomic bomb tests) reaching highest amount in 1963 and then declining. Thus, the dated seeds must be from this short period, and these *Sambucus* seeds should hence be considered *S. racemosa*, which has been more common in Finland since the early 19th century (Hämet-Ahti 1992, Nummi 2008). *Sambucus racemosa* may have been growing at the site in the 1950s and 60s originating from the period after 1829, when the area contained cultivation plots of the citizens (Ruoff 2001a).

The samples of the dated *Sambucus* seeds also included some other species that could be regarded as garden plants, such as *Aquilegia vulgaris* (common columbine), *C. majus*, *Fumaria officinalis* (common fumitory) and *Fragaria vesca* (wild strawberry). These finds could also be from this more recent, ordinary gardening phase, and not from the actual botanic garden period of the site, since, for example, *A. vulgaris* is still a popular ornamental plant in gardens. However, the possibility of the drift of younger *Sambucus* seeds into older layers and thus the contamination of the layers with recent *Sambucus* seeds remains open. *Aquilegia vulgaris* was cultivated in Uppsala Garden in Rudbeck's time (Martinsson & Ryman 2007:178). Earlier, the species was also used as a medicine, and in the Catholic period regarded as a symbol of the Holy Spirit (Ruoff 2001a). It is known to been grown for example in Vadstena Convent in Sweden in the late Middle Ages (Sigurdson & Zachrisson 2012). Former macrofossil finds of *A. vulgaris* come from the early modern period contexts in Helsinki, but the species is yet quite rare in macrofossil materials in Finland (Vuorela & Lempiäinen 1999, Alanko 2017).

In Turku, several species were also found that are now regarded as cultural weeds, but which have also had different uses in earlier centuries, such as *C. album*, *Plantago major* (greater plantain), *Polygonum aviculare* (swine-grass) and *Spergula arvensis* (corn spurrey). However, in botanic gardens the intention has been to cultivate a wide range of plant taxa for botanical purposes and not only for medicinal, useful, or ornamental garden purposes, and thus species that are now considered weeds may have been grown in these academic gardens on purpose. In addition, these plants may also have been garden weeds indicating garden cultivation, even though of the garden plants themselves only few were found.

Not that many useful species were present in the soil samples of the Uppsala and Turku gardens. The former plot of Turku Academy Garden, near the medieval Turku Cathedral and the former area of the market place and the centre of the medieval town, on the shore of the River Aura, had not been investigated archaeobotanically before. No former archaeobotanical analyses exist from Uppsala Linnaeus Garden either. However, in the neighbouring areas of Turku Garden, many archaeological excavations and archaeobotanical analyses have been carried out (e.g. Lempiäinen 1989, 2003, 2007, Vuorela et al. 1996, Nurmenniemi 1999, Seppänen 2003, Lempiäinen-Avci 2007, 2011, 2013, 2015a, 2015b). Further, in Uppsala City area, hundreds of archaeological and soil investigations were carried out already decades ago in order to study the medieval town, a few drillings of these also done in the southwest part of the Linneaus Garden site; and possible foundations of a house found in the southeast part of the site (Medeltidsstaden 3: 1976, 1977). Macrofossil material has also been obtained from excavations of five different blocks of Uppsala City Centre carried out from the 1970s onwards (e.g. Påhlsson 1991, Engelmark 2000, Viklund 2000, 2007:120–121). Macrofossils from the Uppsala Linnaeus and Turku Academy garden areas described here differed from the results of the former archaeobotanical analyses carried out in the town areas in Uppsala and Turku. In the former analyses more of the most common and also some rare useful species have been found, such as cereals, *Humulus lupulus* (hop), *Hyoscyamus niger* (henbane), *Linum usitatissimum* (flax) and *Pastinaca sativa* (parsnip) in Uppsala (Påhlsson 1991, Engelmark 2000), and *Daucus carota* (carrot), *Anethum graveolens* (dill), *Piper nigrum* (black pepper) and *Prunus cerasus* (sour cherry) in Turku (Lempiäinen 2007, Lempiäinen-Avci 2007), while the macrofossils of the garden sites in this study represent more clearly garden soil than the cultivated species themselves.

The role of other remains in the soil together with only few garden plant remains

Only few macrofossil plant remains were found of such garden plants that are known from the literature to have been cultivated in the Uppsala and Turku gardens. The most evident explanation is that the soil of the sites has probably been changed during the centuries. New soil may have been brought for better managing the gardens for cultivation. Soil may have been turned in the beginning of the new phases of the gardens, for example in Uppsala after the fire in 1702 and before the reconstruction in the 1920's (Martinsson 2007, Martinsson & Ryman 2007). Fill soil may have been brought to Turku Garden after the garden's operation moved to Helsinki in 1829, and the area was divided into cultivation plots for citizens (Ruoff 2001a). At the latest in the 1960s, when the Sibelius Museum was constructed on the other half of the site in Turku, the soil of the other half could have been disturbed too. However, though upper layers may be fill soil, the area of the old *Quercus robur* in Turku is probably quite untouched. Furthermore, in the present Uppsala Linnaeus Garden, the ground level is half a meter lower than the present street level of the city indicating no heavy filling in later years. Although the soil was turned in the reconstruction project in the 1920s in Uppsala Garden revealing germinating plants from the seed bank of Linnaeus' time, it is not likely that the soil was changed thoroughly (Martinsson 2007). Moreover, the gardeners of the present Linnaeus Garden have not been allowed to dig deeper than 70 cm below ground in order to avoid possible medieval layers, and thus the deepest of my samples could have been from totally untouched layers.

On the other hand, this supposedly obvious reason of fill soil could be questioned on the grounds of other remains in the soil. Most of the soil samples from every pit in both the Uppsala and Turku gardens included remains of fish (scales and bones), small animal bones and chips of wood and charcoal in abundance, strongly referring to fertilization of the gardens for gardening purpose, with kitchen waste, ashes from ovens or stoves, and other components. This may be evidence of original garden soils and thus states against fill soil brought from somewhere else. Today, remains of weeds, gravel, charcoal, brick pieces and animal bones can be interpreted as fertilization and soil improvement of gardens, differing from interpretations in the past, when weeds were interpreted as indicators of cultural mud, charcoal only as indicator of hearth remnants, brick pieces as indicators of buildings, and animal bones as food waste (Ericsson & Guldåker 2015). Therefore, also the macrofossil plant remains in the same soil samples with fertilizer elements could be regarded as representatives of gardening phases of the sites and not as contents of fill soil.

Another possible evidence of gardening practices are the fungal spores of Sporormiella, Sordaria, and Gelasinospora obtained in pollen analysis from Uppsala Garden. These fungal spores grow on animal dung, e.g. on cow dung (Carrión et al. 2000, Doyen & Etienne 2016), and thus might originate from the spread of animal dung in order to manure the garden as part of a strategy for the maintenance of the garden and the plants.

In addition to plants, animals and people lived in the sites of the Uppsala and Turku gardens. In Kalm's garden in Turku there were outbuildings, a house for a gardener, areas for sheep, a cowhouse and a stable for horses (Kari 1940, Ruoff 2001a). In Linnaeus' garden in Uppsala, exotic animals were kept in an orangery or in an animal house and in a yard (Martinsson 2007). Thus, household waste would have been presumable at the sites, and small animal bones found in soil would not necessarily have been from household waste but from animals living at the site, for example mice with the domestic animals. However, the finds of small bones have not been identified in this study.

Another presumable explanation for scarce macrofossil material may be the poor preservation of seeds in garden soil. Still, the possibility of preservation of seeds even in oxygen-containing and not properly waterlogged garden environment remains, as discussed in another study concerning the same kind of sampling in garden environment as in this (Alanko et al. 2015). The fact that in botanic gardens each taxon is grown in small numbers, only a few specimens of each, may also result in small numbers of plant remains. Plants from other climatic regions in gardens cannot necessarily even produce seeds if they are not completely adapted to the northern climate. Insufficiency of macrofossil analysis in these cases and the benefit of pollen analysis in concert has been noted in garden studies (Alanko 2017, Alanko & Lempiäinen-Avci forthcoming.).

Conclusions and future prospects

The macrofossil analyses from the academy gardens of Uppsala in Sweden and Turku in Finland did not clearly show the tight connections the gardens had in the form of their parallel development and the networks between the people operating in the gardens in the 17th and 18th centuries. The reason was probably the relatively scarce material found in both of the gardens. Some equivalent taxa were found, but not to the extent that a conclusion of a strong connection between the gardens could be drawn from macrofossil data alone. However, because the literature demonstrates that the affiliation existed, the similarities in the macrofossil materials of the gardens can be attributed to their close relations. Alternatively, some of the shared macrofossils could be interpreted as being of the kind usually found in archaeobotanical studies of the same temporal context. Nevertheless, since these two sites were gardens, and not settlement sites, as usually is the case in archaeobotanical studies, the results presented here could be interpreted as an example of macrofossil assemblages typical of garden sites.

The plants that were found as macrofossils were mainly mentioned in the literature, if not in all plant lists, at least in one of them. Extensive catalogues of plants cultivated in the Uppsala Linnaeus Garden in different periods of the garden were available, and even though similar ones did not exist of the Turku Academy Garden, quite long list of plants grown in Turku could be formed. The plants that were found as macrofossils and in plant lists too, showed the preservation ability of seeds in garden soils.

The macrofossil finds in Uppsala succeeded in revealing the period preceding the establishment of Rudbeck's garden, even though the attempt was to study the garden phase. The dated samples reached from the deepest layer, the period before the garden, to the uppermost layer, probably from the Linnean period. Therefore, the soil in Uppsala Garden has apparently not been much disturbed, and the deeper layers are from the older periods of the plot. Mainly due to technical challenges of the sampling, as old layers as in Uppsala may not have been reached in Turku. Still, the dates that were gained from Turku Garden and appeared to be modern, showed that the upper layers in the garden soil near the ground surface were not old and from the original period of garden cultivation. The results do not, however, confirm unequivocally the differences between the gardens, because enough suitable material for dating was not available from either of the sites to make clear conclusions. Sampling in the garden sites was not a complete success, but it still gained information of plants and gardening at the sites that otherwise would have been kept in darkness because no excavations would be carried out in the sites.

Scarce macrofossil finds from these garden sites indicate that in future studies the probability of finding remains of cultivated garden plants in such sites is quite low. Instead, other kinds of plant remains, such as garden weeds, and other remains in garden soil may demonstrate the past of a garden site too. Concerning future research, when sampling or excavating is carried out in unbuilt sites that are not known as gardens beforehand, similar kinds of macrofossil assemblages and the other particles in soil that were found in this study may, hence, be regarded as indicators of garden soil.

Combining analyses of macrofossil plant remains and pollen with application of AMS-radiocarbon dates resulted more valuable information of the garden sites than would have been possible through macrofossil studies alone. Many examples of garden studies worldwide have shown that multidisciplinary approach with combination of methods and collaboration of specialists can most probably gain extensive evidence of past gardens; applying for example garden archaeology together with the literature sources, and soil, pollen and macrofossil analyses (Malek 2013). If gardens are investigated from core soil samples without excavated areas, as in the cases presented here, several methods could be added in order to study the soil. Chemical analyses of garden soil could provide information of fertilisation of cultivated plots (Currier & Locock 1991); insect remains analysed from soil samples could reveal horticultural relationships in gardens through recovered pollinator or pest insects (Murphy & Scaife 1991, Larew 2013); and phytolith analysis could provide evidence of gardening practices, such as irrigation, or phytoliths from cultigens (Horrocks 2013). In cases, such in this study, when it is not possible or probable to have the opportunity to carry out excavations or apply many methods together, it is still worthwhile, considering resources available, to study sites with even less methods. If it is possible to collect some knowledge of an interesting site through archaeobotanical research with the literature background, it should not be let undone. However, without archaeological context and finds that could date the soil layers, it is necessary to have at least some radiocarbon dates from plant remains found.

Considering future studies, an archaeobotanical study of the other former garden plot of Pehr Kalm in Sipsalo in Turku, with small test-ditch excavations, remains a possibility. The study of this site was considered in 2013, when I had an opportunity to visit the place, which is in private ownership, and to make an overview of the present conditions. In addition to Turku Academy Garden, Pehr Kalm cultivated the new American introductions in the Sipsalo garden first, when he came back from North America, since the Academy did not yet have a proper garden (Kari 1940, Kerkkonen 1959). After Kalm's period, the Sipsalo garden was run by the Academy's gardener until 1824, and the University hold the garden land until 1903 (Kukkonen 1979). In the surveys from the 1950s and 1970s, 16 plant species were found that had probably survived from Kalm's period (Kukkonen 1979). Since the plot was used as a garden after Kalm's experiments had ended, it was exposed to digging of the soil and planting of new species. Still, the place seemed quite untouched with the borders still visible in 2013. It is unlikely that the soil has been changed on a larger scale, and thus suitable spots for archaeobotanical sampling could perhaps be found. It would be interesting to see if Sipsalo revealed more macrofossils of Kalm's time than the sites studied here.

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Appendix 1. Plants (84 taxa) cultivated in Turku Academy Garden according to Kalm's planting reports from 1759 and 1768 (Kerkkonen 1936, Kari 1940; scientific names are checked and corrected to present form according to Catalogue of Life 2014, 2016; Kasvien suomenkieliset nimet).

Useful species for manufacture	English name	Reported success and use
Morus alba	white mulberry	Had succeeded in Sipsalo for 14 years and could feed 4000 caterpillars of silk moth (*Bombyx mori*) per year
Morus nigra	black mulberry	
Morus rubra	red mulberry	
Prunus virginiana	chokecherry	Thrived through winters well; for fine woodcraft
Juglans cinerea	white walnut	Could not ripen its nuts till 1768, but nuts succeeded to germinate in 1776
Juglans nigra	the eastern black walnut	Survived the climate but did not flower
Isatis tinctoria	woad	Was in demand for a dye plant and flourished
Reseda luteola	dyer's weed	Survived; dyers regarded it good
Rubia tinctorum	the common madder	Grew well in dry places
Carthamus tinctorius	Safflower	Ripened only in warm and dry summers
Solidago canadensis	Canadian golden-rod	Thrived and was good for dyeing wool yellow
Dipsacus sp.	teasel	Thrived
Nicotiana tabacum	tobacco	Cultivated wildly in Turku town, in Academy Garden for seeds
Acer saccharum	sugar maple	Did not grow
Asclepias syriaca	common milkweed	
Linum perenne	perennial flax/lint	
Amelanchier canadensis	Canadian serviceberry	(syn. *Mespilus canadensis*)
Serratula coronata	plumeless saw-wort	
Edible plants	**English name**	**Reported success and use**
Malus domestica	different apples	
Pyrus communis	pear	
Prunus domestica	plum	
Prunus americana	American plum	
Prunus cerasus	sour cherry	
Rubus occidentalis	black raspberry	
Corylus americana	American hazelnut	
Zea mays	maize	Did not ripen without growing in plant frame
Parthenocissus inserta	grape woodbine	Needed to cover for winter
Fragaria virginiana	Virginia strawberry	
Oxalis sp.	wood sorrels	Good for salad; valuable for medicine (from America)
Crambe maritima	sea kale	Thrived well, was used by English gentry in early spring
Panicum miliaceum	millet	Survived
Lathyrus tuberosus	earth-nut pea	A good kitchen plant
Solanum tuberosum	potato	Was mentioned modestly, not found interesting
Cucumis melo	melon	
Cucurbita pepo	pumpkin	
Citrullus lanatus	watermelon	
Fagopyrum esculentum	buckwheat	(from Sweden)
Fagopyrum tataricum	Tartary buckwheat	(from Siberia)
Brassica oleracea Acephala / Sabellica Group	ornamental kale	(syn.? *Brassica laciniata* (Kerkkonen 1936) (snittkål in Swedish)
Beta vulgaris	chard	(*Beta vulgaris* ssp. *vulgaris* var. *cicla / Beta vulgaris* var. *flavescens)*
Rumex patientia	patience dock	

Appendix 1 cont.

Medicinal plants	**English name**	**Reported success and use**
Rheum sp.	different rhubarbs	Thrived
Sambucus nigra	elder	Survived and flowered but berries did not ripen; flowers would have used in pharmacies (from Sweden)
Sambucus canadensis	American elderberry	Survived and flowered but berries did not ripen; flowers would have used in pharmacies
Cochlearia officinalis	common scurvygrass	Flourished, used yearly in the pharmacies of Turku
Solanum dulcamara	woody nightshade	Flourished, stems used yearly in the pharmacies of Turku
Datura (*stramonium*)	thorn apple	
Althaea sp. (*racemosa*)	althaea plant	
Cornus sanguinea	common dogwood	
Porteranthus trifoliatus	bowman's root	(syn. *Spiraea trifoliata)*
Gladiolus sp.	gladiolus (from America)	
Melilotus albus	white melilot	
Centaurea benedicta	blessed thistle	(syn. *Carduus benedictus)*
Silybum marianum	milk thistle	(syn. *Carduus mariae)*
Hyssopus officinalis	hyssop	
Plants for hedges	**English name**	**Reported success and use**
Syringa vulgaris	common lilac	Did not get damaged in frost
Acer platanoides	Norway maple	
Tilia cordata	common linden	Beared well cutting and survived frost
Morus alba	white mulberry	Made low hedges, suffered in cold winters
Crataegus sp.	hawthorn (Swedish)	Dense and beautiful hedge, did not ripen in cold summers
Rhamnus catharticus	common buckthorn	Useful also for dyers and as a medicine
Crataegus grayana	scarlet hawthorn	
Picea abies	spruce	Wide nice hedge
Prunus spinosa	blackthorn	More vulnerable than hawthorn
Berberis sp.	barberry	Survived frost quite well
Hippophaë rhamnoides	sea buckthorn	
Ribes uva-crispa	gooseberry	Most beautiful hegdes
Ribes Rubrum Group	redcurrant	Beautiful hedges
Ribes alpinum	mountain currant	Hedges cut in different shapes
Caragana arborescens	Siberian pea tree	Seedlings grown from seeds and planted as hedges
Rhamnus purshiana	cascara buckthorn	Mostly got frozen in cold winters (from America)
Lonicera sp.	honeysuckle	Good for low hedges
Ligustrum sp.	privet	Have not been used to the climate
Spiraea salicifolia	the bridewort spiraea	
Spiraea trilobata / Physocarpus opulifolius	Asian meadowsweet / common ninebark	(syn. *Spiraea opulifolia)*
Carpinus sp.	hornbeam	
Sambucus sp.	elder	Not good for hedges, suffered too much the frost
Ornamental plants	**English name**	**Reported success and use**
Convolvulus sepium	larger bindweed	For pyramids and cover for gazebos
Rubus odoratus	purple-flowering raspberry	Sutvived the climate well; edible berries taste good
Vicia biennis		For pyramids and cover for gazebos
Monarda coccinea	bergamot	Suitable for flower garden
Fodder plants	**English name**	**Reported success and use**
Medicago falcata	sickle alfalfa	Spread largely, cold summers did not ripen; good for livestock
Lathyrus heterophyllus	Norfolk everlasting pea	Thrived; good for livestock
Hedysarum alpinum	sweet-broom	Thrived in poor soil
Onobrychis viciifolia	common sainfoin	Was not sure could it survive the climate

Appendix 2. Plant macrofossils from Uppsala Linnaeus Garden, pits 1 to 6 in total.

Plant macrofossils from Uppsala Linneaus Garden																																			
Soil sample	U1/1	U2/1	U2/2	U2/3	U2/4	U2/5	U2/6	U2/7	U3/1	U3/2	U3/3	U3/4	U3/5	U3/6	U3/7	U3/8	U3/9	U3/10	U3/11	U4/1	U4/2	U4/3	U4/4	U4/5	U5/1	U5/2	U5/3	U5/4	U5/5	U6/1	U6/2	U6/3	U6/4	U6/5	Total
Depth below ground (cm)	27-34	15-24	24-32	32-34	34-42	42-52	52-59	59-59	8-14.	14-21	21-30	30-37	37-45	45-51	51-59	59-70	70-79	79-88	88-96	27-39	39-45	45-55	55-65	65-72	40-56	56-70	70-81	81-90	90-100	37-47	47-54	54-62	62-70	70-78	
All samples approx 1 litre and collected with a sampler																																			
Species and other taxa in alphabetical order in groups of use and ecology with number of seeds, fruits, diaspores																																			
Garden plants and Useful plants																																			
Cerealia charred						*1*									*1*																				**2**
Chelidonium majus	10	7							1	1		2	5	2	1	*1*					2	25	54	4										1	**116**
Datura stramonium												1									3	1													**5**
Fragaria vesca			1																																**1**
Hyoscyamus niger																		1																	**1**
Nicandra physalodes														1																					**1**
Rubus idaeus	1	2																																	**3**
Rubus sp.		3			1																														**4**
Secale cereale charred																							*1*												**1**
Cultural weeds																																			
Aethusa cynapium														1		1																			**2**
Alchemilla sp.																					2	2													**4**
Apiaceae							1																		1										**2**
Atriplex cf. *hortensis*												1																							**1**
Chenopodium album					2						2	1		1	1	2		2				1			1										**13**
Chenopodium hybridum			1		1	2	1	1	1	1	1	8	6	4	4	2		1	1			1			3	4	2			2					**47**
Chenopodium sp.	1						2		5	12	2	1	4	1	4				1		1		1			1		1					1	1	**39**
Galium cf. *spurium*																		*1*																	**1**
Lamium sp.																														1					**1**
Potentilla sp.																							1												**1**
Prunella vulgaris																					1	1													**2**
Ranunculus cf. *acris*												1																							**1**
Ranunculus repens										1							*3*	*1*																	**5**
Scrophularia cf. *auriculata*																														1	4				**5**
Stellaria media													*1*					*1*																	**2**
Trifolium cf. *campestre*																	1																		**1**
Meadow plants																																			
Poa sp./Poaceae																												*1*							**1**
Poaceae	3										1	1					*1*				*1*	*1*								1					**9**
Viola sp./cf. *hirta*/cf. *odorata*																				2															**2**
Wetland plants																																			
Carex cf. *nigra*																		*1*																	**1**
Carex sp. distigmatae															*1*			*1*																	**2**
Carex sp. tristigmatae			1																			*1*													**2**
Juncus sp.							1	1																											**2**
Trees and shrubs																																			
Betula cf. *pubescens*																				1															**1**
Betula sp.																							1												**1**
Picea abies charred needle						*1*			*1*			*1*										*2*	*1*		*1*										**7**
Pinaceae scales of cones	1																					1													**2**
Indet.	1	4			1		3			4	1	1	1			1	3	2		1	1	1	2					1		2					**30**
cf. receptacle																												*1*							**1**
Number of macrofossils	17	16	3	0	5	4	8	2	8	19	7	18	17	10	12	7	8	11	2	4	11	37	61	4	6	5	2	4	0	7	4	0	1	2	**322**
Number of taxa	5	3	3	0	3	3	4	2	4	4	4	9	4	6	6	4	3	8	2	2	6	10	6	1	4	2	1	2	0	4	1	0	1	2	**36**
n:o in *italics* = chrarred																																			

Appendix 3. Plant macrofossils from Turku Academy Garden, pits 1 to 7 in total.

Plant macrofossils from Turku Academy Garden																																									
All samples approx 1 litre and collected with a sampler or with a small shovel																																									
PIT	T1/1	T1/2	T1/3	T1/4	T1/5	T2	T3/1a	T3/1	T3/2	T3/3	T3/4	T3/5	T3/6	T3/7	T3/8	T4/1a	T4/1b	T4/2	T4/3	T5/1	T5/2	T5/3	T5/4	T5/5	T5/6	T5/7	T6/1	T6/2	T6/3	T6/4	T6/5	T6/6	T6/7	T7/1	T7/2	T7/3	T7/4	T7/5	T7/6	T7/7	T7/8	**TOTAL**
Depth below ground (cm)	45-56	56-64	64-75	75-81	81-83	22-32	24-32	32-40	40-47	47-55	55-61	61-68	68-74	74-82	82-90	14-16	45-57	57-63	63-65	41-50	50-59	59-68	68-75	75-80	80-86	86-89	8.-13	20-32	32-40	40-47	47-52	52-57	57-62	31-36	37-47	47-56	56-64	64-73	73-81	81-91	91-102	**8-102**
Species and other taxa in alphabetical order in groups of use and ecology with number of seeds, fruits, diaspores																																									
Garden plants and Useful plants																																									
Aquilegia vulgaris																													2													**2**
Chelidonium majus								2	3																				4			2	3				1					**15**
Fragaria vesca																2											1		1													**4**
Fragaria vesca/F. moschata																																					1					**1**
Hyoscyamus niger									1																																	**1**
Rubus idaeus																											1															**1**
Rubus sp.																											1															**1**
Salvia sp.																					*1*																					**1**
Sambucus racemosa/S. canadensis																2					1						11	6	1						1	1						**23**
Cultural weeds																																									
Aethusa cynapium																2													4													**6**
Ajuga pyramidalis/reptans/genevensis																1													1													**2**
Apiaceae																													2		1	1	1									**5**
Atriplex sp.																				1																						**1**
Cerastium sp.																	2																									**2**
Chenopodium album									1							8		1		1		1					21	3		14	3	1	1		2			1				**58**
Chenopodium glaucum/rubrum																											1															**1**
Chenopodium hybridum																1					1								1	1												**4**
Chenopodium sp.																3		1				1	4					2	2	1						1						**15**
Fallopia convolvulus																1																1										**2**
Fumaria officinalis																1													1													**2**
Galeopsis cf. *speciosa*																											2															**2**
Galium sp.																											1															**1**
Lamium sp.																												1														**1**
Persicaria sp.																												1														**1**
Plantago major								1									3			1	5	1	2				4	4				1		1	4	18	4	2				**51**
Polygonum aviculare	3							5	4	2	1	1	2	2		2				4	4			1			19	1	1							1						**53**
Potentilla sp.																											1															**1**
Rumex sp.														1		1																										**2**
Scrophularia cf. *auriculata*					1			4	1		1									6	4	1	2						2			3	3					1				**29**
Spergula arvensis						1									1	60											5	14	1							1						**83**
Stellaria media																					1	2	1		1									1		2	3	2				**13**
Trifolium repens																						1																				**1**
Urtica sp.																											4															**4**
Meadow plants																																									
Myosotis sp.																											2															**2**
Poa sp.														7	1												6	1	1			1	1									**18**
Poa sp./Poaceae									3	2	1					2				1														2	1	5	1	3				**21**
Poaceae																		1									5								1							**7**
Stellaria cf. *graminea*																																				1						**1**
Viola sp./cf. *hirta*/cf. *odorata*																																		1	1							**2**
Viola sp.																1											2		5									1				**9**
Wetland plants																																									
Carex sp. distigmatae								*2*								1												1														**4**
Empetrum nigrum																1																										**1**
Juncus sp.								1								2											3	2	1													**9**
Veronica cf. *scutellata*/cf. *officinalis*																2																										**2**
Trees and shrubs																																									
Betula sp.																																					1					**1**
Picea abies charred needle										*1*										*1*	*1*																				*1*	**4**
Pinaceae scales of cones						1					1					1	1	1	1					1	1		1	1						1		1	1	1	1			**15**
Indet.	2	3						1				1				1	2	1			1	3	1				3	6	2		1		1				1		2			**32**
N:o in italics = charred																																									
Number of macrofossils	5	3	0	0	1	2	0	16	13	5	4	2	2	10	2	95	8	5	1	15	19	10	11	2	1	0	94	43	32	16	5	10	10	6	10	31	13	11	3	0	1	**517**
Number of taxa	1	0	0	0	1	2	0	6	6	3	4	1	1	3	2	19	3	4	1	7	8	6	5	2	1	0	19	12	16	3	2	7	5	5	6	9	7	7	1	0	1	**47**