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University of Turku

Faculty of Science and Engineering
Biodiversity unit

Supervised by

Professor Felix Bittmann
Lower Saxony Institute for Historical Coastal Research
Department of Natural Sciences
Wilhelmshaven, Germany

Associate Professor Jenny Hagenblad
Department of Physics, Chemistry and Biology (IFM)
Linköping University
Linköping, Sweden

Docent Sanna Huttunen
Herbarium
Biodiversity unit
University of Turku
Turku, Finland

Docent Timo Vuorisalo
Department of Biology
University of Turku
Turku, Finland

Reviewed by

Doctor Otto Brinkkemper
Cultural Heritage Agency
Department of Landscape
Amersfoort, the Netherlands

Doctor Jacob Morales
Department of Historical Sciences
University of Las Palmas de Gran Canaria
Las Palmas, Spain

Opponent

Doctor Sabine Karg
Institute for Prehistoric Archaeology
Freien Universität Berlin
Berlin, Germany

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To Baran

"Look wide, beyond the immediate stones in your path,

see what that path is leading to, and go ahead with good cheer".

Lord Robert Baden-Powell, 1857-1941

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ABSTRACT

Plant remains are derived from archaeological contexts and therefore they provide an interesting source material for investigating the role of economic plants and environments in the past. Plant remains can reflect past activities such as cultivation, consumption, trade and migration. Plant remains provide data and information for a number of other disciplines, and methods from other fields such as ^{14}C radiocarbon dating, genetics and isotope analysis can be used to obtain additional data from macrofossil plant materials. In this thesis, I combined macrofossil, pollen, radiocarbon and genetic data in order to study what kind of new information can be achieved from archaeological contexts. I studied how cultivation, consumption, trade and barley migration are reflected in the archaeobotanical and historical data from ca. AD 1000 to the 20th century in southern Finland. Primary data used in this study consists of carbonised, waterlogged and mineralised archaeobotanical plant remains i.e. macrofossils recovered from archaeological excavations, and dried plant material derived from historical collections. Besides archaeobotanical analyses, palynology and genetics as well as radiocarbon dating are also involved in reconstruction and interpretation of past activities.

I studied early stages of agriculture and economy of a medieval rural village in Espoo at Mankby, and I found that rye (*Secale cereale* L.) cultivation started in the 12th century and continued until the abandonment of the village in 1556. The reason for the dominance of rye may be that it was considered a safer choice of crop as it is quite well suited to Finnish climatic conditions and it thrives on poor soils. Based on the study, it seems that the medieval cultivation of rye was increasing, but concentrated in some villages in southern Finland, and barley (*Hordeum vulgare* L.) was still important in most other parts of the country. I also studied what kind of information can be acquired from graves by combining macrofossil and pollen data. I found that plant material in graves is preserved only occasionally where the high proportion of metal oxides or calcium have preserved the plant remains. However, interesting results were gained from a 16th century grave at the Kappelinmäki cemetery in Kauskila, Lappeenranta. There, the grave gave evidence of the deceased's last meal, since a large number of mineralised raspberry (*Rubus idaeus* L.) seeds and some fish bones were

discovered from the pelvis and stomach area. Pollen analysis of the same grave gave evidence of past environment, funeral practices and ritual usage of plants.

I also discuss the usage and origin of the plants, as I found that the plant material derived from the 1790s latrine at the sea fortress of Ruotsinsalmi in Kotka was mainly influenced by Russian food traditions. For instance, millet (*Panicum miliaceum* L.) and buckwheat (*Fagopyrum esculentum* L.) played an important role in the diet in the sea fortress. Finally, I tested the utility of archaelogical and historical samples of barley as sources of genetic data. I show that DNA concentrations obtained from charred archaeological barley grains are too low for successful KASP genotyping, while dried grains from herbariums and seed collections had in general a sufficient DNA quality for genetic analysis. I further show that genotypic variation in the historical samples of Finnish six-row barley is geographically clustered, while in the two-row barley genetic structuring is not linked to geography. Genotyping of functional markers revealed that the majority of barley cultivated in Finland in the late 19th and early 20th century was late-flowering under increasing day-length.

In general, the results of this thesis show that the selection of used plant taxa got more versatile from the Iron Age to the medieval era, however, from medieval to 1790s the number of used plant taxa did not grow remarkably as the archaeobotanical data is rather similar in 1790s as in the Middle Ages. From the medieval onwards, the number of used plants is growing due to the intensification of trading networks overseas. Significant agricultural change did not occur in Finland in 1000 AD to 1900 AD, as barley was the most common cultivated plant. However, local differences may occur, as e.g. rye was cultivated in coastal areas. As six-rowed barley has a long cultivation history in Finland as a main crop, it has adapted to the climate and the genetic structure of barley landraces is geographically clustered.

TIIVISTELMÄ

Kasvijäänteet ovat peräisin arkeologisilta kohteilta ja siksi ne tarjoavat mielenkiintoisen lähdemateriaalin menneisyydessä käytettyjen kasvien ja muinaisten ympäristöjen tutkimukselle. Kasvijäänteet antavat tietoa viljelystä, kulutuksesta, kaupankäynnistä ja kasvien levinnästä. Kasvijäänteet tarjoavat tietoa muille tieteenaloille sekä lisäksi niitä voi käyttää aineistona esimerkiksi ^{14}C radiohiiliajoituksissa, geneettisessä tutkimuksessa sekä isotooppianalyyseissä.

Väitöskirjassani tutkin miten viljely, kulutus, kaupankäynti ja kasvien levintä näkyvät eteläsuomalaisessa arkeobotaanisessa ja historiallisessa aineistossa 1000-1900-luvuilla. Tutkimusaineistoni koostuu hiiltyneistä, hiiltymättömistä ja mineralisoituneista kasvijäänteistä, jotka ovat peräisin arkeologisilta kohteilta sekä kuivana säilytetyistä historiallisten kokoelmien kasvinäytteistä.

Espoon Mankbyssä sijaitsevan keskiaikaisen kylän varhaista viljelyä ja taloutta koskevan tutkimukseni mukaan rukiin (*Secale cereale* L.) viljely alkoi Mankbyn kylässä jo 1100-luvulla jatkuen aina kylän autioitumiseen asti vuoteen 1556. Ruis on vaatimaton kasvupaikan ja lämpötilan suhteen, joten se oli todennäköisesti turvallisempi ja siten taloudellisesti kannattavampi valinta ohran sijaan. Rukiin viljely oli 1000-luvulla lisääntymässä, mutta se oli aluksi keskittynyt vain tiettyihin kyliin Etelä-Suomessa, kun taas ohra (*Hordeum vulgare* L.) oli edelleen suosituin viljalaji suurimmassa osassa maata.

Haudoista tehtyjen kasvijäänneanalyysien perusteella voidaan todeta, että kasviaines säilyy parhaiten haudoissa, joissa on metalliesineitä tai luuta runsaasti, sillä esineiden metallisuolat ja luista erittynyt kalsium säilövät kasvijäänteitä. Esimerkiksi Lappeenrannan Kauskilan Kappelinmäen kalmistosta löytyi 1500-luvulle ajoitettu hauta, jossa oli vainajan vatsassa tuhansia vadelman (*Rubus idaeus* L.) siemeniä ja pienen muikkukalan luita. Siemenet olivat säilyneet vainajan luista erittyneen kalsiumin johdosta mineralisoituneina. Kasvijäänneanalyysin myötä saatiin tietoa ruokavaliosta ja haudasta tehty siitepölyanalyysi puolestaan antoi tietoa ympäristön kasvillisuudesta menneisyydessä sekä kasvien käytöstä haudassa.

Kotkan Ruotsinsalmen merilinnoitusta käsittelevässä tutkimuksessani havaitsin, että sotilaiden ruokavaliosta perustui venäläiseen ruokatraditioon, kun taas paikallisia kasvisperäisiä ruoka-aineita käytettiin vähemmän. Esimerkiksi hirssillä (*Panicum miliaceum* L.) ja tattarilla (*Fagopyrum esculentum* L.) oli huomattava rooli arkipäivän ruuassa. Venäläiset kauppiaat toivat merilinnoitukselle hirssin lisäksi mahdollisesti myös hapankirsikkaa, karhunvatukoita, tattaria, mausteita ja viikunoita sekä viljoja joko suoraan Venäjältä ja kauempaa ulkomailta.

Ohran DNA:ta (*Hordeum vulgare* L.) koskevien tutkimusten mukaan hiiltyneiden, arkeologisten ohranjyvien DNA:n määrät ovat liian vähäiset käytettäväksi geneettisissä analyyseissä. Geneettiset analyysit kasvimuseoiden ja siemenkokoelmien jyvistä, jotka on kerätty tuoreena ja kuivatettu, puolestaan sisälsivät riittävästi DNA:ta analyysien tekemiseen. Tulokset lisäksi osoittivat, että suomalainen kuusitahoinen ohra on voimakkaasti keskittynyt maantieteellisesti, kun taas nuorempaa ja harvemmin viljeltyä kaksitahoista ohraa viljeltiin tasaisesti maan eri osissa. Geneettisten analyysien perusteella näyttää siltä, että suurin osa 1800-luvun lopulla ja 1900-luvun alussa Suomessa viljellystä maatiaisohrasta oli myöhään kukkivaa lajiketta.

Väitöskirjani tulokset osoittavat, että arkeobotaanisilla analyyseillä saadaan lisätietoa varhaisesta viljelystä, taloudesta, kaupankäynnistä ja ruokavaliosta, jotka puolestaan tukevat merkittävästi arkeologista tutkimusta. Yhdistämällä eri menetelmiä, kuten kasvijäänne- ja siitepölytutkimusta, radiohiiliajoituksia ja geneettisiä analyysejä, saadaan tutkimusaineistosta enemmän tietoa, kuin vain yhdellä tutkimusmenetelmällä. Hiiltyneen materiaalin käyttö geneettisissä analyyseissä ei tuottanut tulosta, mutta sen sijaan kuivana talletetut tai kosteissa oloissa säilyneet kasviaineistot voivat antaa yllättäviäkin tutkimustuloksia.

LIST OF ORIGINAL PUBLICATIONS AND AUTHOR CONTRIBUTIONS

This thesis is based on the following publications, which are referred to in the text by their Roman numerals:

I Lempiäinen-Avci M, Haggrén G, Rosendahl U, Knuutinen T & Holappa M. 2017. Archaeobotanical analysis of radiocarbon-dated plant remains with special attention to *Secale cereale* (rye) cultivation at the medieval village of Mankby in Espoo (Finland). *Vegetation History and Archaeobotany* (2017) 26: 435. DOI: 10.1007/s00334-017-0604-4

II Lempiäinen-Avci M, Laakso V & Alenius T. 2017. Archaeobotanical remains from inhumation graves in Finland, with special emphasis on a 16th century grave at Kappelinmäki, Lappeenranta. *Journal of Archaeological Science: Reports* 13 (2017) 132–141. DOI:10.1016/j.jasrep.2017.03.038

III Lempiäinen-Avci M & Kykyri M. 2017. 18th century sea fortress of Ruotsinsalmi, Kotkansaari in Finland. Archaeological finds and archaeobotanical data of log latrine. *Estonian Journal of Archaeology* (2017) 21: 1: 30–51. DOI: 10.3176/arch.2017.1.02

IV Lempiäinen-Avci M, Lundström M, Huttunen S, Leino M W & Hagenblad J. 2018. Archaeological and historical materials as a means to explore Finnish crop history. *Environmental Archaeology*. DOI: 10.1080/14614103.2018.1482598

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Author contributions to the original publications:

	I	**II**	**III**	**IV**
Original idea	ML-A, GH	ML-A	ML-A	ML-A
Lab work and analyses for macrofossils	ML-A	ML-A	ML-A	ML-A
Lab work and analyses for aDNA	.	.	.	ML, MWL, JH
Lab work and analyses for pollen	.	TA	.	.
Writing the manuscript	ML-A, GH, UR, TK, MH	ML-A, VL, TA	ML-A, MK	ML-A, ML, SH, MWL, JH

ML-A=Mia Lempiäinen-Avci, GH=Georg Haggrén, UR=Ulrika Rosendahl, TK=Tarja Knuutinen, MH=Maija Holappa, VL=Ville Laakso, TA=Teija Alenius, MK=Marita Kykyri, ML=Maria Lundström, SH=Sanna Huttunen, MWL=Matti W. Leino, JH=Jenny Hagenblad

1. INTRODUCTION

The study of plant remains which have survived in archaeological contexts is called archaeobotany or paleoethnobotany (Renfrew 1973). The words *archaíos* and *palaiós* originate from Greek meaning “ancient” and “old”. Plants have been used for producing a large variety of economic products, and plants have always been an important part of everyday life for humans. Therefore, plant remains may provide important source of information, because they can be used to reconstruct the interactions of past living societies and their environments (Renfrew 1973; Hastorf 1988; Jacomet & Kreuz 1999). The key interest for archaeobotanists are which plants were used in the economy, when, where and how did the utilization of plants change over time. These aspects reflect changes in past activities such as cultivation, consumption and trade. Depending on perspective, archaeobotanical material can cast light on these research topics. For these reasons, plant remains from archaeological contexts form an interesting study material for investigating the role of economic plants in Finland during prehistory to historical times. (For a chronology of historical and prehistoric periods in Finland, see **Table 1**).

Plant remains found in archaeological contexts can reflect the past environment, in the same way plants forming current flora can be used as indicators of contemporary environmental conditions at the site. Especially noteworthy is that changes in plant taxa in the archaeobotanical material can also reflect changes in the species abundance, increase or loss of biodiversity in the studied area, and plant communities in particular can indicate past conditions of the environment. Due to the ability to reflect the environmental conditions, many plants are used, for example, to determine the types of soil (e.g. Cappers 1993/1994; Lempiäinen T 2010; Birks 2014 and references therein).

Archaeobotany, the study of plant remains in cultural settings is multidisciplinary (Livarda 2014, **Fig. 1**). Material derives from archaeological contexts where the interests of research questions are purely archaeological. However, the archaeobotanical data is comparable to ecological research as data is typically composed of lists of species occurring at study sites based on pollen or macrofossils. Due to the nature of the data, analysis methods used in biology can be applied in archaeobotanical research. In addition, methods from other fields such as radiocarbon dating, genetics and isotope analysis can be used to obtain additional data from macrofossil materials. Data from all above mentioned sources can be combined and used to draw conclusions on past activities and environments.

The study of plant remains from archaeological sites provides data and information for a number of disciplines. Archaeobotany should be recognized as an important and integral part of archaeological research (Hastorf & Popper 1988). As artefacts, archaeobotanical materials form a valuable source of information and therefore they are also an important part of Finnish history. For this reason, the archaeobotanical remains should be treated and curated as any other archaeological artefacts (Salick, Konchar & Nesbitt 2014). Data should be available in open access databases and the archaeobotanical sample itself should be stored in institutes where they are accessible and their preservation is secured and guaranteed.

Table 1. Prehistory is the period before written sources, while history – in the narrow sense – is the study of the past using written evidence (Renfrew & Bahn 1994). Chronology of prehistoric and historical periods of southern and western Finland is according to Vahtola (2003) and Haggrén et al. (2015).

CHRONOLOGY		CALENDAR YEARS
Historical periods	Pre Modern Period	AD 1800 – 1520
	Middle Ages	AD 1520 – 1200 / 1150
Prehistoric periods	Iron Age	AD 1200 – 500 BC
	Bronze Age	500 – 1700 BC
	Neolithic	1700 / 1900 – 5200 BC
	Mesolithic	5200 – 8850 BC

Figure 1. Besides artefacts, archaeological contexts provide e.g. macrofossils and pollen, which can be analysed further by using methods such as radiocarbon dating, genetic or isotope analysis. Biological and archaeological data together can be used to draw conclusions on past activities and environments. Photo on top: Excavations at Lahti market place 2013. Lahden kaupunginmuseo, Piritta Häkälä.

1.1. Archaeobotanical material: sampling and preservation of plant remains

In archaeobotany a researcher rarely has a possibility to affect specimen sampling as material usually derives from excavations that are planned and sampled according to interests of archaeological research. This may sometimes limit the study questions that can be answered. The preservation state of archaeobotanical material is highly affected by natural and cultural processes. Plant remains are preserved only in favourable circumstances as charred (carbonised), mineralised, waterlogged (uncharred) or dry (desiccated) remains. Generally, plant material that has preserved dry derives from arid areas such as Egypt, where outstandingly rich remains of dried plants have been discovered (Zohary, Hopf & Weiss 2012). Plant material can also be preserved occasionally by metal oxides, as impressions in clay or frozen. (Renfrew 1973; Jacomet & Kreuz 1999; Zohary, Hopf & Weiss 2012).

Archaeobotanical material discussed in this study is preserved either charred (article **I**), mineralised (article **II**) waterlogged (article **III**) or dry from historical contexts (article **IV**).

Charred material

Charred plant remains are the most common source of plant material revealed from archaeological sites as they survive in most environments (Zohary, Hopf & Weiss 2012). In this study, archaeobotanical material revealed from the medieval village in Espoo at Mankby was preserved in a charred state in fossilised fields, hearths, pits and the floor area near the ovens at a two-roomed house and inside a stone cellar (**I**). Plant remains may have charred when they were exposed to high temperatures, in most cases due to open fires (Zohary, Hopf & Weiss 2012). This could occur because of overheating near a hearth, in a parching oven, in a house fire or burning of fields, as well as in cremation graves (Renfrew 1973; Viklund 1998). Charred plant remains found during excavations provide information about the site itself, as well as of nearby areas where the material may have come from (Viklund 1998). In Finland, the archaeobotanical research also relies largely on ancient misfortune as the majority of plant remains are found charred.

The most productive contexts, where charred macrofossils have been recovered in Finland include, for example, a Viking age waste pit containing more than 8000 cereal remains from Lieto at Pahka (Onnela, Lempiäinen & Luoto 1996). From the medieval period an assemblage of 6000 cereals from a rural site storage in Lieto, at Rähälä dated to AD 1200, can be mentioned (Lempiäinen T 1996). Moreover, medieval castles at Kastelholm in Åland and in Hämeenlinna revealed storages with more than 20 000 cereal grains in both sites (Onnela 2004; Savunen 2017). Additionally, an assemblage of 7000 flax (*Linum usitatissimum* L.) seeds, together with more than 30 000 weed seeds and 1500 rye (*Secale cereale* L.) grains were recovered from a house in the rural village of Lahti, which was destroyed by a fire in 1851 (Lempiäinen-Avci 2013a).

Mineralised material

Plant remains get mineralised when inorganic substances replace the organic content of the plant. The most common way of mineralising is via calcium carbonate ($CaCO_3$), silica or phosphate (Zohary, Hopf & Weiss 2012). Article **II** presents mineralised raspberry seeds recovered from a grave in Lappeenranta, at Kauskila. Here, the raspberry seeds had been mineralised due to the high levels of calcium originating from the bones of the deceased in the cemetery. Also briefly discussed is a grave found at Porvoo Cathedral. In this grave, leaves and stems of sphagnum moss (*Sphagnum* sp.) were preserved due to metal oxides from the silver needles and bronze spirals found in the grave.

In Finland, all reports concerning mineralised plant remains derive from graves. At the Katariina Kirkkomäki cemetery in Turku, spikes and stalks of rye and young birch branches (*Betula* sp.) were found in separate graves, together with bronze artefacts belonging to the dresses of the buried women (Lempiäinen T 2005). Moreover, spikes of rye were also found in a woman's grave at Tuukkala in Mikkeli (Heikel 1889; Lempiäinen T 2002). Both sites date to ca. AD 1100. In these cases, it is plausible that plant remains were preserved due to the metal oxides from bronze artefacts.

Waterlogged material

Plant remains deposited under water or in waterlogged conditions, and therefore in anaerobic circumstances, can be preserved for centuries or even millennia (Karg 2007; Tolar et al. 2010). Waterlogged plant material allows a much better insight into the diversity of plant use than at the average dry land site, where only carbonised plant remains are preserved. For instance, if the conditions are favourable, fragile plant tissues may survive in an excellent state, and even green leaves or intact berries or fruits can be found in waterlogged sediments (Tolar et al. 2010). Waterlogged plant material has usually survived only in medieval or younger layers at urban sites of Finland due to the clayey soils. Article **III** presents the waterlogged plant material preserved in human faeces found from a primitive toilet, a latrine, at the sea fortress of Ruotsinsalmi in Kotkansaari.

Large waterlogged assemblages have been found in medieval layers in Turku, where for example a stave vessel contained almost 4000 remains of economic plants such as millet (*Panicum miliaceum* L.), fruits, spices and vegetables (unpublished data by Lempiäinen-Avci et al. 2018). In addition, tens of thousands of weed seeds were discovered in medieval layers during excavations at Lake Mätäjärvi in Turku (Lempiäinen T 1989). Moreover, in layers of the Lyseo site in Oulu dating to AD 1600–1700 more than one thousand charred barley (*Hordeum vulgare* var. *vulgare*) grains were found together with hundreds of waterlogged fig (*Ficus carica* L.) and raspberry (*Rubus idaeus* L.) seeds (Lempiäinen-Avci 2015). Besides these medieval and urban contexts, one very interesting exception has been documented from the Mesolithic site of Riihimäki. There, a large bark layer and water chestnuts (*Trapa natans* L.), preserved waterlogged in peat layers, were revealed (Matiskainen 2002; Matiskainen & Ruohonen 2004).

Historical material

Historical collections include herbarium specimens, stored at natural history museums that maintain collections of preserved plant specimens, vascular plants, bryophytes, lichens, algae, and fungi. Collections may also include other types of plant material obtained from, for instance, stuffing in historical objects e.g. furniture and bedding, or from construction materials, and those historical materials may be available for archaeobotanical studies. For example, an 18th century sofa in the Sinebrychoff Art Museum in Helsinki was filled with rye spikelets (Lempiäinen-Avci 2016), and this material is now stored at the Turku University Herbarium (TUR).

The method of preparation and storage of plant material depends on the type and purpose of use of the plant being processed. Most herbarium specimens are stored dry, pressed and mounted on standard herbarium sheets, and plant parts that cannot be easily pressed are dried in boxes or paper bags. Moreover, seed collections in museums most often include cereals, but also other cultivars, legumes and even wood. Seeds are sometimes stored dry in glass jars, where the preservation has been very good due to the sealed jars and anoxic environment (Leino 2010).

In addition to dry-preserved herbarium material, the collection may contain liquid preserved plant parts, photographs, microscope slide preparations, specially prepared specimens suitable for DNA or other chemical extraction, and other preserved materials. Specimens at natural history museums are typically used as references for identification and comparison with unknown samples, documenting species distribution and variation within species, for phenological studies e.g. of fruiting and flowering times, or genetic studies among others. Therefore, each sample or specimen has a label bearing documentary information. (Bridson & Forman 1998; Hämet-Ahti et al. 1998).

Material investigated and published in article **IV** comprised of historical grain material derived from the collections at the Herbarium (TUR) of the University of Turku were the material was pressed and mounted on paper and stored dry, while the historical grain material from the Mustiala Agricultural Museum and the Nordiska Museet in Sweden were dried and stored in glass jars. The oldest sample derived from the Turku University Herbarium (TUR) dates to 1872 and the youngest is from 1921. All materials from Mustiala date to 1890s and from Nordiska Museet to 1882. These dried grain materials were used for a genetic study to investigate the origins of Finnish barley landraces. Results from genetic analysis can be used as an additional source of information to support conclusions on archaeological macrofossil data. Historical collections of biological material are important genetic resources for taxonomic, evolutionary and historical research (Leino et al. 2009).

1.2. Economic plants in archaeobotanical findings

Archaeobotanical findings cast light on e.g. the cultivation, domestication, consumption, trade and migration of economic plants. Archaeobotanical investigations from prehistory to medieval and historical times demonstrate how a large number of cultivated and wild plants were first introduced and then gradually became essential parts of the local economy. Based on general synthesis of archaeobotanical data collected in Finland since 1980s it is plausible that there were two major waves in the medieval period, when several new food plants and other economic plants were introduced in Finland (Lempiäinen T 2007). The expansion of the Catholic Church from ca. AD 1100 onwards led to the establishment of churches, monasteries and castles in Finland (Harjula et al. 2018). This movement of new people and new traditions must have triggered the introduction of medicinal plants in particular to Finland. Even though Finland never belonged to the Hanseatic League (AD 1100−1669) (Kuujo 1981), another wave of introduction took place during the Hanseatic period with the intensification of trade overseas. Further, the Age of Discovery from the 15th to 17th

centuries, during which European ships travelled around the world to search for new spices among other things, probably caused the third wave of introduction of new plants into the Finnish archaeobotanical data, especially of those used as stimulants.

In most cases, new additions did not replace the traditional ones, but were added to the surrounding nature, daily economy and local diet. Moreover, the investigation of the migration of these new taxa has indicated that some of them were grown here and still grow as part of Finnish flora, namely as archaeophytes and neophytes, while some of the species never grew here and had to be imported (Suominen & Hämet-Ahti 1993; Lempiäinen T 1999 and references therein). These imports would offer a means of distinction due to their low availability and high costs (Livarda 2014). It is noteworthy that there must have been earlier introduction waves long before the Middle Ages, as barley appeared here at some point during the Late Neolithic or Early Bronze Age and rye during the Iron Age (Lempiäinen T 2006). However, the early finds of cereals are rare and their appearance as newcomers is less evident and less abundant in archaeobotanical material than medieval newcomers.

Cultivation

The first signs of economic use of plants in Finnish archaeobotanical material derive from the Early Bronze Age. This early data is based on the finds of naked barley grains (*Hordeum vulgare* var *nudum*) and *Hordeum* -type pollen dated to 1690−1260 cal BC (Pihlman & Seppä-Heikka 1985; Vuorela & Lempiäinen T 1988; Asplund 2008). During the Late Bronze Age, the cereal material is also very scarce as there are only a couple of finds from that period. As there are only a few grain and pollen finds from these early phases (e.g. Vuorela 1999), it is plausible to assume that they indicate only small scale agricultural activities in Finland at that time.

During the Iron Age the number of introduced species grew gradually in Finland. Besides naked barley also hulled barley (*H. vulgare* var. *vulgare*), oat (*Avena* sp.), club wheat (*Triticum aestivum* L. ssp. *compactum* (Host) MK), bread wheat (*T. aestivum* L.) and emmer or spelt wheat (*T. dicoccum* (Schrank) Shüebl.) /*T. spelta* L.) and rye (*Secale secale* L.) occur in archaeobotanical finds (Lehtosalo-Hilander 1999; Lempiäinen T 2005; Holmblad 2010;

Vanhanen & Koivisto 2015). However, in the Iron Age data the number of cereal finds is rather small during the first centuries, while towards the end of the period significant changes can be seen in the numbers of charred grain finds, those cereals still overwhelmingly being dominated by barley.

Growing amounts of cereal finds towards the end of Iron Age in Finland may indicate that cultivation had achieved a permanent role and cereals had yielded an important role as a staple food in daily life. Analysis indicates that barley was the primary crop closely followed by rye. Some minor crop species may have grown in the fields accidentally as weeds, and in some cases mixed finds in samples can indicate rotation of the cultivated species.

Cereals were cultivated mainly for their food value; grains were used in a variety of food products, including breads, gruels and porridges, as well as in brewing and as animal fodder (Kelly 1997; Sexton 1998). Cereal straw also provided a valuable resource for structures, roofing and bedding. It is plausible, that different types of cereals had different values. As Terttu Lempiäinen (2005) has noted, rye is rare in the archaeological record, and its status was maybe perceived as being higher.

Besides cereals, peas (*Pisum sativum* L.), broad beans (*Vicia faba* L.), flax (*Linum usitatissimum* L.), Gold of Pleasure (*Camelina sativa* L.) and hemp (*Cannabis sativa* L.) have also been found in the Iron Age archaeobotanical material in Finland (Häkkinen & Lempiäinen T 1996; Vanhanen 2012; Lempiäinen-Avci 2017). Later in the Middle Ages they were accompanied by other cultivated plants, including hop (*Humulus lupulus* L.), buckwheat (*Fagopyrum esculentum* L.), herbs, and medicinal plants such as lovage (*Levistichum officinale* L.) and henbane (*Hyoscyamus niger* L.) (Lempiäinen T 2003; 2007). However, generally their presence in the data is rather scarce.

Given, that barley dominated the botanical material from its appearance at least until the 16th century or even to the 18th century (Lempiäinen T 2003; Onnela 2003), it may be that a significant agricultural change did not occur in Finland. The result provides an interesting contrast with Scandinavia. For example, in Sweden other cereal species besides *Hordeum* have already been under cultivation to some extent at the end of the Bronze Age. Further, rye accompanied barley e.g in Sweden already in AD 400 (Grabowski 2011) and in Estonia from the 7th century onwards (Tvauri & Vanhanen 2016), which in both cases is rather early compared to Finland. In Norway barley, wheat and oats were cultivated since the Early Bronze Age, while rye is almost absent from the archaeobotanical material throughout prehistory (Soltvedt & Henningsmoen 2016).

Consumption

As van der Veen (2018) has noted, an important aspect of archaeobotanical research is to determine what was eaten and how the diet changed over time or differed between social groups. When food is eaten it largely disappears from the record unless there are plant remains that have survived through the digestive system. Therefore, the archaeobotanical data is biased and the precise diet is usually difficult find out in archaeobotany. However, occasional evidence of what plants were consumed can be found e.g. in the stomach contents of bog bodies, mummies and well-preserved graves, or if coprolites are preserved in cesspits. Moreover, sealed contexts such as storages or vessels with plant remains are also reliable indicators of plant use and consumption (van der Veen 2003; 2018).

According to van der Veen (2018) consumption studies may reveal differences between consumer groups or geographical areas. In rural sites, the economy is largely dependent on local products such as crops, vegetables and wild plants. In contrast, towns and military sites show evidence of imports, herbs and exotic products. Plant taxa discovered in rural sites are much more modest than those from towns and military sites. In Finland, plant material from the Iron Age is rather modest, while the medieval town of Turku has yielded a large range of fruits, nuts, vegetables, herbs, spices, and oil-rich seeds. This also applies to the military base in Ruotsinsalmi (**III**), as a large variety of economic plants were found at the site.

Inevitably, all assemblages of plant remains representing food provide a biased picture of which plants were consumed because of the effects of different preservation. For instance, in Finland there is a great difference between the preserved plant taxa in medieval charred and waterlogged material. Plant remains found from fireplaces, fields and storages are most likely charred cereals, while waterlogged material is more versatile including e.g. remains of berries, fruits, pericarps of cereals, millets, spices, herbs and legumes (unpublished data by Lempiäinen-Avci et al. 2018).

Sometimes it is difficult to estimate if the plants were meant for human or animal consumption, or, indeed, for both. For instance in Mankby (**I**) grains found from the cellar were all well-formed and large, and there was a low concentration of weed seeds in the samples, suggesting that cereals were processed grain, therefore more likely to be for human consumption. However, in cases when there are only few grains, it is hard to estimate if the grains were really grown for consumption, or whether they were just weeds that grew in fields among some other plants. In Finland, this applies for instance to remains of oats (*Avena sp.*), which are sometimes found within barley assemblages.

Trade

Trade in archaeobotany usually concerns plant taxa that cannot permanently grow in the study area, have never been cultivated there, or which require considerable efforts to cultivate. Therefore, exotic or imported plants are the most easily identifiable sign of trade in the archaeobotanical record (Livarda 2011). At the very start they might have represented luxuries, but later on they often lost this status. For instance, figs (*Ficus carica* L.) are found in the medieval town of Turku for first time in the 13th century and the number of finds increases towards the 15th century (Lempiäinen T 1995; Nurmenniemi 1999; Lempiäinen-Avci 2013b; Lempiäinen-Avci 2014). Later on, fig seeds are found from Helsinki in the 16th – 17th century layers (Lempiäinen T & Vuorela 1994; Lempiäinen-Avci 2013c) and remains of this exotic fruit have migrated north, as they are found in Oulu in 17th century layers (Lempiäinen-Avci 2015). The results from earlier phases in particular reflect the significant increase in availability through international Hansa trade that occurred in the Baltic and elsewhere.

It is difficult to estimate if cereals were cultivated locally or traded. As McClatchie et al. (2015) has noted, although local production of cereals is often assumed, transport and trade of products is also possible. Moreover, communities may also have focused on the production of certain crop types, and then traded them with other communities for access to alternative crop types (McClatchie et al. 2015). Hence, in Finnish material traces of transport and trade are not that evident prior to the Middle Ages, as exotic plant taxa are missing from Iron Age contexts. Further, in Mankby (**I**) for instance, it is not absolutely certain where the first rye grains originate - did Swedish settlers bring rye with them from Sweden, did they use local landraces or buy it from Tallinn? However, in the archaeobotanical data from medieval urban contexts, there is better evidence that plants were traded, as there are many foreign species present among the taxa. For instance, the results from Kotka (**III**) can be explained by the fact based on written sources, that Russian merchants imported food items from abroad to the military base in Kotka. It is noteworthy that the contrast between the medieval data from Turku (e.g. Lempiäinen T 2007) and the 1790s data from Kotka is not that great, more or less the same plant species have been identified from both sites.

Migration

Cereals are economically important and their cultivation history has lasted thousands of years, and the spread of cultivation and migration of cultivars is of special interest. It can be studied using the plant remains found at archaeological sites, historical plant accessions and written sources. One of the world´s most important and earliest domesticated crops is barley, emerging in the Near East around 11,000 years ago (Zohary, Hopf & Weiss 2012). As mentioned already above (see **1.2.** Cultivation) archaeobotanical evidence shows that the cultivation of barley reached Finland at the latest in 1690−1260 cal BC). Although barley is the oldest and most widely cultivated cereal in Finland, it remains unclear where early barley cultivars have migrated in Finland. Unfortunately, the picture of the earliest migration of cereals in Finland is biased, because archaeological excavations are concentrated to southern Finland (Pihlman & Seppä-Heikka 1985; Vuorela & Lempiäinen T 1988; Holmblad 2010; Vanhanen & Koivisto 2015). In addition, the lack of archaeobotanical ^{14}C dated grain material has made it difficult to make detailed studies about the early migration of cultivars in Finland. However, written sources and genetic analysis may be suitable methods to study the origin, migration and trade of plant populations or cultivars within an area (**IV**).

The majority of the genetic variation of Finnish cultivated cereals probably derives from neighbouring countries, and most of the changes in genetic diversity can be assumed to coincide with historical events. For instance, during the Middle Ages, as well as during the early modern era, Finland was an integral part of the Swedish realm. During those periods Finland was colonized by new inhabitants, especially from Sweden (Haggrén 2018). It is plausible that the new settlers imported cereals from the realm. It is known that during the Swedish realm, as well as later on in the 19th century during the Russian realm, cereals were imported to Finland especially if the harvest failed (Vahtola 2003). Nevertheless, import of foreign cereals was crucial to Finnish landraces and especially the modernisation of agriculture together with the spread of commercial barley cultivars around Finland extinguished many of the Finnish landraces (e.g. Heinonen 2009).

1.3. The aims of the thesis

My aim in this thesis is to clarify the role and history of some economic plants that appear in Finnish archaeobotanical and historical materials. Archaeobotanical plant remains form the basic data for the research but I have combined it with information from ^{14}C radiocarbon dating and pollen analysis. Moreover, I have used novel analytical tools such as aDNA genotyping, which has not been used earlier in Finnish archaeobotanical studies. This data can be interpreted from a variety of perspectives and my research questions in this thesis centers on four themes: *cultivation*, *consumption*, *trade* and *migration*.

First, I wanted to find out which plants were part of the daily life, in the agriculture and in the economy in early medieval times in Finland by studying plant remains from a medieval village (article **I**). Second, my aim was by studying the plant material from graves to find out in which circumstances plants are preserved, and if it is possible to reveal indications of diet or ritual usage of plants (article **II**). Third, I was interested in the role of trade in the 1790s sea fortress of Ruotsinsalmi in Kotkansaari at Kotka, eastern Finland. My aims were to reconstruct the food consumption and to discuss the usage and origin of the plant remains found in the sea fortress (article **III**). Fourth, my purpose in article **IV** was to cast light on the origin of barley landraces in Finland. Moreover, the aim was to evaluate the suitability of barley grains from different archaeological and historical samples for aDNA studies.

Finally, the aim was to find out whether connections between late Iron Age and medieval (ca. AD 700−1500) barley populations and historical samples (1872−1921) of barley landraces can be assessed.

2. MATERIAL AND METHODS

2.1. Sampling

The plant material I have used for all studies (**I-IV**) is archaeological plant remains found in connection with archeological excavations as well as material from historical collections (**IV**). Material from archaeological excavations included 155 samples from the medieval rural site in Espoo at Mankby. Samples were collected systematically from the hearths, building contexts and field layers during an archaeological project within the years 2007–2013 by the archaeologists working at the site. From the cemetery located in Lappeenranta at Kauskila Kappelinmäki archaeologists collected 44 samples for macrofossil analysis from the graves for the study during the excavations conducted in 1999–2000. Macrofossil samples were taken systematically from the stomach area as well as under the head and legs of the deceased. For comparison, from the graves where the skeleton and other remains of the deceased had vanished, the samples were taken from the estimated burial layer. In Ruotsinsalmi at Kotkansaari sea fortress excavations were conducted in 2013 and five samples for the study were collected from the latrine by archaeologists. (**Fig. 2, Table 2**).

Historical accessions for aDNA study (**IV**) derived either from Turku University Herbarium (herbarium acronym TUR) in Turku, from botanical collections of the Finnish Natural History Museum, Luomus in Helsinki (herbarium acronym H), the Mustiala Agricultural Museum or from the Historiska Museet in Sweden (**Table 2**). The plant material used for DNA extractions from Turku and Helsinki has been documented in the collection management database KOTKA, see for example: http://mus.utu.fi/TFA.146792 and **Fig. 3.** Sampled material consisted of two-, four- and six-rowed barleys (**Fig. 4**). The historical accessions were sampled by myself, while Jenny Hagenblad and Matti Leino had sampled the material originating from the seed collections in the Mustiala Agricultural Museum, in the Nordiska Museet in Sweden, and in the Nordic Genetic Bank in Sweden. Altogether 27 charred archeological barley grains and 119 dried historical barley grains were obtained for genotyping and analysis of DNA quality (**Table 2**).

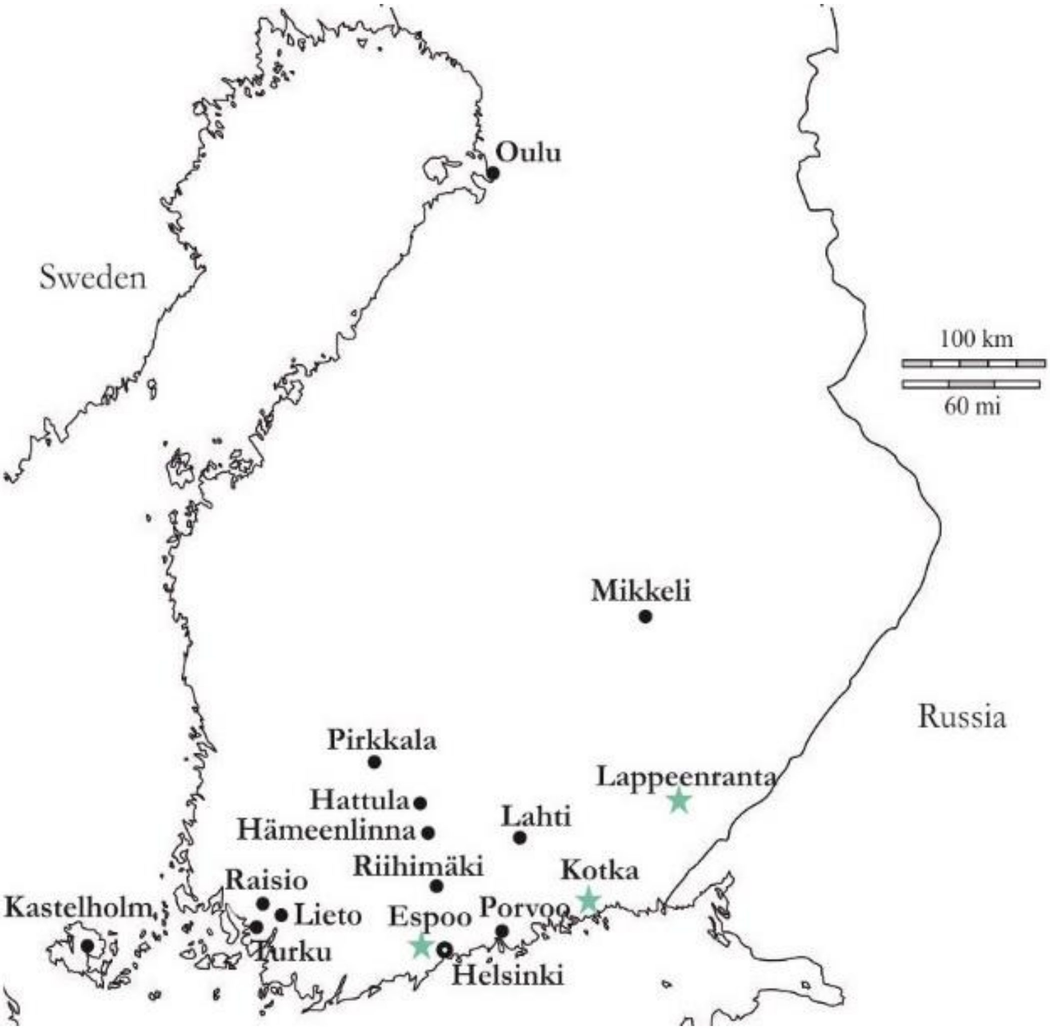

Figure 2. Archaeological sites mentioned in the text and in Table 2. Sites marked with a star refer to articles I–III.

Table 2. Data of the studied archaeological sites and historical accessions.

ARCHAEOBOTANICAL ANALYSIS	Chapter	No. of analysed samples	No. of identified plant remains	No. of identified plant taxa	State of preservation	Dating AD
Espoo, Mankby	I	155	7144	44	charred	1556 – 1100
Lappeenranta, Kauskila	II	44	5782*	9	mineralised	1600 – 1100
Kotka, Ruotsinsalmi	III	5	3036	77	waterlogged	1809 – 1791
Total		204	15962	130		
* including 5719 raspberry seeds from the stomach area						

DNA ANALYSIS	Chapter	No. of analysed seeds	State of preservation	Dating AD
Raisio, Mulli	IV	10	charred	1220 – 980
Espoo, Mankby		2	charred	1500
Pirkkala, Tursiannotko		8	charred	1000 – 800
Hattula, Retulansaari		7	charred	900 – 700
Herbarium, University of Turku, Finland		7	dried	1921 – 1872
Luomus, University of Helsinki, Finland		7	dried	1921 – 1872
Mustiala, Agricultural Museum, Finland		40	dried	1890s
Nordiska Museet, Swedish museum of cultural history		52	dried	1882
NordGen, Sweden		12	dried	.
Total		145		

Figure 3. Studied historical sample ML1 from the Herbarium (TUR) used in genetic analysis. Six-row barley from Karelia Ladogensis, Soanlahti, Valjakka, dates to 1902. Photo: Nelly Llerena Martinez.

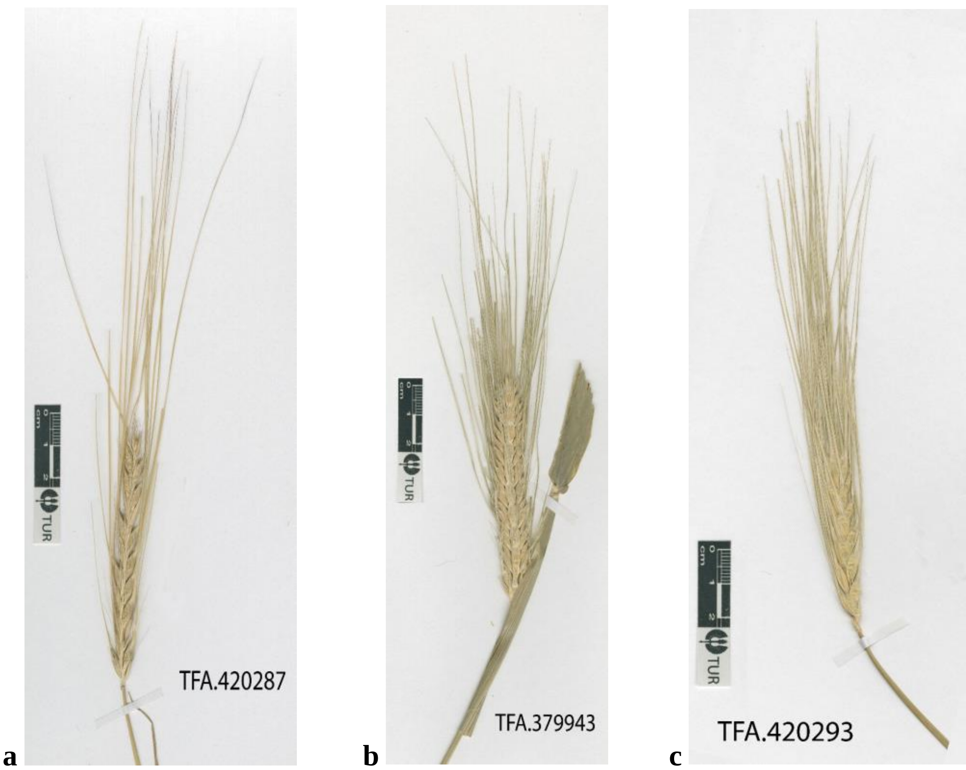

Figure 4. Studied historical samples used in genetic analysis consisted of two-rowed barley (a), four-rowed (b) and six-rowed (c). Photo: Nelly Llerena Martinez.

2.2. Laboratory work

All macrofossil samples were processed and analysed at the Herbarium (TUR). Prior to the extraction, samples were measured for their volume and some coarse evaluation of the sediment type, colour and other notes of the samples were made. The plant remains were then extracted from the soil samples by using manual water flotation (e.g. Pearsall 2000). Organic material was washed through a series of sieves with mesh sizes between 0.25–0.5–1–2 mm trapping the plant remains. After sieving, the charred material was left to dry, while uncharred material was stored wet in +4°C prior to the analysis.

The macrofossil plant material of each fraction was sorted and counted using an Olympus SZX7 binocular stereomicroscope with a magnification of 7.5x–112.5x. The contents of the 0.5–1–2 mm fractions were completely analysed, while 25% of the 0.25 mm fraction was examined. The plant remains were identified to species or genus level by using the modern seed reference collections at the Herbarium (TUR) and at the Niedersächsisches Institut für historische Küstenforschung (NIhK) in Wilhelmshaven, Germany. For identifications, literature such as Beijerinck (1947) and Cappers et al. (2006) was also used. Terttu Lempiäinen from the Herbarium has confirmed the identifications of grains in article **I** and Felix Bittmann (NIhK) has confirmed several taxa in articles **I** and **III**. The nomenclature of native taxa is based on Hämet-Ahti et al. (1998) and exotic taxa follows Cappers et al. (2006; 2009).

Besides identification, for each plant sample the mode of preservation and the level of identification was recorded. Moreover, for each record the exact location and nature of the site, chronology, the number of samples analysed and volume of the analysed samples were noted. All archaeological plant material in this study is part of the collections at the Herbarium (TUR).

In addition to macrofossils, other methods used in this thesis include ^{14}C radiocarbon dating, pollen and DNA analyses. Radiocarbon datings presented in articles **I** and **II** were performed at the Laboratory of Chronology at Luomus (H) and at Poznan Radiocarbon Laboratory in Poland. Pollen analysis presented in article **II** was conducted at the University of Helsinki by Teija Alenius, performed according to Berglund & Ralska-Jasiewiczowa (1986). DNA extractions presented in article **IV** for the archaeological samples were carried out at the University of Warwick, UK by Maria Lundström. Extractions were performed according to Palmer et al. (2009). DNA extractions from historical materials were conducted by Jenny Hagenblad and Matti W. Leino at Linköping University in Sweden following the protocol by Leino et al. (2009). The detailed description of the methodology used for pollen and DNA analyses is discussed in detail in articles **II** and **III**.

3. RESULTS AND DISCUSSION

3.1. Rye cultivation – an indication of local specialization to rye

Archaeobotanical analysis of the samples derived from the fossil fields and buildings of the medieval village of Mankby in Espoo revealed 7144 charred plant remains comprising of 44 different taxa (**I**). However, only two species of crops were found, of which rye was dominating the material. Altogether, 18 charred rye and barley grains were ^{14}C radiocarbon dated. Based on these datings, it seems that both crop species were cultivated from the 13th century onwards, and the cultivation continued until the clearance of the village in the 16th century. The results demonstrate that the early rye cultivation started soon after the Swedish colonisation of the area AD 1000. Further, the result is supported by pollen data from western Uusimaa, where human activity started to modify forest structure generating more open landscape between ca. AD 850 and 1150, with ca. 0.6% land cover were croplands. Moreover, the area for cropland increased rapidly, for instance between AD 1150 and 1550 total of 2.8 % of the land area was used for cultivation (Alenius et al. 2014; 2017). In contrast to barley and rye finds, I did not find any remains of oat (*Avena* sp.) and wheat (*Triticum* sp.), therefore it seems that these species were not cultivated at Mankby. As greatest concentrations of the cereal remains came from the cellar, this may show evidence of storing crops, which may indicate surplus from the harvest. This surplus could have been one reason that the archaeological finds from the village reflect international trade.

Besides agriculture, one important element in the economy of Mankby seems to have been trading. Traces of trade can be seen from the archaeological find material, which has parallels with the material culture of Baltic or Hanseatic towns as e.g. Rhenish stoneware and Bohemian glass beakers were found from the village. However, this internationality is not visible in archaeobotanical material, as I did not find any imported plants like figs and grapes for instance, from the material. Hence, it is always possible that cereals were imported to Manbky to some extent, but this is not traceable in the material. However, based on the cereal finds from the fossil fields it seems that economy at Mankby strongly relied on local cultivation of rye and barley. However, rye was the major crop until the abandonment of the village in 1556. Additionally, the study strengthens the idea that the medieval cultivation of rye was increasing, but it was concentrated in some villages in southern Finland. Some of the sites where rye is predominant are located in the coastal areas of Finland, while those where barley dominates are located mainly in inland or eastern Finland. Reasons for the increasing need for rye may have been consumption habits of the Swedish settlers, or that the peasants were ordered by the Swedish crown to cultivate rye (Österberg 1977; Vilkuna 1998).

3.2. Evidence of consumption and plant usage from graves

In article **II**, a total of 158 graves were analysed for macrofossil content and one grave for pollen content. The time span of the analysed graves was from AD 1200−1800. Preserved plant material was generally very scarce in the studied graves and could rarely be connected to burial rituals or diet. Interestingly, of the analysed graves, only two graves showed archaeobotanical results which can reliably be connected to burial customs or diet. For instance, at the Kappelinmäki cemetery in Kauskila Lappeenranta a sample taken from the stomach and pelvis area of the deceased, revealed 5782 plant remains from 10 different taxa and pollen analysis 18 taxa. Most of the plant remains consisted of mineralised raspberry (*Rubus idaeus* L.) seeds together with few fish bones. Raspberry seeds were ^{14}C dated to the 16^{th} century. Archaeobotanical analysis from the grave gave direct evidence of diet as well as exploitation of local wild food resources. It is evident that the 35-year old male who was buried in the cemetery had eaten raspberries and small fish as the last meal before his death. However, the result is most probably biased as other plant remains indicating meals may have disappeared. Further, the results from pollen analysis of the same grave gave evidence of 18 plant taxa, including Rosaceae which could originate from the raspberries eaten, but the other taxa revealed in pollen analysis most likely reflect the surrounding environment rather than diet. Besides reflecting the local environment, the pollen results may also indicate funeral practices or ritual usage of plants.

Another result was derived from Porvoo Cathedral from a grave dated to the 17th to 18th centuries, belonging to a 6-month-old baby, presumably wrapped in a shroud judging from the silver needles and bronze spirals found from the grave. The skeleton of the baby was well preserved and the archaeobotanical sample was taken under the head (Lagerstedt 2007). I found pieces of human skull with skin, hair and attached leaves and stems of sphagnum moss (*Sphagnum* sp.) in the sample, and it is presumable that the moss remains originate from a pillow or mattress on which the baby was placed. These organic remains had a blue-green colour as they had been stained by metals. It is evident that the preservation of moss was due to metal oxides from the needles and spirals. Based on these studies, it seems that the best preservations of plant remains can be derived from graves with metal artefacts where the metal oxides have preserved the plant remains, or from graves with enormous amounts of bones where the high proportion of calcium dissolved in the soil from the bones have mineralised the plant remains. It can also be concluded, that it is very fruitful to combine macrofossil and pollen analysis in order to reveal evidence of consumption and plant usage in graves.

3.3. Traded foodstuffs from Russia

The well preserved waterlogged human faeces from the latrine in Ruotsinsalmi sea fortress, revealed 3036 plant remains and 77 taxa. The results indicate the soldiers' diet and the origins of their food (**III**). The analysed samples consisted of seeds and achenes, as well as fish bones and scales. The results show that the diet was mainly based on buckwheat (*Fagopyrum esculentum* L.) and millet (*Panicum miliaceum* L.). Despite the small appearance of cereals, which I found in the samples, they must have played an important role in the diet as well. Millet and sage (*Salvia* sp.) were published now for the first time in the Finnish archaeobotanical data.

Based on the archaeobotanical material it can be hypothesized that the diet, in general, was mainly influenced by Russian food traditions but berries and some cultivated crops most probably had a local origin, coming from the forests and fields of the Kotka area. These berries and crops were presumably bought from local peasants and merchants. Buckwheat could have been grown locally as well, as it has been cultivated mostly in slash-and-burn areas in eastern Finland. It is known from the historical sources, that Russian merchants Fjodor Larkin, Jakov and Gavril Vavulin delivered several foods to the sea fortress. Their merchandise consisted mainly of Russian products, but also imported spices, stimulants and other luxuries (Kauppi 1993). Based on the archaeobotanical data, my conclusion is that Russian merchants traded at least millet, blackberries, spices and figs to the sea fortress, as they do not grow in Finland. In addition, some cereals, buckwheat and sour cherries could have been traded to some extent, as it is known from historical sources that these items were traded. The strong Russian influence in the archaeobotanical data can be explained by the fact that the inhabitants at the Ruotsinsalmi sea fortress were mostly Russian soldiers who moved there with their families, so the sea fortress obtained plenty of food traditions from Russia (Harjunpää 1978).

3.4. Migration of barley landraces in Finland

The poor preservation of DNA in the analysed charred archaeological material in article **IV** led to difficulties in obtaining indigenous DNA from the grains. Therefore, the DNA concentrations obtained from the charred barley remains were too low for successful KASP genotyping and also all SNPs failed. DNA concentrations being too low, it was not possible to explore connections between Late Iron Age and Medieval barley populations as we had aimed to do. However, our result confirms the earlier reported difficulties in obtaining aDNA from charred grains noted e.g. by Nistelberger et al. (2016). It seems that the rapid decomposition of most plant materials means unsuccessful aDNA analysis. Therefore, the availability of suitable ancient materials and the success rate of ancient DNA analysis makes future studies for Finnish economic plants very challenging. Further, instead of using charred plant material, for successful genotyping it is recommended to use archaeological plant material preserved in waterlogged or preferably desiccated conditions, combined with the most sensitive analysing methods (Lundström et al. 2018).

Although the archaeological material did not yield genotyping data, the results from genotyping dried barley grain from historical collections were more successful. Firstly, the results confirmed the previously shown strong genetic differentiation between the two-row and six-row barleys (Malysheva-Otto, Ganal & Röder 2006; Kolodinska Brantestam et al. 2007; Malysheva-Otto et al. 2007; Yahiaoui et al. 2008; Leino & Hagenblad 2010; Aslan et al. 2015). Secondly, six-row barley accessions from northern and southern Finland tended to cluster apart, and the reason for this is most likely due to its adaptation to climate over its long cultivation history in Finland. Thirdly, in contrast to six-row barley, two-row barley does not seem to have geographical structuring as it is more recent and a rarely cultivated crop in Finland. However, the geographical area sampled for two-rowed barley was much smaller compared to six-row barley. Fourthly, the result we got by genotyping of functional markers showed that the majority of barley cultivated in Finland in the late 19th and early 20th century was a late-flowering type, and this result supports previous observations from northern European barley (Jones et al. 2008; Lister et al. 2009; Aslan et al. 2015). Finally, our study also supports previous studies where KASP has been noted to be a cost-effective method for genetic analyses of ancient DNA (Lister et al. 2013, Hagenblad et al. 2017). Alternative methods for aDNA include Next Generation Sequencing, and compared to this the laboratory work in KASP is fairly straightforward, and the data analysis does not require bioinformatics expertise or massive computational power (Lundström et al. 2018).

4. CONCLUSIONS

In the presented thesis, I have synthesized and interpreted the disparate archaeobotanical and historical data from Finland spanning ca. 1000 to 1900 AD to contribute to our understanding of economic plant usage. The studies describe four different perspectives from which archaeobotanical data can be approached: *cultivation* history, *consumption* and usage of plants as stable food, plants indicating *trade* and *migration* of cultivated plants. Looking at things on a large time scale is the defining, but also challenging feature of this work. Many interesting phenomena, like the selection and variety of economic plants, only emerge when they are viewed long term and from large-scale data. Comparing these data, general trends as well as introductions of non-indigenous species can be traced in Finnish prehistory and the Pre-Modern Period. The current archaeobotanical dataset from different archaeological sites and historical material gives numerous details on the evolution of plant use at various periods from prehistory to historical times.

The long history of rye cultivation in Mankby strengthens the idea that the rye cultivation was increasing in medieval times, and it was concentrated in some villages in southern Finland, while barley was still important in most other parts of the country. The origin of this new cultivation tradition remains unclear, but the material culture from Mankby indicates close trading contacts to Sweden and Estonia, and therefore it is plausible that the network overseas influenced the selection of cultivated crops. As has been noted earlier, it seems that intensive rye cultivation started in Sweden and Estonia earlier than in Finland, and therefore either of these countries could have influenced the selection of cultivated species in coastal areas in Finland.

My results indicate that preserved plant material can be associated only with graves of good preservation of bones and where metal artefacts have been provisioned. A possible reason for the good preservation of archaeobotanical plant remains is that calcium dissolved from the bones had mineralised the plant remains, while metal oxides derived from the metal artefacts in the grave had preserved the plant remains. This observation is supported by other studies from graves, where, for instance, plant fibres have been preserved in connection with bronze brooches (Lukešová 2017). The combination of macrofossil and pollen analysis is proved to be very fruitful when studying graves, and any kinds of archaeological contexts (Kihno & Hiie 2008; Vermeeren & van Haaster 2002; Corbineau et al. 2018). Therefore, it is not surprising that the results from my study also showed increasing number of taxa when combining macrofossil and pollen analysis.

The results at the sea fortress of Ruotsinsalmi in Kotka indicate strong connections to Russia, which is understandable, as the inhabitants of the fortress were mostly Russian soldiers who moved there with their families, so the sea fortress acquired plenty of influences from Russia (Harjunpää 1978). It is also known from historical sources, that merchants brought Russian products as well as fruits and spices of Mediterranean origin to the fortress (Kauppi 1993).

The number of plant taxa identified from latrines is typically very high (see e.g. Wiethold; Hald et al. 2018; unpublished data by Lempiäinen-Avci et al. 2018) and even though I identified 77 different plant taxa, the amount of plant taxa from Ruotsinsalmi could have been even higher with the combined analysis with pollen. As Hald et al. (2018) have noted, pollen is important in the reconstruction of past diet as they can reveal plants that otherwise are invisible, for instance leafy taxa that are eaten before seed-setting or spices that were grounded for powders.

The majority of barley cultivated in Finland in the late 19th century and early 20th century was a late-flowering type. Moreover, Finnish six-row barley showed strong geographic clustering likely due to climate adaption over long time. In contrast, Finnish two-rowed barley does not seem to be linked to the geography. The result of low DNA for utilizing the samples in aDNA studies is similar with previously reported difficulties in obtaining aDNA from charred material. Therefore, it is plausible that earlier reports of endogenous DNA from material obtained in Europe are false (Nistelberger et al. 2016). Charred material derived from archaeological contexts seem to be impossible to use in aDNA studies, which makes future studies for Finnish economic plants very challenging. However, waterlogged materials could be an alternative for aDNA studies, if the most sensitive analysing methods are used (Lundström et al. 2018).

To conclude, studies in articles **I-IV** support the view that the selection of used plant taxa got more versatile from the Iron Age to medieval times, however, from medieval to 1790s the number of used plant taxa did not grow remarkably as the archaeobotanical data seems to be rather similar in 1790s as in the Middle Ages. In the Iron Age and the medieval period, barley was the most common cultivated plant, however, local differences may occur. From the medieval onwards, the number of used plants grew due to the intensification of trading networks overseas. As six-rowed barley has a long cultivation history in Finland as a main crop, it has adapted to the climate and different landrace populations of it have clustered to different geographical areas. Migration of barley could be studied in more detail with a wider sample material. Now, the eastern influence of barley migration could not be studied, due to the small sample material.

ACKNOWLEDGEMENTS

I have a passion for seeds - those little and beautiful things - which under a microscope can lead me to very different, unbelievable and fascinating stories. One story tells me about medieval life a thousand years ago, another story can be about a burial of a male and his last meal five hundred years ago, while smelly poo is telling me a story about soldiers' diet three hundred years ago.

This passion for seeds is also the reason, why I wanted to carry out a PhD project. There were so many stories I wanted to explore! Nevertheless, this project would not have been possible without archaeologists who gave me samples to analyse, thank you all lovely archaeologists around Finland. I want to thank Georg Haggrén, who has always been supportive to me and you, Georg, have encouraged me to take challenges. I have been very happy to work with you and the wonderful team in the Mankby and Raasepori -projects.

Nor would this been possible without excellent support I always got from the Department of Biology, especially from my supervisor Timo Vuorisalo. When I first arrived at the department, I had a meeting with Timo, and when I came out from his office, I had three clear and well-structured manuscripts in my hand! I thought, wow, I am going to make this!

I am lucky to have three other supervisors as well. Sanna Huttunen never says no to my ideas, but she tells me what is realistic and what I should prioritize. Sanna, you have given me so much of your time, that I even do not have words to say how much I appreciate that. Your door is always open when I need some advice or I want to tell about my ideas, and you are always ready to listen. When I enter your office, you just remove your moss samples from a chair and ask me to sit down. It does not matter how busy you actually are, you always have the time to listen and solve the problem or find information about the issue I am wondering. I am very thankful to you about all the academic support, as well as for your friendship.

My supervisor Felix Bittmann has given me excellent teaching in identifying macrofossils, and his advice has been very valuable. Thank you Felix, for your positive attitude, for spending hours with me by the microscope in Germany, exploring the seeds collection,

trying to find precise identifications for my material and, most importantly, discussing with me what my results actually mean. I always feel very welcome in the institute, thanks to you Felix and others in the institute!

One day I got an idea of doing some aDNA analyses from grains. That project was totally out of the limits of my comfort zone, as I do not know anything about genetics. I am very thankful that I met Jenny Hagenblad and her team in a seminar in Stockholm. During that seminar, she promised to get involved into my project and later on, she became my supervisor. I want to thank you Jenny for your advices and patience, somehow you always managed to make time for me and support me. You were also asking not only how my research is doing, but also how I am doing. This caring and warm support was very important to me, thank you!

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REFERENCES

Alenius T, Haggrén G, Oinonen M, Ojala A, Pitkänen R-L (2014) The history of settlement on the coastal mainland in Southern Finland. Palaeoecological, archaeological, and etymological evidence from Lohjansaari Island, Western Uusimaa, Finland. *Journal of Archaeological Science* 47: 99–112.

Alenius T, Haggrén G, Koivisto S, Sugita S, Vanhanen S (2017) Landscape dynamics in southern Finland during the Iron Age and the Middle Ages using pollen based Landscape Reconstruction (LRA) and macrofossil data. *Journal of Archaeological Science: Reports* 12: 12–24.

Aslan S, Forsberg N E G, Hagenblad J, Leino M W (2015) Molecular Genotyping of Historical Barley Landraces Reveals Novel Candidate Regions for Local Adaption. *Crop Science* 55: 66.

Asplund H (2008) *Kymittæ. Sites, Centrality and Long-term Settlement Change in the Kemiönsaari Region in SW Finland*. Annales Universitatis Turkuensis. Ser. B osa. Tom. 312. Humaniora. Painosalama Oy, Turku.

Beijerinck W (1947) *Zadenatlas der Nederlandsche Flora*. H.Veenman & Zonen, Wageningen.

Berglund B E, Ralska-Jasiewiczowa M (1986) Pollen analysis and pollen diagrams. In: Berglund B E (ed) *Handbook of Holocene Palaeoecology and Palaeohydrology*. Wiley, Chichester. pp. 455–485.

Birks J H B (2014) Challenges in the presentation and analysis of plant-macrofossil stratigraphical data. *Vegetation History and Archaeobotany* 23: 309–330.

Bridson D, Forman L (1998) *The Herbarium Handbook*. 3rd ed. Royal Botanic Gardens Kew, Whitstable Litho Printers Ltd, UK.

Cappers R T J (1993/1994) Botanical macro-remains of vascular plants of the Heveskesklooster Terp (The Netherlands) as tools to characterize the past environment. *Palaeohistoria* 35/36: 107–167

Cappers R T J, Bekker R M, Jans J E A (2006) *Digital seed atlas of the Netherlands* (book and website: www.plantenatlas.eu). Barkhuis, Groningen.

Cappers R T J, Neef R, Jans J E A (2009) *Digital atlas of economic plants* (book and website: www.plantenatlas.eu). Groningen Archaeological Studies 3. Barkhuis & Groningen University Library, Groningen.

Corbineau R, Ruas M-P, Barbier-Pain D, Fornaciari G, Dupont H, Colleter R (2018) Plants and aromatics for embalming in Late Middle Ages and modern period: a synthesis of written sources and archaeobotanical data (France, Italy). *Vegetation History and Archaeobotany* 27: 151–164.

Forsberg N E G, Russell J, Macaulay M, Leino M W, Hagenblad J (2015) Farmers Without Borders – Genetic Structuring in Century Old Barley (*Hordeum vulgare*). *Heredity* 114 (2): 195–206.

Grabowski R (2011) Changes in cereal cultivation during the Iron Age in southern Sweden: a compilation and interpretation of the archaeobotanical material. *Vegetation History and Archaeobotany* 20: 479−494.

Haggrén G, Halinen P, Lavento M, Raninen S, Wessman A (2015) Muinaisuutemme jäljet. Suomen esi- ja varhaishistoria kivikaudelta keskiajalle. Gaudeamus.

Haggrén G (2018) Six Estate Landscapes. Traces of Medieval Feudalisation in Finland? In: Kouki P, Kirkinen T (eds) *Landscapes of the Past and Future. Current Finnish Research in Landscape Archaeology*. Monographs of the Archaeological Society of Finland 6.

Hagenblad J, Morales J, Leino M W, Rodríguez-Rodríguez A C (2017) Farmer Fidelity in the Canary Islands Revealed by Ancient DNA from Prehistoric Seeds. *Journal of Archaeological Science* 78: 78–87.

Hald M M, Mosekilde J, Magnussen B, Søe M J, Hansen C H, Mortensen M F (2018) Tales from the barrels: Results from a multi-proxy analysis of a latrine from Renaissance Copenhagen, Denmark. *Journal of Archaeological Science: Reports* 20: 602–610.

Harjula J, Hukantaival S, Immonen V, Ratilainen T, Salonen K (2018). *Koroinen. Suomen ensimmäinen kirkollinen keskus*. Turun Historiallinen Arkisto 71. THY, Keuruu.

Harjunpää K (1978) Ruotsinsalmen linnoitusyhdyskunta ja sen elämä. In: Airola O, Harjunpää K (eds) *Ruotsinsalmen merilinnoitus 1790−1855*. Kymenlaakson museon julkaisuja, Myllykosken Kirjapaino Oy. pp 85−117.

Hastorf C A, Popper V S (1988) *Current paleoethnobotany. Analytical Methods and Cultural interpretations of Archaeological Remains*. The University of Chicago Press, Chicago and London.

Hastorf C A (1988) The Use of Paleoethnobotanical Data in Prehistoric Studies of Crop Production, Prosessing, and Consumption. In: Hastorf C A, Popper V S (eds) *Current paleoethnobotany. Analytical Methods and Cultural interpretations of Archaeological Remains*. The University of Chicago Press, Chicago and London.

Heikel A O (1889) Tuukkalan löytö. *Suomen Muinaismuistoyhdistyksen Aikakauskirja* 10. pp 179–224.

Heinonen M (2009) *Maatiaiskasvien ylläpitoviljely Suomessa*. Maatalouden Tutkimuskeskus. Jokioinen, Viestintä- ja informaatiopalvelut.

Holmblad P (2010) Coastal communities on the move. House and polity interaction in southern Ostrobothnia 1500 BC–AD 1. *Archaeology and Environment* 26.

Häkkinen K, Lempiäinen T (1996) Die ältesten Getreidepflanzen der Finnen und ihre Namen. *Finnish-Ugrische Forschungen* 53. pp 115–182.

Hämet-Ahti L, Suominen J, Ulvinen T, Uotila P (1998) *Retkeilykasvio*. Täysin uudistettu painos. Luonnontieteellinen keskusmuseo, Kasvimuseo, Helsinki.

Jacomet S, Kreuz A (1999) *Archäobotanik*. Ulmer, Stuttgart.

Jones H, Leigh F J, Mackay I, Bower M A, Smith L M, Charles M P, Jones G, Jones M K, Brown T A, Powell W (2008) Population-based Resequencing Reveals that the Flowering Time Adaptation of Cultivated Barley Originated East of the Fertile Crescent. *Molecular Biology and Evolution* 25: 2211–2219.

Kauppi U-R (1993) Kymenlaakson linnoitustyöt taloudellisena vaikuttajana 1700–1800 lukujen taitteessa. − Kasarmin aidan kahden puolen. In: Lappalainen J T (ed) *Kaksisataa vuotta suomalaista varuskuntayhteisöä*. Historiallinen Arkisto 101. SHS, Helsinki. pp 49−70.

Karg S (2007) The HANSA Network Project. In: Karg S (ed) *Medieval Food Traditions in Northern Europe*. Publications from the National Museum Studies in Archaeology & History, 12. Copenhagen. pp 9–12.

Kihno K, Hiie S (2008) Evidence of pollen and plant macroremains from the sediments of suburban area of medieval Tartu. *Estonian Journal of Archaeology* 12: 1.

Kolodinska Brantestam, A, von Bothmer R, Dayteg C, Rashal I, Tuvesson S, Weibull J (2007) Genetic Diversity Changes and Relationships in Spring Barley (*Hordeum vulgare* L.) Germplasm of Nordic and Baltic Areas as Shown by SSR Markers. *Genetic Resources and Crop Evolution* 54: 749–758.

Kuujo E (1981) Turun kaupungin historia 1366−1521. Turun Sanomat, Turku.

Lagerstedt J (2007) Porvoon tuomiokirkon kirkkomaa. Arkeologinen kaivaus. Kaivauskertomus. Museoviraston arkisto. Unpublished research report. National Board of Antiquities, Helsinki.

Leino M W, Hagenblad J, Edqvist J, Strese E M K (2009) DNA Preservation and Utility of a Historic Seed Collection. *Seed Science Research* 19: 125–135

Leino M W, Hagenblad J (2010) Nineteenth Century Seeds Reveal the Population Genetics of Landrace Barley (*Hordeum vulgare*). *Molecular Biology and Evolution* 27 (4): 964–973.

Leino M W (2010) Frösamlingar på museer – ny teknik gör värdelösa föremål värdefulla igen. *Nordisk Museologi* 2010: 96–108.

Lempiäinen-Avci M (2013a) *Lahden kylä. Kasvijäännetutkimus*. Tutkimusraportti. Turun yliopisto, biologian laitos, kasvimuseo. Research report. 28 p.

Lempiäinen-Avci M (2013b) *Turku, Itälaituri. Kaupunkiarkeologisten kaivausten makrofossiilitutkimukset*. Tutkimusraportti. Turun yliopisto, biologian laitos, kasvimuseo. Research report. 22 p.

Lempiäinen-Avci M (2013c) *Helsinki, Presidentinlinna – Mariankatu 2 makrofossiilitutkimukset*. Tutkimusraportti. Turun yliopisto, biologian laitos, kasvimuseo. Research report. 24 p.

Lempiäinen-Avci M (2015) *Oulu, Lyseon lukion tontti. Kasvijäänneanalyysi*. Tutkimusraportti. Turun yliopisto, biologian laitos, kasvimuseo. Research report. 29 p.

Lempiäinen-Avci M (2016) Sinebrychoffien empiresohva kätkee sisälleen merkittävää kasvihistoriaa. *Verhoilija* 1/2016.

Lempiäinen-Avci M, Elo R, Alenius R, Bläuer A, Huttunen S, Saloranta E, Ratilainen R (2018) *Ecofacts from medieval latrine and yard – an interdisciplinary study of the environmental circumstances at town of Turku in Finland*. Unpublished manuscript.

Lempiäinen T (1989) *Turun muinaisen Mätäjärven kasvijäänteet*. In: Kostet J, Pihlman A (eds) Turun Mätäjärvi. Turun Maakuntamuseo: Raportteja 10. pp 193–214.

Lempiäinen T, Vuorela I (1994) Vanhankaupungin maaperäarkiston paleoekologiset tutkimukset. *Narinkka: Helsinki 1550–1640*. Helsingin kaupunginmuseo, Gummerus Kirjapaino Oy, Jyväskylä.

Lempiäinen T (1995) Macrofossil Finds from the Medieval Turku, SW Finland. In: Kroll H, Pasternak R (eds) *Res archaeobotanicae*. 9th Symposium IWGP Kiel.

Lempiäinen T (1996) Liedon Rähälän keskiaikainen viljavarasto – lisää tietoa Aurajokilaakson viljanviljelystä. *Kentältä poimittua* 3. pp 110–119.

Lempiäinen T (2002) Plant macrofossils from graves and churches. In: Viklund K, Engelmark R, Griffin K, Lempiäinen T, Robinson D E (eds) *NAG 2000 in Umeå*. Archaeology and Environment 15: 144–161.

Lempiäinen T (2003) Kasviarkeologiaa Aurajoen rannoilla. In: Seppänen L (ed) *Kaupunkia pintaa syvemmältä. Arkeologisia näkökulmia Turun historiaan.* Archaeologia Medii Aevi Finlandiae IX: 323–340.

Lempiäinen T (2005) Ruis rautakauden Suomessa ja Katariinan Kirkkomäen ruisolkipunos. In: Immonen V, Haimila M (eds) *Mustaa valkoisella. Ystäväkirja Kristiina Korkeakoski-Väisäselle*. Dark Oy, Vantaa. pp 110–118.

Lempiäinen T (2007) Archaeobotanical evidence of plants from the medieval period to early modern times in Finland. In: Karg S (ed) *Medieval Food Traditions in Northern Europe*. Publications from the National Museum Studies in Archaeology & History, 12. Copenhagen. pp 97–118.

Lempiäinen T (2010) The weeds of the ancient cereal fields in the macrofossil materials (abstract). In: Hirvilammi J (ed) *Varhainen viljely Suomessa*. Suomen maatalousmuseo Sarka, Kopijyvä, Jyväskylä. pp 4–19.

Lister D L, Thaw S, Bower M A, Jones H, Charles M P, Jones G, Smith L M J, Howe C J, Brown T A, Jones M K (2009) Latitudinal Variation in a Photoperiod Response Gene in European Barley: Insight into the Dynamics of Agricultural Spread from 'Historic' Specimens. *Journal of Archaeological Science* 36 (4): 1092–1098.

Lister D L, Jones H, Jones M K, O'Sullivan D M, Cockram J (2013) Analysis of DNA Polymorphism in Ancient Barley Herbarium Material: Validation of the KASP SNP Genotyping Platform. *Taxon* 62 (4): 779–789.

Livarda A (2011) Spicing up life in northwestern Europe: exotic food plant imports in the Roman and medieval world. *Vegetation History and Archaeobotany* 20: 143–164.

Livarda A (2014) Archaeobotany in Greece. *Archaeological Reports* 60: 106–116.

Lukešová H, Palau A S, Holst B (2017) Identifying plant fibre textiles from Norwegian Merovingian Period and Viking Age graves: The Late Iron Age Collection of the University Museum of Bergen. *Journal of Archaeological Science: Reports* 13: 281–285.

Lundström M, Forsberg N E G, Heimdahl J, Hagenblad J, Leino M W (2018) Genetic analyses of Scandinavian desiccated, charred and waterlogged remains of barley (*Hordeum vulgare* L.).

Malysheva-Otto L V, Ganal M V, Röder M S (2006) Analysis of Molecular Diversity, Population Structure and Linkage Disequilibrium in a Worldwide Survey of Cultivated Barley Germplasm (*Hordeum vulgare* L.). *BMC Genetics* 7: 6.

Malysheva-Otto L V, Ganal M V, Law J R, Reeves J C, Röder M S (2007) Temporal Trends of Genetic Diversity in European Barley Cultivars (*Hordeum vulgare* L.). *Molecular Breeding* 20 (4): 309–322.

McClatchie M, McCormick F, Kerr T R, O´Sullivan A (2015) Early medieval farming and food production: a review of the archaeobotanical evidence from archaeological excavations in Ireland. *Vegetation History and Archaeobotany* 24: 179–186.

Matiskainen H (2002) *Riihimäen esihistoria*. Riihimäen kaupunginmuseo, Karisto Oy, Hämeenlinna.

Matiskainen H, Ruohonen J (2004) *Esihistorian pauloissa*. Riihimäen kaupunginmuseo, Karisto Oy, Hämeenlinna.

Nistelberger H M, Smith O, Wales N, Star B, Boessenkool S (2016) The Efficacy of High-throughput Sequencing and Target Enrichment on Charred Archaeobotanical Remains. *Scientific Reports* 6: 146.

Nurmenniemi E (1999) *Turun Vanhan Suurtorin keskiaikainen kasvillisuus*. Pro gradu -tutkielma. Biologian laitos, Turun yliopisto. Unpublished master’s thesis.

Onnela J, Lempiäinen T, Luoto J (1996) Viking Age Cereal cultivation in SE Finland – a study of charred grain from Pahamäki in Pahka, Lieto. *Annales Botanici Fennici* 33: 237–255.

Onnela J (2003) Häme Castle as a Subject of Research. In: Mikkola T, Vilkuna A-M (eds.) *At Home Within Stone Walls: Life in the Late Medieval Häme Castle.* Archaeologia Medii Aevi Finlandiae F VIII. pp 151–164.

Onnela J (2004) *Vanhakantaisia viljelykasveja Etelä-Suomessa. Kasvijäännetutkimuksia ja kokeellista arkeobotaniikkaa*. Lisensiaatintutkimus. Turun yliopisto, Biologian laitos, Systemaattis-ekologinen kasvitiede. Unpublished lisensiate thesis.

Palmer S A, Moore J D, Clapham A J, Rose P, Allaby R G (2009) Archaeogenetic Evidence of Ancient Nubian Barley Evolution from Six to Two-Row Indicates Local Adaptation. *PLoS ONE* 4 (7): e6301.

Pearsall D M (2000) *Paleoethnobotany. A handbook of procedures*. 6th edn. Academic Press, San Diego.

Pihlman S, Seppä-Heikka M (1985) Indication of Late neolithic Cereal Cultivation at the Kotirinne Dwelling Site at Niuskala, Turku, SW Finland.

Memoranda Societatis pro Fauna et Flora Fennica 61: 85–88.

Renfrew J M (1973) *Palaeoethnobotany. The prehistoric food plants of the Near East and Europe*. Methuen & Co Ltd, London.

Renfrew C, Bahn P (1994) *Archaeology. Theories, Methods and Practice*. Thames and Hudson Ltd, London.

Salick J, Konchar K, Nesbitt M (2014) *Curating Biocultural Collections. A Handbook*. Royal Botanic Gardens, Kew, United Kingdom.

Savunen N (2017) *Ruista ja ohramallasta Kastelholman linnalla. Keskiaikaisen vilja-aineiston arkeobotaaninen tutkimus*. Pro gradu –tutkielma. Helsingin yliopisto, Filosofian, historian, kulttuurin ja taiteiden tutkimuksen laitos, Arkeologian oppiaine. Unpublished master's thesis.

Soltvedt E-C, Henningsmoen K E (2016) Agricultural and household activities in Vestfold, Southeast Norway, as illustrated by pollen data and the charred remains of crops and wild plants. *Environmental Archaeology* 21: 11–30.

Suominen J, Hämet-Ahti L (1993) *Kasvistomme muinaistulokkaat: tulkintaa ja perusteluja*. Kasvimuseo, Luonnontieteellinen keskusmuseo, Vammalan kirjapaino, Vammala.

Tolar T, Jacomet S, Velušečk A, Čufar K (2010) Recovery techniques for waterlogged archaeological sediments: a comparison of different treatment methods for samples from Neolithic lake shore settlements. *Vegetation History and Archaeobotany* 19: 53–67.

Tvauri A, Vanhanen S (2016) The find of pre-viking age charred grains from fort-settlement in Tartu. *Estonian Journal of Archaeology* 20(1): 33.

Vahtola J (2003) *Suomen historia. Jääkaudesta Euroopan unioniin*. Otavan Kirjapaino Oy, Keuruu.

Vanhanen S (2012) Archaeobotanical study of a Late Iron Age agricultural complex at Orijärvi, Eastern Finland. *Fennoscandia Archaeologica* XXIX. pp 55–72.

Vanhanen S, Koivisto S (2015) Pre-Roman Iron Age settlement continuity and cereal cultivation in coastal Finland as shown by multiproxy evidence at Bäljars 2 site in SW Finland. *Journal of Archaeological Science: Reports* 1: 38–52.

Viklund K (1998) Cereals, weeds and crop processing in Iron Age Sweden: methodological and interpretive aspects of archaeobotanical evidence. *Archaeology and Environment* 14.

Vilkuna A-M (1998) *Kruunun taloudenpito Hämeen linnassa 1500-luvun puolivälissä*. Bibliotheca Historica 31. SHS, Helsinki.

Vermeeren C, van Haaster H (2002) The embalming of the ancestors of the Dutch royal family. *Vegetation History and Archaeobotany* 11: 121–126.

Veen van der M (2003) Luxury foods. *World Archaeology*, 34(3). pp 405–427.

Veen van der M (2018) Archaeobotany: the archaeology of human-plant interactions. In: Scheidel W (ed) *The Science of Roman History. Biology, Climate, and the Future of the Past*. Princeton NJ, Princeton University Press. pp 53–95.

Vuorela I, Lempiäinen T (1988) Archaeobotany of the Site of the Oldest Cereal Grain Find in Finland. *Annales Botanici Fennici* 25: 33–45.

Vuorela I (1999) The beginnings of agricultural land use in Finland: An assessment based on palynological data. In: Miller U, Hackens T, Lang V, Raukas A, Hicks S (eds) *Environmental and cultural history of the Eastern Baltic region*. PACT 57. Conseil de L'Europe, Rixensart. pp 339–351.

Wiethold J (1995) Plant remains from town-moats and cesspits of Medieval and post-Medieval Kiel (Schleswig-Holstein, Germany). *Res Archaeobotanicae – 9th Symposium IWGP*. Kroll H, Pasternak R (eds) Oetker-Voges-Verlag, Kiel. pp 359–384.

Yahiaoui S, Igartua E, Moralejo M, Ramsay L, Molina-Cano J L, Ciudad F J, Lasa J M, Gracia M P, Casas A M (2008) Patterns of Genetic and Eco-Geographical Diversity in Spanish Barleys. *Theoretical and Applied Genetics* 116 (2): 271–282.

Zohary D, Hopf M, Weiss E (2012) *Domestication of Plants in the Old World*. 4th ed. Oxford University Press, UK.

Österberg E (1977) *Kolonisation och kriser. Bebyggelse, skattetryck, odling och agrarstruktur i västra Värmland ca 1300–1600.* Bibliotheca Historica Lundensia.

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