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Archaeobotany in Estonia – history, state of the art and future perspectives

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ABSTRACT
Archaeobotany is currently an underutilised discipline in Estonian archaeological research. This paper sheds light on the current state of archaeobotanical research in Estonia by analysing the spatial and temporal distribution of archaeobotanical sampling across three time periods: until 1980, 1981–1999, and 2000–2024. We outline the usages of archaeobotany and the benefits that the analysis of plant remains can offer in acquiring a deeper understanding of archaeological questions. While archaeobotanical sampling is a common practice in many countries, the discipline is struggling in Estonia due to a lack of researchers, laboratories, samples, and, ultimately, awareness of its value in understanding the past. In this article, we show how sediment sampling patterns have led to a spatially and temporally unequal archaeobotanical knowledge within Estonia. We emphasise the need for compulsory sampling during archaeological excavations, combined sampling for macro- and potentially microbotanical remains, as well as sampling from different contexts besides sediment, such as dental calculus, pottery food crust, and surfaces and pores of tools.

KEYWORDS
archaeobotany, macrobotanical remains, microbotanical remains, sediment samples.

Introduction

Plant exploitation has been widespread throughout history for food, medicine, animal fodder, utensils, handicrafts, fuel, and building materials. However, dedicated archaeobotanical research in Estonia has been limited and sporadic, especially compared to material culture studies and zooarchaeology.

Plant remains are among the tiniest finds in archaeological research and are often overlooked. Despite their importance for understanding both the past and future of humanity (Lodwick 2019), they are not as prominent in archaeology as they could be, with the term 'plant blindness' having been established to describe the situation (e.g. Mooney & Martín-Seijo 2021 and references therein). However, systematically involving plants in studies can reveal a more complex and dynamic view of the past and open up new research questions about past populations, their culture, and economy. Archaeobotanical studies have demonstrated the significant research potential of plant remains, addressing topics such as plant domestication, agricultural practices, the use of wild foods, culinary history (e.g. wine and beer making, the use of spices), diet and health, trade and exchange of plants, and the use of plants in textiles, baskets, and rituals (Pearsall 2019; Lancelotti & Madella 2023).

In 2005, Ülle Sillasoo highlighted the crisis in Estonian archaeobotany due to several interrelated reasons. The lack of researchers meant that archaeobotany could not compete with other disciplines, leading to unemployment or part-time work for specialists. Additionally, there was no scientific research based on archaeobotanical finds, primarily due to the nature of rescue excavations, where sediment samples[1], even when taken, were often left unstudied and unpublished due to financial constraints and a lack of specialists (Sillasoo 2005). It has been noted that in Great Britain, the rise of developer-funded archaeology since the mid-1990s and early 2000s has been linked to a decline in archaeobotanical work, including the number of samples, the level of expertise, and report quality (Lodwick 2019), with similar issues reported in other European countries and Estonia being no exception.

Twenty years later, archaeobotanical research in Estonia remains largely stagnant. Given global developments, such as the growing emphasis on micro-archaeology (Weiner 2010), rapid scientific advancements, new research questions, multiproxy and multimethod studies, it is time to re-evaluate the state and future prospects of archaeobotanical research in Estonia. Similar studies have been conducted in Great Britain, with Lisa Lodwick providing a broader European perspective (Lodwick 2019). Overviews of local archaeobotanical research and the challenges it faces have also been published in Finland (Lempiäinen 2006), Lithuania (Minkevičius 2022), Poland (Badura et al. 2022), and Norway (Kjesrud et al. 2023). More than a decade ago, an excellent article on archaeobotanical

1 We recognise the terminological challenges between the words 'soil' and 'sediment'. In published literature, archaeobotanical samples have been referred to as both soil samples and sediment samples. Geologically, 'sediments' is a broad term describing all types of naturally occurring particles, while 'soils' are various transformations of sediments over time. Therefore, we use 'sediment samples' as a general term for samples taken for archaeobotanical research. Similarly, *pinnas* (in Estonian) can be translated as 'sediment', encompassing rocks, sediments (*setted* in Estonian), and soil or topsoil along with the cultural layer (EnDic 2004), while *muld* (in Estonian) translates to 'soil'.

methods and good practices was published in Lithuanian (Kisielienė 2013), considerably increasing expertise and awareness in the field there.

The main purposes of this article are:

1. To provide a historical overview of archaeobotanical studies and trends in Estonia, including both macro- and microbotanical research, as well as the current state of archaeological plant remains study in Estonia, with an overview of previously discovered and analysed plant material (Johanson et al. 2024).
2. To discuss the main problems and needs in Estonian archaeobotany, emphasizing the importance of systematic sampling and collecting macro- and microremains from different environments (pottery, dental calculus, sediment) as a standard in archaeological investigations.
3. To raise the awareness of the potential of microremains from different environments (pottery, dental calculus, sediment) as a supplementary method for understanding past practices, alongside the increasing potential of biomolecular archaeological methods.

This article focuses on both macro- and microbotanical remains (Fig. 1) (Pearsall 2019; Lancelotti & Madella 2023). Macrobotanical remains include

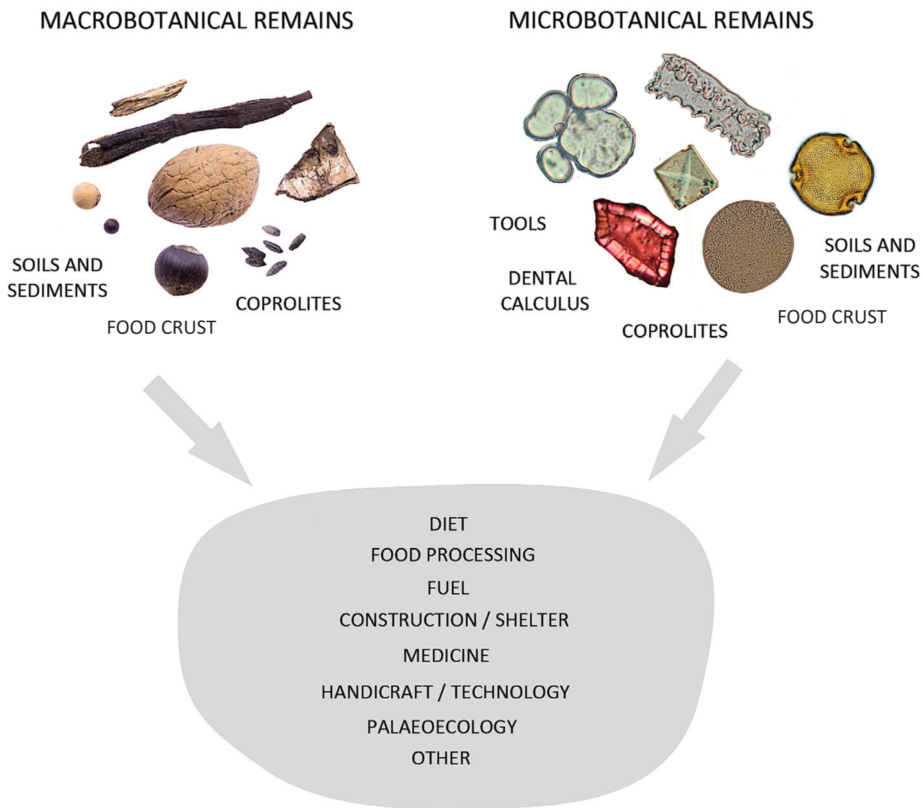


FIG. 1. Plant remains and their potential in archaeological research. Drawing by Jaana Ratas, modified by Kristiina Johanson.

large plant remains visible to the naked eye, such as seeds, fruits, nuts, wood, roots, tubers, stems, and leaves. Archaeobotany, though, is mostly concerned with carpological remains, i.e. fruits and seeds, as the latter, with their hard exterior, are more likely to survive than vegetative structures. Microbotanical remains, visible only under a microscope, range from 2–250 µm, typically measuring less than 100 µm, and include phytoliths, calcium oxalate crystals, starch granules, spores, and pollen grains (Lancelotti & Madella 2023, 704–705). These remains have specific preservation needs but are generally resilient and likely to preserve in various environments. Recently, archaeobotanical research has expanded to the molecular level, including diagnostic biomolecules, isotopic studies, DNA, and proteomics (Fraser et al. 2011; Fiorentino et al. 2015; Wales & Kistler 2019; Kistler et al. 2020). Although these fields are beyond the scope of this article, initial studies on Estonian material exist, such as pottery food crust analysis revealing plant use through lipid analysis (Oras et al. 2018; Papakosta et al. 2019; Chen et al. 2023) and isotopic analysis of medieval charred grains to detect manuring (Lempiäinen-Avci et al. 2025). While plants have been used in various aspects of human life, such as in handicrafts, construction, and fuel, this article focuses specifically on plant remains left behind by people in their activities but not significantly altered by humans.

Macrobotanical remains

HISTORY OF THE DISCIPLINE AND MAIN RESEARCHERS IN ESTONIA

Globally, palaeoethnobotany or archaeobotany has its roots in the first half and middle of the 19th century, when well-preserved plant remains from Egyptian tombs and Swiss lakeside villages were studied (Pearsall 2019, 4). After the publication on the plants from Swiss pile dwellings by Oswald Heer in 1865 (Heer 1865), the collection and study of macroremains gained momentum in Europe. Still, it took another century for the potential of plant remains for archaeological research to be fully realised, which happened after the publication of the excavations at Star Carr in England by J. G. D. Clark in 1954 (Clark 1954). In the Americas, interest in botanical remains started with the investigation of Peruvian mummy bundles in the second half of the 19th century (Scheel-Ybert 2016) but accelerated only after the 1930s (Gilmore 1931; Jones 1936). In the 1950s and 1960s, the emphasis on the study of palaeoenvironment and subsistence practices, connected to the rise of the New Archaeology movement, brought along an increase in collecting and identifying plant macroremains. The widespread use of flotation as a method for separating plant macroremains began after the publication of Stuart Struever's work in 1968 (Struever 1968) and led to the recovery of plant remains from a much wider variety of sites than before.

The first instances of collecting and identifying macrobotanical remains in Estonia date from the 1930s, when charred cultivated cereals and peas were collected during the excavations of the Iron Age hillforts, such as Kuusalu Pajulinn (Schmiedehelm 1939) and Iru hillfort (Vassar 1939), identified by Nikolai Rootsi. After the Second World War, archaeobotanical remains were studied by Heigo Miidla (Tartu hillfort) (Trummal 1964), Jaan Lepajõe (Soontagana hillfort), Hugo Richard Sutter (Rõuge hillfort), and Latvian botanist Alfrēds Rasiņš (Asva, Iru, Kuusalu, Otepää hillforts) (Rasiņš 1959b). Rasiņš was the only one at the time who specifically analysed archaeological samples and published the history of cultivation in Estonia and Latvia. Systematic collection and research of macrobotanical remains in Estonia started only in the late 1980s under the influence of processual archaeology, when the Laboratory of Geoarchaeology and Ancient Technology was created at the Institute of History of the Estonian Academy of Sciences in Tallinn, where archaeobotanists (Vilve Ernits, Jüri Piiper, Teeli Remmelg and Mihkel Tammet) also played an active role. One of the first samples analysed was from the medieval cesspits on Lossi (Lätte during the Soviet time) Street in Tartu, excavated in 1985–1987 (Tammet 1988). Owing to the aforementioned laboratory as well as the archaeological unit of the Estonian Heritage Society (EMS AGU), established in 1988 and responsible for conducting an increasing number of rescue excavations in medieval towns (Russow et al. 2005, 167), sediment samples were taken from nearly all mainly medieval town excavations in Estonia. The main name connected to this boost of archaeobotany in Estonia is Ülle Sillasoo, whose primary interest was in plants in the medieval diet (Sillasoo 1989; 2001; 2002; Sillasoo & Hiie 2007). In addition, projects were completed by botanists Mari Uudelt (Uudelt 1991), Maria Abakumova (Abakumova 1990; Abakumova & Sillasoo 1991) and Mihkel Tammet (Tammet 1988). Since 1988, plant remains have been studied by archaeobotanist Sirje Hiie (e.g. Kihno & Hiie 2008).

Systematic sampling for macrobotanical material came to a standstill in the early 2000s. The reasons for this are manifold. After Estonia regained independence, the number of excavations decreased, caused by the restructuring of the economy, the adoption of the Estonian national currency, and the freezing of grand construction plans from the late 1980s (Russow et al. 2005, 168). Private companies that survived in the market economy had to cut down on their expenses. During the mid-1990s, the system of personal research grants was introduced. Sadly, this meant that archaeobotany was not prioritised in scientific research or in development-led excavations. Thus, taking sediment samples and identifying plant remains were among the first expenses to be cut back. In the broader sense, this meant that trained archaeobotanists remained unemployed, and the discipline essentially froze. In 2007, Sillasoo and Hiie summarised the archaeobotanical work in medieval towns in Estonia (Sillasoo & Hiie 2007), and the article largely discusses material gathered and identified in the 1990s. Over the last 25 years, only sporadic research, including plant identifications from excavations, has been conducted (Kadakas, U. et al. 2010; Kadakas, V. et al. 2010; Sillasoo 2015; Lõugas et al. 2019; Russow et al. 2019; Lõugas 2021; Malve et al. 2022; Reppo et al. 2022; Niinesalu-Moon et al. 2023).

The lack of archaeobotanists in Estonia has, in some cases, instigated the employment of foreign scholars. For example, plant remains from the Ruhnu Valgi Stone Age site, Tartu prehistoric settlement site, and Narva-Jõesuu 2b Neolithic settlement site have been analysed by Santeri Vanhanen (e.g. Tvauri & Vanhanen 2016; Vanhanen et al. 2023), sediment samples from Karksi Order Castle by Monika Badura (Valk et al. 2012; 2013; Banerjea & Badura 2019; Banerjea et al. 2019), and grains from Uppsala Street in Tartu by Mia Lempiäinen-Avci (pers. comm., November 2024). These undertakings reflect personal relationships between Estonian archaeologists and foreign specialists or excavations at sites that are part of international research projects. As of 2025, Estonia does not have a permanent position for a specialised archaeobotanist.

The main research subjects in the field of macrobotanical remains in Estonia are largely connected to Ülle Sillasoo. As indicated above, in the 1990s, rescue excavations in medieval and modern period towns also included the collection of sediment samples, usually from cesspits. The investigation of this large body of material resulted in two bachelor's works (Sillasoo 1989; Uudelt 1991), a master's thesis (Sillasoo 1996), several publications on the topic (Tammet 1988; Abakumova 1990; Abakumova & Sillasoo 1991; Sillasoo 1995; 1997; Kihno & Hiie 2008), and was completed with thorough summaries of medieval plant food consumption in Estonian towns (Sillasoo 2001; 2007; 2013; Sillasoo & Hiie 2007). This considerable amount of material gathered and analysed in the 1980s and 1990s is still regularly used in studies about medieval town life (Haak & Johanson 2024).

The second research subject was entirely instigated by Ülle Sillasoo and was completed in her doctoral thesis, *Plant Depictions in Late Medieval Religious Art in Southern Central Europe: An Archaeobotanical Approach*, which was defended at the Central European University in 2005. Although not dealing with Estonian samples, this interdisciplinary study, combining botany, archaeology, and art, resulted in several publications (Sillasoo 2003; 2006; 2009; 2014) and serves as a perfect example of the wide use of archaeobotanical material. As a third research subject, we might consider the growing knowledge about plant use in Stone Age sites, led by Aivar Kriiska and Santeri Vanhanen, with their first article recently published (Vanhanen et al. 2023).

THE CURRENT STATE AND CHALLENGES OF ARCHAEOBOTANICAL RESEARCH IN ESTONIA

In archaeological contexts, macrobotanical remains mostly appear charred, as without charring they can only preserve in extreme conditions, such as waterlogged, extremely dry, or frozen environments (e.g. Cappers & Neef 2012). In Estonia, archaeobotanical material consists of charred remains from various sites and uncharred remains from waterlogged contexts. Charred examples, often found in thick layers, typically come from grains of cultivated plants stored in granaries that caught fire. These are available from Iron Age and medieval hillforts (e.g. Kuusalu, Iru, Asva, Rõuge, Rosma, Tartu Toome Hill). Uncharred plant remains have been gathered from medieval and early modern town occupation layers, particularly in the tightly packed, damp, and oxygen-poor conditions of cesspits excavated in Tartu, Tallinn, Viljandi, and Pärnu. We hardly know of more specific contexts, as these are usually not detailed in the excavation or archaeobotanical reports.

In addition, macroscopic remains include carbonised food, such as porridge remains or bread, as well as charcoal. While carbonised food remains have not been knowingly recovered in Estonia, such remains have been studied in other countries, yielding interesting insights into the species used and food preparation methods (e.g. González Carretero et al. 2017; Valamoti et al. 2021; Kabukcu et al. 2023). An example of this potential is offered by Bishop et al. (2023), who identified charred remains of root tubers of *Ficaria verna* and *Lathyrus linifolius* from flotation[2] sediment alongside pieces of charcoal, showcasing how important it is to be mindful of all sample types.

Charcoal from archaeological sites in Estonia has been gathered since at least 1921, both as examples of available archaeological material (Marge Konsa, pers. comm., February 2025) and, in some cases, for the identification of species (Kriiska & Lõugas 2005, 273). Since the 1950s, charcoal samples have been collected for radiocarbon dating as well as species identification. These samples are preserved in separate collections, such as the natural scientific collection at the University of Tartu. Despite this, there have been very few anthracological investigations. Systematic gathering and documenting of charcoal from the Madi stone grave in the 1960s by Jüri Selirand allowed for the identification of species selected for prehistoric funeral pyres (Soots 2012; Konsa 2022). Uncharred wood analysis, primarily conducted by dendrologist Alar Läänelaid, has focused on wood species identification and dendrochronological dating of wooden constructions (e.g. Läänelaid 1999; 2004; Bernotas 2008; Kriiska et al. 2011; Roio et al. 2016). Single wood identifications have also been conducted by Sirje Hiie (in Pedäjäsaare, see Aun 2001), Mihkel Tammet (in Tuiu, see Peets 1995, 467), and Regino Kask (in Kohtla, see Oras et al. 2018).

Carpological remains from archaeological sites in Estonia have mostly been gathered in two ways. Visible plant remains are often picked by hand during excavations, which is quick and convenient but only effective for larger seeds, such as hazelnut shells or cereal grains (e.g. Kriiska et al. 2021; Khrustaleva & Kriiska 2022; Niinesalu-Moon et al. 2023). However, gathering archaeobotanical material from sediment samples provides a more nuanced picture of past vegetation and plant use, revealing smaller seeds from gathered plants and weeds

2 Flotation, as a standard method for treating sediment samples, is the recovery of small finds, especially botanical remains, by using water. The lighter organic material floats to the surface and is then collected with sieves.

(see also Maltas et al. 2023). The most common sampling strategy in Estonia has been judgemental or selective sampling (on sampling strategies, see e.g. D'Alpoim Guedes & Spengler 2015, 78; Lancelotti & Madella 2023, 702; Maltas et al. 2023, 3). This means that most Estonian sediment samples have been taken from contexts deemed important (e.g. fireplaces, pits, middens) or 'promising' (oxygen-free environments, e.g. cesspits) during excavations. However, the sampling strategy is almost never described or justified in the identification reports. These reports usually include information on the sample volume, flotation steps, and the sieves used. The material collected is commonly analysed either in full or by taking subsamples of 100–300 mL. After the analyses, a species list is usually made available.

Identifying plant remains requires the use of manuals for seeds and fruits of Estonian wild species (e.g. Rasiņš 1954; Karmin 1967; Ratt & Reitan 1969) as well as crop plants (e.g. Jacomet 2006). A reference collection of modern species is also necessary. Ülle Sillasoo started building a reference collection in the 1990s, which has grown to include 250 species of seeds and other plant parts. This collection is currently housed in the archaeobotany collections of the University of Tartu. Recently, the authors have expanded this collection to include other plant parts, such as dried roots, stems, leaves, and flowers of over 150 plant species. A separate reference collection of seeds and fruits was started by the archaeobotanists of the former Institute of History of the Academy of Sciences of the Estonian SSR and is now housed in the Archaeological Research Collection of Tallinn University.

After identification, sorted archaeological plant remains should ideally be stored for future research, whether for learning or comparative purposes or re-identification. Unfortunately, this has not always been the case in Estonia, severely inhibiting their availability for future studies. The situation seems to be better with hand-picked grains, fruits, and seeds, as these are often included in find collections. However, the storage of sediment samples that have not been floated is an even bigger issue. Current strategies for storing sediment samples in Estonia are sporadic and unregulated. The University of Tartu's natural scientific collection currently stores all samples taken by archaeologists, but space is rather limited. Only small amounts of sediment are stored in fridges. At Tallinn University, large sediment samples are not stored (Lõugas 2020), while smaller samples are only preserved for a short while in fridges. As organic remains may dry out and become unidentifiable over time, all samples should be processed quickly. This aspect is closely related to the lack of dedicated researchers – without them, sediment samples cannot be effectively collected.

MACROBOTANICAL PLANT REMAINS FROM ESTONIAN ARCHAEOLOGICAL SITES

The current state of research on plant remains in Estonia is summarised in a dataset created for this article (Johanson et al. 2024), along with Figs 1–3, which present 173 instances of plant remains gathered from archaeological contexts. These episodes have been analysed across three periods, shown by separate colours in Fig. 2: until 1980, between 1981–1999, and 2000–2024. Most episodes represent a single site, though there are exceptions. For instance, when different archaeologists or archaeobotanists worked on the same site, their efforts were considered as separate episodes. This is seen in the case of Asva, where hand-picked cereal grains from the 1930s constitute one episode, while extensive sediment sampling by Uwe Sperling during the third period represents another. If the same site was excavated over multiple years by the same archaeologist, samples taken each year were counted as a single episode.

The analysis revealed sporadic and uneven coverage of plant remains from archaeological sites, both temporally and geographically (Fig. 2). Town contexts are the most represented, with Tartu having 60, Tallinn 32, and Viljandi 24 analysed episodes. More than half (96) of the data on plant remains comes from the period between 1981 and 1999. During these 19 years, almost half (47) of the instances of archaeobotanical sampling were from Tartu, with the majority (32) of projects analysed by Ülle Sillasoo. In Viljandi, 14 samples came from a single 1996 project involving geoarchaeological drilling (Valk 1996). Some counties, such as Jõgeva and Järva, lack botanical data from archaeological sites altogether, while others, including Lääne, Rapla, Valga, Põlva, and Lääne-Viru counties, have very little.

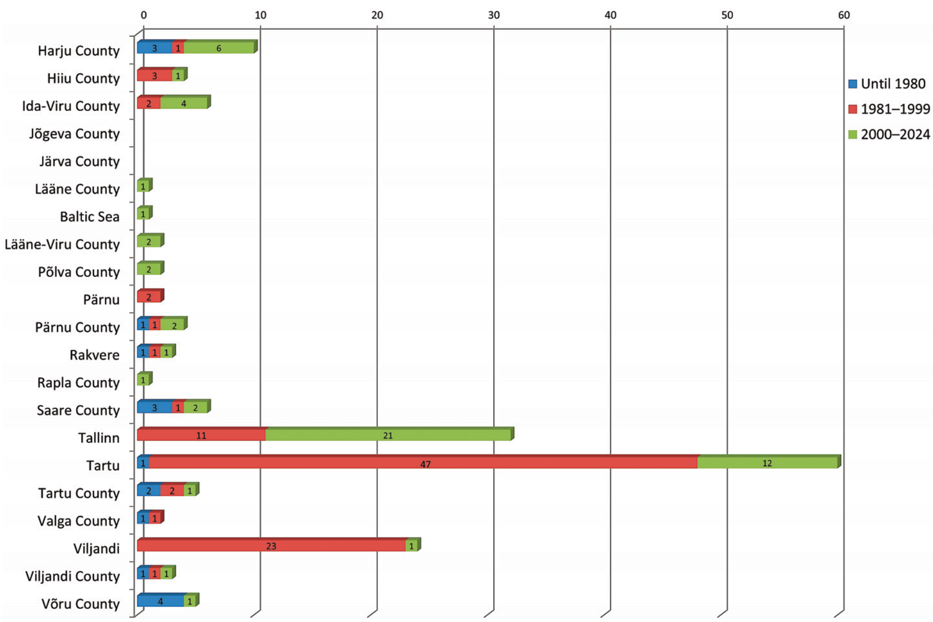


FIG. 2. The number of instances of plant remains gathered from archaeological contexts, categorised by Estonian counties and larger towns. The different colours indicate the periods during which the samples were collected.

The difference in sampling can also be seen when dividing excavations into problem-oriented and development-led works, the latter including preliminary and rescue excavations. Most plant remains were gathered from development-led projects (117), with 54 instances from problem-oriented excavations. Most sampling for plant remains in development-led excavations occurred during the second period, while sampling in problem-oriented excavations remained relatively stable throughout the research period.

Regarding the nature of the samples (Fig. 3), plant remains from 49 sites were hand-picked during excavations, while sediment samples were taken from the remaining 122. Hand-picked plant remains include those visible during excavation, such as hazelnut shells and cereal grains. While the number of hand-picking events remained relatively constant across all periods, sediment samples were not taken in the first period but were clearly abundant (72) in the second period, coinciding with the rise of development-funded archaeology, especially in medieval towns, and the presence of several archaeobotanists (see above for details).

The number of sediment samples decreases significantly during the third period, but the nature of the excavations does not seem to be determinant here. Rather, the reason is the lack of engaged archaeobotanists and the current situation, where taking sediment samples is not considered a necessary part of fieldwork. Recently, sediment samples have been collected during problem-oriented excavations, such as in Asva (Sperling et al. 2021) and Karksi (Valk et al. 2012; 2013), as well as during rescue excavations with exceptional organic preservation, such as the landfill of Jahu Street in Tallinn (Heinloo 2014; Russow

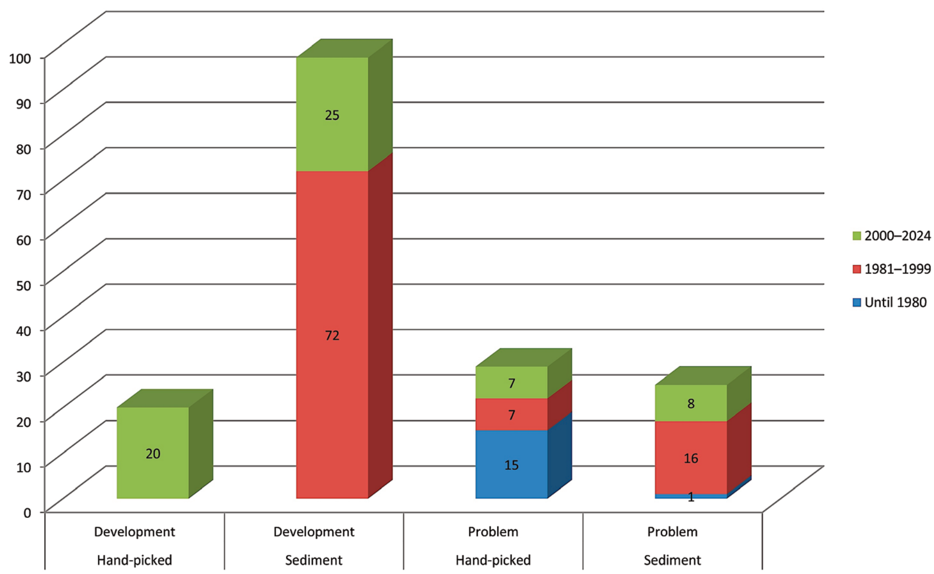
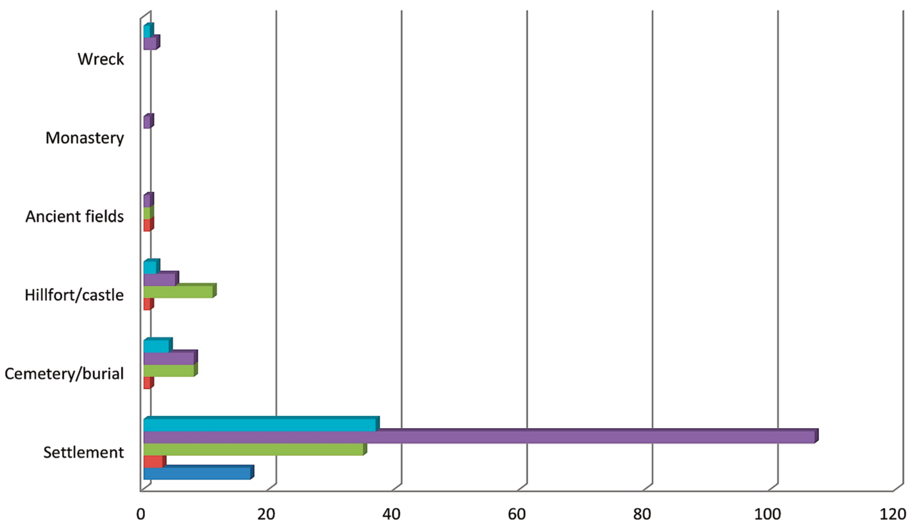


FIG. 3. The number of instances of plant remains gathered either as sediment samples or hand-picked from development-led excavations and problem-oriented excavations.

et al. 2019). In some cases, samples have also been taken to gather additional information when other finds are scarce (Reppo et al. 2022).

The largest amount and volume of sediment samples have been collected from Asva hillfort, where 222 sediment samples (10 L each) were taken between 2012–2014 and 2018–2020. Other extensively sampled sites include Uderna (200 samples), VII quarter in Tartu (197), Jägala Jõesuu ancient fields (170), Narva-Jõesuu 2B settlement site (106), and the cesspits of Lossi 3 in Tartu (88). During the second period (1981–1999), sample volumes were smaller (100–600 mL), likely due to the organic-rich cultural layers of towns. However, in the last decade, sample volumes have increased significantly, especially in problem-oriented excavations. In Asva and Viru-Nigula, sample volumes reached 10 L, all of which were flotated. In Karksi Order Castle, all samples weighed at least 5 kg (Valk et al. 2013, 83).

When examining the coverage of archaeobotanical material by site type and period of use (Fig. 4), settlement sites (both rural and urban) are the most numerous, accounting for 199 instances (the numbers presented are somewhat higher than the total number of sites analysed, as several sites span multiple periods). About half (107) of these include samples taken from medieval occupation layers. Seventeen settlement sites with plant remains date to the Stone Age, mostly featuring hand-picked hazelnut shells. Of the 35 samples from Iron Age settlements, most originate from Late Iron Age occupation layers exposed during



	Settlement	Cemetery/burial	Hillfort/castle	Ancient fields	Monastery	Wreck
Modern Period	37	4	2			1
Middle Ages	107	8	5	1	1	2
Iron Age	35	8	11	1		
Bronze Age	3	1	1	1		
Stone Age	17					

FIG. 4. The number of instances of plant remains gathered from different archaeological contexts by site type and broad site date.

town excavations. Thirteen instances are hillforts, with eight being Late Iron Age hillforts featuring hand-picked cereal grains from the first period. Other site types, such as burials, shipwrecks, monasteries, and castles, are represented by single cases.

THE RESEARCH OF MACROBOTANICAL REMAINS IN THE EASTERN BALTIC

When comparing the state of archaeobotany in eastern Baltic countries, the situation in Finland is not much different. Integrated research on plant materials from Finnish archaeological sites has not been undertaken systematically or extensively (Lempiäinen-Avci 2022). Since the 1980s and 1990s, archaeobotanical material has been published by Marjatta Aalto (Aalto 1982; 1997) and Terttu Lempiäinen (e.g. Lempiäinen 1995; 1999; 2002; 2007). Over the last decade, several archaeobotanists have completed their PhDs: Teija Alanko in 2017, Annemari Tranberg in 2018, and Mia Lempiäinen-Avci and Santeri Vanhanen in 2019. Tranberg and Alanko have both focused on medieval and post-medieval garden archaeology, though Tranberg has also studied plants in post-medieval burials (e.g. Tranberg 2015). Vanhanen has concentrated on wild plant gathering (Vanhanen & Pesonen 2016; Vanhanen 2019; Vanhanen et al. 2023) but has also studied cereal cultivation (Vanhanen 2012; 2020; Vanhanen & Koivisto 2015; Vanhanen et al. 2019). Lempiäinen-Avci has been involved in several studies on the beginnings and advancement of cultivation (e.g. Lempiäinen-Avci et al. 2018; 2024). She has also researched plant remains in graves (Lempiäinen-Avci et al. 2017) and underwater archaeobotany (Lempiäinen-Avci et al. 2022). At present, she is the only trained and active archaeobotanist in Finland.

In Lithuania, several archaeobotanists are working in the field. Giedrė Motuzaitė Matuzevičiūtė has studied the origins and development of agriculture in Lithuania together with Mindaugas Grikpėdis (Grikpėdis & Motuzaitė Matuzevičiūtė 2016; 2018; 2020), the history of millet cultivation (Motuzaitė Matuzevičiūtė & Laužikas 2023), and changes in crop repertoires (Motuzaitė Matuzevičiūtė et al. 2022; Abdrakhmanov et al. 2025). She has also analysed plant remains from different Lithuanian archaeological sites (e.g. Motuzaitė Matuzevičiūtė et al. 2020; Karaliūtė et al. 2023). Gytis Piličiauskas, with the help of archaeobotany specialists, has written about early crop production in the southeastern Baltic region (Piličiauskas et al. 2021). Karolis Minkevičius is researching subsistence strategies in Lithuania via archaeobotany (e.g. Minkevičius et al. 2020; 2023). In addition, it should be noted that Vilnius University has a dedicated Bioarchaeology Research Centre, headed by Motuzaitė Matuzevičiūtė, where archaeobotanical and zooarchaeological material is stored, and research is conducted on a regular basis.

In Latvia, Alfrēds Rasiņš was the main researcher focused on archaeobotanical material during the Soviet times and the only botanist working exclusively with archaeological material in the Baltic countries (Rasiņš 1959a; 1959b; Rasiņš & Tauriņa 1983). In recent decades, plant macrofossils from archaeological sites have been studied by Aija Ceriņa (Brown et al. 2017; Kalniņa et al. 2018; Vasks et al. 2019; Brinker et al. 2020; Zariņa et al. 2023). A few papers have been published in which plant macrofossils have been used together with pollen for reconstructions of vegetation around archaeological sites (e.g. Kalniņa et al. 2004; Stivrinš et al. 2016). More recently, a paper on early farming subsistence strategies in the northeastern Baltic region (Oras et al. 2023) has summarised current knowledge of early cultivated plants in Latvia and Estonia.

Similarly to Estonia, taking sediment samples and archaeobotanical research are not officially required during archaeological excavations in Latvia and Finland. This results in a situation where trained specialists cannot find sufficient work, are forced to seek opportunities elsewhere, and the discipline barely survives. However, in Lithuania, archaeobotanical sample collection is a compulsory part of any archaeological excavation that contains the appropriate context for sample collection, such as cesspits, houses, fireplaces, and domestic pits. The collection of botanical and zooarchaeological material is regulated by the Archaeological Heritage Management Regulation, approved by the Ministry of Culture. This regulation provides guidance that every archaeologist must follow while excavating an archaeological site; systematic archaeobotanical sampling for macrobotanical research is an integral part of each archaeological excavation (see 15.12.3, 15.12.4 in Lietuvos Respublikos kultūros ministerija). This regulation is periodically updated and modified to align with advances in archaeological science.

The situation regarding sediment sampling is better on the western side of the Baltic Sea, for example, in Norway, where archaeobotanical sampling gradually became a regular part of rescue excavations of prehistoric sites in the 1980s. Although detailed requirements for sampling and reporting vary by region, this has lead to the collection of significantly more archaeobotanical material (Hjelle et al. 2017), thereby sustaining the discipline. In Poland, the collection and analysis of plant remains have been consistently carried out over the last 100 years (Badura et al. 2022).

Microbotanical remains

HISTORY OF THE DISCIPLINE AND MAIN RESEARCHERS IN ESTONIA AND THE NEIGHBOURING COUNTRIES

Microscopic plant remains discussed in this chapter – pollen, phytoliths, and starch grains – were recognised and started to be studied centuries ago. The study of starch and pollen grains began already in the 17th century, after the building of microscopes that enabled the observation and examination of plant anatomy at a microscopic level (Ducker & Knox 1985). In the following two centuries, the potential of starch grains to determine the genus and species of plants was fully understood, leading to the development of taxonomic atlases and keys (Kovárník & Beneš 2018, 84). Archaeological starch was first studied from residues on stone tools in the late 1970s and early 1980s (Pearsall 2019, 4). The widespread presence of ancient starch and the increasing number of research methods brought along a boost in publications.

The study of phytoliths began in the 19th century, focusing on their production in living plants and formation within plant physiology. The first archaeological applications appeared in the early 20th century. Significant attention was drawn to phytoliths in archaeobotanical and archaeological research by Irwin Rovner's paper (Rovner 1971). Since the 1980s, archaeological phytolith research has expanded significantly, with the 21st century seeing a rapid increase in publications, standardisation efforts, and a broader range of research topics (see Piperno 1988; Hart 2016).

Fossil pollen from geological layers was first studied in the second half of the 19th century, but its real potential was realised after Lennart von Post presented the first modern quantitative pollen analysis in 1916. Biostratigraphy, palaeoecology, and changes in vegetation and climate have been the main application of palynology since then. The first instances of determining human influence in these studies include the paper by Johannes Iversen (1941). Although by the early 1980s, fossil pollen had been studied from burials, coprolites, floor surfaces, vessels, mortars, and milling stones, indicating diet and site activities (Bryant & Holloway 1983), the analysis of fossil pollen from archaeological contexts, other than addressing palaeoenvironmental questions, has remained sporadic.

Phytoliths, starch grains, and pollen grains can be gathered from various archaeological contexts, including sediments, pottery (food crust), dental calculus, coprolites, and artefact pores (Fig. 1). Sediment samples for microbotanical research can be taken as subsamples from macrobotanical samples. Different microremains can be recovered from the same subsample using complex stepwise procedures (e.g. Horrocks 2005) and various chemicals.

Pollen analysis in Estonia began in 1924 when a sediment sample from a bone harpoon at the Kunda Lammasmägi Stone Age site was sent to Stockholm to be studied by Lennart von Post. The following year, Paul William Thomson, a student from Estonia, went to Stockholm to learn these techniques and soon published his first results on the stratigraphy of Estonian swamps and lake sediments (Thomson 1925), followed by palynological dating attempts of Estonian Stone Age sites (Thomson 1930). This initiated cooperation between archaeologists and palynologists, making the combination of archaeological material with vegetation history a standard practice in the 1930s (Kriiska & Lõugas 2005, 272), as seen in the excavations of the Moksi, Siivertsi, and Kunda Lammasmägi sites (Indreko 1932; Lõugas 1988, 17). Initially, the main focus of palynological research was on archaeological dating sites.

During the Soviet era, research shifted towards explaining changes in plant cover and climate (Lõugas 1988, 20), resulting in a well-documented Late Glacial and Holocene bio- and chronostratigraphy (see references in Poska 2001). From the 1980s, studies on cultivation and human influence as reflected in pollen diagrams began to emerge (e.g. Rõuk & Tõnisson 1984; Pirrus & Rõuk 1988). This led to more thorough recording of human impact, with sampling areas chosen near archaeological sites. Close collaboration between archaeologists (Aivar Kriiska, Valter Lang, Heiki Valk) and palynologists (Siim Veski, Anneli Poska, Kersti Kihno) in the 1990s and early 2000s resulted in several studies on the beginnings of cultivation based on pollen cores (e.g. Lang 1999; Poska 2001; Poska et al. 2004; Kriiska 2009).

The main research subject in archaeology related to microbotanical remains in Estonia is pollen analysis. With other sources being limited, cereal-type pollen in core sediments is often considered direct evidence of crop cultivation, suggesting the introduction of farming in the northeastern Baltic around the 5th millennium BC (Kriiska 2009, 167; Vasks 2015). However, pollen-based evidence should be interpreted cautiously due to methodological issues (see Oras et al. 2023). Potential errors include uncertainties in dating, pollen identification, and pollen source area (Lahtinen & Rowley-Conwy 2013, 668; Josefsson et al. 2014; Grikpėdis & Motuzaite-Matuzeviciute 2018). After a period of intense research on early crop cultivation in the late 1990s and early 2000s (e.g. Veski 1998; Poska 2001), recent palynological studies have returned to focusing more on reconstructing vegetation, environment, and palaeoclimates, while human impact remains a significant part of many studies as well (e.g. Poska et al. 2017; Väli et al. 2024).

In Estonia, research on archaeological starch and phytoliths is still in its early stages. The first phytolith study in Estonia examined the sediment composition of slash-and-burn fields from the 16th to the 19th centuries (Ponomarenko et al. 2019). Phytoliths have been extracted and identified from sediment samples along with macroremains and pollen at Karksi Order Castle (Banerjea & Badura 2019; Banerjea et al. 2019) and the Jägala Jõesuu ancient fields (Kriiska et al. 2023). In Estonian laboratories, microremains from archaeological sediment samples have yet to be analysed, although available samples from various contexts (e.g. ancient field systems and the gut areas of buried individuals) are stored in the natural scientific collection of the University of Tartu. Recent studies have also analysed pottery food crust and human dental calculus to detect plant microremains for reconstructing human diet (Oras et al. 2018; Unt 2021; Chen et al. 2023; Unt 2024; Tõrv et al. in prep.). These studies have mainly focused on phytoliths and starch grains but have also detected other microscopic plant remains, such as calcium oxalates, pollen, and wood fragments.

In other eastern European countries, the study of plant microfossils is quite similar to that in Estonia. Pollen has been quite extensively researched in all these countries, also in relation to human impact. In Lithuania and Finland, there have been discussions about the reliability of pollen analysis for reconstructing ancient crop cultivation (Grikpėdis & Motuzaitė Matuzevičiūtė 2018; Lahtinen & Rowley-Conwy 2013; Lahtinen et al. 2017). In Lithuania, the first studies on phytoliths were published over a decade ago (Stančikaitė et al. 2009), but no further development has followed in this area. In Latvia, different plant remains (macroremains, pollen, phytoliths) were analysed in Riga and Cēsis (Banerjea & Badura 2019) as part of the Ecologies of Crusading project (Pluskowski 2019a; 2019b). In Finland and the Nordic countries, the first attempts to analyse phytoliths were made several decades ago (Risberg 1990; Vuorela 1991; Borgmark 1998; Risberg et al. 2002). However, in Finland, only a few projects have been completed, with microremains recovered and identified from dental calculus and food crust on pottery sherds (Juhola et al. 2014; 2019). In contrast, the Nordic countries have recently conducted several multi-proxy studies, analysing phytoliths, starch, diatoms, pollen, and fungal spores from dental calculus, tools, and sediment (e.g. Norström et al. 2019; Out et al. 2022). Additionally, food preparation techniques have been studied using preserved starch grains from charred cereal grains (e.g. Cordes et al. 2021).

Discussion

The aforementioned points highlight the major challenges in Estonian archaeobotanical research. From our perspective, these challenges are as follows, shortly outlined here and expanded upon below:

1. The archaeobotanical coverage of Estonian archaeological sites is extremely uneven, with most samples originating from a few medieval town excavations. The lack of mandatory sediment sampling during excavations further exacerbates this issue.
2. The study of sediment samples using multiple proxies (such as macrobotanical analysis combined with pollen, phytoliths, and starch, in addition to carpological remains) is almost non-existent. These proxies are essential for maximizing the information available.
3. There is a significant and continuous need for non-sediment samples, such as dental calculus and pottery, to enhance our understanding of past plant use.

COLLECTING SEDIMENT SAMPLES

We strongly advocate for the systematic collection of sediment samples for archaeobotanical analysis as a minimal requirement for all archaeological excavations. The 20-year standstill in Estonian archaeological discourse has relegated the sampling and research of botanical remains to a secondary priority during fieldwork. This has created a vicious cycle: the limited interest in documenting plant remains has led to a shortage of researchers, which in turn discourages field archaeologists from collecting sediment samples, as they fear flooding collections with samples that may never be analysed. However, this approach risks losing valuable historical insights that detailed analyses could provide.

Sediment samples should be strategically collected from various sites and chronological contexts to form a diachronic picture of archaeological plant use both locally and across Estonia. Often, only larger visible seeds are collected during coarse sieving, which, while a good start, is insufficient for reconstructing various human activities, such as subsistence, diet, and handicrafts. This method tends to yield one-sided results, primarily capturing larger seeds, such as cereal grains and nut shells, while smaller seeds and other botanical remains (Termansen et al. 2024), along with small animal and fish remains, are frequently overlooked. The importance of small seeds is multifaceted. Locally, crop weeds can offer insights into farming strategies. Additionally, many plants now considered weeds were historically used for food. For example, fat hen (*Chenopodium album*), whose seeds and leaves are edible, has been consumed for centuries (Mueller-Bieniek et al. 2019; Lempiäinen-Avci 2022 and references therein). In addition to fat hen, the consumption of pale persicaria (*Polygonum lapathifolium*), corn spurry (*Spergula arvensis*), black bindweed (*Fallopia convolvulus*), rye brome (*Bromus secalinus*), and manna-grass *(Glyceria fluitans*) has also been suggested (Behre 2007 and references therein). Furthermore, gathering and identifying sediment sample assemblages in their totality can provide environmental information on the site.

A clear sampling strategy is essential, detailing where and how much sediment to collect. In hunter-gatherer sites, larger sediment samples are necessary because the majority of consumed plants were edible roots and tubers, which require larger samples to increase recovery potential (Bishop et al. 2023). Roots and tubers were often pounded or ground before cooking, reducing their likelihood of being found (Vanhanen & Pesonen 2016, 50), whereas nutshells, as waste material, are more likely to be charred and preserved (Bishop et al. 2023). For example, at Staosnaig (Scotland), around 30 000–40 000 hazelnut shells were found, compared to only 414 fragments of *Ficaria verna* roots (Mason & Hather 2000), yet both were considered important foodstuffs at the site. The optimal sampling volume for hunter-gatherer sites is suggested to be at least 20 L per chosen excavation unit (commonly 1 × 1 m squares) (Bishop et al. 2023, 79). For later periods, when carpological remains are more numerous, smaller sample volumes may suffice, but multiple samples should be taken according to a chosen strategy. The sampling strategy is also dependent on the characteristics of the sediment. For sandy sediments, where organic material is poorly preserved, larger samples (at least 30 L or more) should be collected, while from peaty and waterlogged sediments, where plant remains preserve well, smaller sample sizes (0.5–5 L) are sufficient (Kisielienė 2013, 333). Ideally, a combination of blanket sampling (from all layers and areas/squares) and judgemental sampling (more samples from visible features such as hearths, storage pits, cesspits, etc.) should be used. Stratigraphic sampling is needed to reconstruct the history of plants available and used at a given site, for example, establishing changes in cultivated crops, weeds, agricultural practices, as well as environmental conditions (e.g. changes in shoreline, land drainage events, etc.) (Kisielienė 2013). Processing collected samples on-site during excavations through wet sieving (in the case of waterlogged sediments) or flotation (for most other sediments) should be encouraged, as it allows a quick assessment of the preservation of organic remains, which can help adjust the sampling strategy, as well as mitigate the storage challenges when dealing with large sample volumes.

Establishing a code of good practices with guidelines on the sampling strategy, volume, necessary equipment, and packaging will be detailed in a separate document in the near future (Johanson 2025).

MULTIMETHOD ANALYSIS COMBINING MACRO- AND MICROREMAINS

The need for combined analyses arises because different proxies have their advantages and disadvantages regarding preservation, specificity of taxonomic identification, and potential to answer research questions. Seeds, when available, can usually be identified to the species level, but their preservation requires specific environmental conditions. Pollen typically prefers anaerobic contexts for preservation, so pollen from mineral sediments is often degraded and lacks identification features. However, studies have shown that herbs, cultivated plants, and weeds are generally better represented by pollen than seeds in prehistoric cultivation layers and clearance cairns (Hjelle et al. 2017, 299). Although taphonomic processes may affect the preservation of characteristic features of seeds and fruits, seeds are much more likely to be identified to the species level than microremains, such as pollen, phytoliths, or starch granules.

Regarding pollen, while some taxa can be confidently identified to genus or even species level, others cannot be identified with high precision. Unfortunately, one of the biggest challenges of palynology has been distinguishing the pollen of wild grasses from cultivated ones (e.g. Lahtinen & Rowley-Conwy 2013; Albert & Innes 2020). One pollen type can include pollen from plants belonging to different species, families, or even genera (Beug 2004). For example, the *Hordeum*-type pollen can also include pollen of *Glyceria fluitans*, *Bromus inermis*, and *Elymus arenarius* (Lahtinen & Rowley-Conwy 2013, table 2 and references therein). Phytoliths are the best-preserving microremains, but they are not produced by many plant families and are not commonly identified to species level due to a lack of diagnostic features (e.g. Hart 2016). Several activities, such as food preparation, handicraft (weaving, basketry, textiles) (e.g. Lancelotti & Madella 2023, 701), or zones of animal pens and grazing areas, may not leave macroscopic archaeobotanical evidence, and better-preserving microremains (e.g. phytoliths) could be the only evidence of their presence. While pollen has mostly been used to determine the vegetation around a studied site, pollen from the occupation layers can originate from other sources, such as dung, manure, or construction materials brought to the site (Dimbleby 1985), and these studies are much rarer. In addition to pollen, wood and charcoal create environmental data for the excavated site. Furthermore, wood anatomical analyses can improve the quality of radiocarbon dates. Wood species can be identified, and those with shorter lifespans can be chosen for analysis as they offer more precise dates.

Considering the above, taking sediment samples for archaeobotanical research and/or combined studies of micro- and macroscopic analysis from archaeological contexts should be encouraged. There are several examples to prove the need. For instance, in the Neolithic Çatalhöyük in Turkey, microscopic fibres and phytoliths from flax (*Linum usitatissimum*) were found in sediment samples, providing evidence of textile production activities that were not apparent from macroremains alone (Wendrich & Ryan 2012). Combined analyses of plant remains, both pollen and macroremains, have been carried out at several burial sites. In a medieval burial site in Lappeenranta, Kappelinmäki in Finland (Lempiäinen-Avci et al. 2017), more than 5000 raspberry seeds from the gut contents of burial No. 22 indicated the food eaten by the deceased. The pollen analysis revealed spores of clubmosses (*Lycopodium*), *Pteridium*, *Sphagnum*, and pollen grains of Cichorieae and Poaceae, which might refer to possible burial rituals (e.g. food offerings or ears of cereals placed in the grave), medicinal plants, or grave bedding. In the Early Medieval burial site at Toppolanmäki (Finland), the presence of a woven clubmoss carpet or mattress softened with sphagnum moss was suggested to have been in the grave pit (Moilanen et al. 2022). It is similarly known from elsewhere in Europe that mosses, reeds, bracken, meadow plants, and heather were used as covering, embedding, or cushion material in coffins or graves (e.g. Gilchrist & Sloane 2005).

In Estonia, the potential of microscopic plant remains has been unevenly realised, with only pollen analyses being utilised with some regularity. Already in 1992, Sillasoo emphasised the importance of collecting pollen samples from both natural and occupation layers, advocating for combined macrofossil and palynological analysis at Rakvere Theatre Hill (Sillasoo 1992). Later, similar thoughts were expressed by Kihno and Hiie (2008, 50). However, by now, only sporadic instances of this approach have occurred, such as the excavations in the Riga suburb (the plot of the department store Kaubahall and former post office) in Tartu in the 1990s (Kihno & Hiie 2008), the plot of the old department store in Tartu, Riia 2 (Kihno & Hiie 2016), Vabaduse Square in Tallinn (Kadakas, U. et al. 2010; Kadakas, V. et al. 2010), Karksi Order Castle (Valk et al. 2012), and Pulli settlement site (Poska & Veski 1999). During the latter two excavations, monoliths extending through several layers were taken from the profile, enabling further analysis by layers in laboratory conditions. The combined results of pollen and macroremains would provide a complementary overview of changes in the vegetation around the site as well as plant use within the site. For example, in Karksi, the pollen analysis revealed a high frequency of cereal pollen (40%) in the peat layers. Since the majority of cereal plants self-pollinate and thus produce only small quantities of pollen, it was considered unlikely that this amount derived from nearby cultivated fields. Instead, it might reflect the storage or processing of cereals within the castle. However, the absence of cereal and weed remains in the macrobotanical collection might indicate poor preservation conditions for uncharred plant remains (Valk et al. 2012). Additionally, palynological research has taken place at other archaeological sites where preservation conditions for pollen are considered promising, such as the peat sites of Kääpa and Akali, where sediment sequences have been recovered, but no analyses of macroremains have been carried out. Recently, sediment samples for combined analyses of macroremains and phytoliths were taken from the Jägala Jõesuu site (Kriiska et al. 2023), but the results of these analyses have not yet been published.

THE NEED FOR NON-SEDIMENT SAMPLES FOR DETECTING PLANT REMAINS

In Estonia, the sampling of tools, pottery, and dental calculus has been rare, yet the potential is immense, given the array of articles published globally in this field. Typically, plant microfossils from dental calculus, pottery, and tool pores are studied in relation to human diet and food processing (García-Granero et al. 2015; 2021; Lucarini & Radini 2020; Ivanova et al. 2023). For instance, a combined study of use-wear and microfossils was conducted in the Neolithic Haua Fteah cave (northern Libya). Use-wear analysis of grinding stones effectively identified traces from plant processing, while residue analysis revealed starch grains and phytoliths from the Paniceae and Andropogoneae tribes. Additionally, wood macrofossils from the grinding stones suggest that these artefacts might have been used to soften or separate plant fibres for specific tasks such as making cordage (Lucarini et al. 2016). Microfossil residue analysis can also reveal or confirm the consumption of plants not commonly eaten today, such as acorns (Saul et al. 2013; Gismondi et al. 2018; Ge et al. 2021) or the underground storage organs of water lilies (Henry et al. 2011).

Evidence of possible handicraft activities has been found in microremains from Motala in Sweden, where dental calculus analysis revealed phytoliths from *Phragmites* reeds, suggesting that the individual had been consuming or manipulating reeds with their teeth (Norström et al. 2019). In Estonia, the few available studies have focused on diet, either from food crust (Chen et al. 2023) or dental calculus (Unt 2024), but residue analysis has also provided insights into cooking processes. For example, abundant wood remains in food crust and dental calculus might indicate the use of wood as fuel for cooking, or the use of wooden lids, ladles, or sticks to stir the meal.

One advantage of sampling artefacts is that it can be done on items excavated years ago and stored in collections. However, sediment sampling would be necessary for comparisons, as intact sediment samples are ideally needed to rule out contamination from excavation and curation conditions. As Jones and Charles (2009) suggest, to maximise information, an ideal approach would involve sampling sediment, artefacts, and human and animal remains, using a multi-method approach that combines chemical and microscopic residue analyses. Our article focuses on botanical remains, even though the mentioned contexts, such as sediment, food crust, and dental calculus, often reveal other types of microremains, which are also of major importance. For example, diatoms in dental calculus or food crust could indicate the type of water that was used for cooking or fish consumption (Chen et al. 2023); feathers and pollen grains in dental calculus might suggest inhaled dust (Radini et al. 2017; Unt 2024); and fungal spores, depending on the species, could indicate intestinal parasites (Juhola et al. 2019) or unwashed vegetables (Chen et al. 2023).

Call for action

As is evident, the potential of plant macro- and microremains is immense, and much could be achieved in an ideal world. However, realistically, we should start with small steps across various interconnected aspects. First, it is essential to maintain a stable number of researchers who are not affected by fluctuations in science funding. Additionally, as 90% of excavations are development-funded projects, (archaeobotanical) sampling must be integrated into the basic requirements of archaeological fieldwork. Achieving this requires the establishment of a systematic and sustainable research tradition, along with the consistent training of new archaeobotanists. So, how can we build a sufficiently viable research tradition (Fig. 5)?

FIG. 5. The 'gears' of archaeobotanical research. The smaller gears may turn more quickly, but they are as important in the machinery as the larger ones.

First, it is crucial to raise awareness – especially within the archaeological community – about the potential of archaeological plant remains. Second, integrating archaeobotany as a separate course into the study programmes of archaeology, botany, and environmental studies (as suggested by Sillasoo 2005) will help ensure a constant influx of interested students and future scientists. Third, this effort must be closely linked to strong cooperation between universities and the National Heritage Board, particularly regarding sampling requirements. Additionally, fostering cooperation between academic disciplines (e.g. botany, folklore studies, geology, dentistry, and indigenous technology) will support joint projects, attract interested students, and create opportunities for interdisciplinary consultation.

Regarding sampling, we currently have a working guide of good practices (Lõugas 2020) for gathering sediment and charcoal samples, but we need to go further. We should establish precise protocols, describe the nuances of sampling different sites, provide step-by-step instructions, and emphasise the potential of sampling for microfossils. The first guide of this kind will be available shortly (Johanson 2025). We also need agreements on curating artefacts that can potentially be sampled for microfossils or biomolecular analysis, as too intensive cleaning can destroy valuable residues.

A wider discussion is needed to understand the viewpoints of all parties involved in sediment sampling for plant remains in Estonia. Several strategic questions must be addressed, such as: Where should sediment samples be stored? Should each analyst retain a 'backup' sample to ensure replicability, and if so, for how long? What are the requirements for such collection spaces in terms of temperature, moisture, and microscopic airborne pollutants?

In terms of international collaboration, cooperation is already underway with Mia Lempiäinen-Avci in Finland and Anita Radini in Ireland, with the first joint publications (Lempiäinen-Avci et al. 2025) being published and shared supervision of students (Unt 2024). Future plans for international cooperation include expanding collaboration to other neighbouring countries, building shared reference collections, creating databases for the microremains of northern and eastern European plants, and mapping local indigenous plants. Active scientific research is, naturally, a prerequisite for securing funding, but due to the shortage of senior researchers in archaeobotany across the Baltic countries, joint applications could be a viable way forward. Now is the time to set the gears in motion.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in DataDOI at https://doi.org/10.23673/re-496.

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Arheobotaanika Eestis – ajalugu, uurimisseis ja tulevikuperspektiivid

Kristiina Johanson, Agnes Unt ja Sirje Hiie

RESÜMEE

Taimede rolli inimajaloos ei saa alahinnata. Neid on inimajaloo vältel kasutatud toiduks, loomasöödaks, käsitööks, kütuseks ja ehitusmaterjalina ning neist on valmistatud ravimeid ja tarbeesemeid. Vaatamata nende olulisusele on arheobotaanika Eestis siiani võrdlemisi väheuuritud teadusvaldkond. Artikli eesmärk on anda ülevaade arheobotaanika ajaloost Eestis, arutleda valdkonna peamiste

probleemide üle ning rõhutada süstemaatiliselt erinevatest keskkondadest (keraamika, hambakivi, mullaproovid) proovivõtu tähtsust.

Nii Euroopas kui ka Ameerikas sai arheobotaanika alguse 19. sajandil, mil uuriti taimede jäänuseid Egiptuse haudadest, Šveitsi järveasulatest ja Peruu muumiatest. Distsipliin arenes märkimisväärselt pärast flotatsioonimeetodi kasutuselevõttu 1968. aastal. Eestis algasid esimesed makrobotaanilised uuringud 1930. aastatel, kui rauaaegsetest linnustest leiti söestunud teravilja ja herneid. Süsteemne uurimistöö sai alguse 1980. aastate lõpus, kui Tallinnas loodi geoarheoloogia ja muinastehnoloogia labor. 2000. aastate alguses aeglustus uurimistöö majanduse restruktureerimise ja kaevamisrahastuse vähenemise tõttu. Seejärel on arheobotaanilised uuringud Eestis olnud pigem juhuslikud, sageli läbi viidud välisteadlaste kaasabil kohalike arheobotaanikute vähesuse tõttu. Peamised uurimisvaldkonnad on olnud keskaegsete toidutaimede analüüs ning arheobotaanika ja kunsti seosed, kusjuures mõlema teemaga on tugevalt seotud Ülle Sillasoo.

Arheoloogilises kontekstis on makrobotaanilised jäänused tavaliselt söestunud, säilides ainult äärmuslikes tingimustes. Eestis hõlmavad need peamiselt raua- ja keskaegsete linnuste kaevamistel leitud söestunud viljateri ning niisketest ja hapnikuvaestest tingimustest pärit söestumata karpoloogilisi jäänuseid kesk- ja varauusaegsete linnade kultuurkihis.

Makrobotaaniliste jäänuste uurimisseis Eestis on kokku võetud tabelis (Johanson et al. 2024) ja joonistel (jn 2–4). Analüüs hõlmab 173 taimejäänuste kogumise episoodi, mida käsitleti kolme perioodi kaupa: kuni 1980, 1981–1999 ja 2000–2024. Tulemused näitavad, et arheoloogiliste taimejäänuste proovide katvus Eestis on ebaühtlane ja juhuslik. Enamik andmeid pärineb linnakontekstidest, eriti Tartust ja Tallinnast. Rohkem kui pooled (96) andmed on kogutud ajavahemikus 1981–1999 ning neist 47 on pinnaseproovid Tartu linnakaevamistelt. On ka maakondi, kust arheobotaanilisi proove ei olegi kogutud. Enamik taimejäänuseid on kogutud pääste- ja arenduskaevamistel (117) ning vaid 54 juhul probleemkaevamistel. Taimejäänused pärinevad peamiselt pinnaseproovidest (122 juhul), samas kui 49 juhul on neid kogutud pinnasest noppides ning sel juhul on kogutud vaid silmaga nähtavaid, sõelale jäävaid seemneid, näiteks viljateri ja metspähklikoori.

Pinnaseproovide arvu ja suurust muististe lõikes võrreldes selgub, et suurim kogus (222 proovi, igaüks 10 L) on võetud Asva linnusest Uwe Sperlingu juhitud kaevamistel aastatel 2012–2014 ja 2018–2020. Teised ulatuslikumalt kaevatud kohad on Uderna (200 proovi), Tartu VII kvartal (197), Jägala Jõesuu (170), Narva-Jõesuu 2b (106) ja Lossi 3 jäätmekastid (88). Teise perioodi (1981–1999) pinnaseproovid olid võrdlemisi väikesed (100–600 mL), mis oli ilmselt tingitud orgaanikarikkast kultuurkihist, mille puhul see kogus näis piisavalt representatiivne. Kui vaadata taimejäänuste kogumise kontekste, siis kõige arvukamad on asulakohad ning üle poole neist on keskaegse kihistusega. Seitseteist asulat, kust on taimejäänuseid kogutud, on kiviaegsed ning peamiselt on tegu pinnasest nopitud pähklikoortega. Kolmteist on linnamäed, millest kaheksa hilisrauaaegsed, kust on käsitsi nopitud viljateri. Teised muistiseliigid, nagu kalmed, kloostrid, keskaegsed linnused ja laevavrakid, on esindatud vaid üksikute taimejäänuste kogumise episoodidega.

Mikrobotaaniliste jäänuste uurimine Euroopas algas õietolmu ja tärklise vaatlemisega juba 17. sajandil, mil mikroskoopide ehitus võimaldas osakesi ära tunda. Arheoloogilise tärklise määramiseni jõuti aga alles 1970. aastate lõpus ja 1980. aastate alguses, mil avaldati esimesed publikatsioonid kiviesemetelt eraldatud tärkliseterade kohta. Fütoliitide uurimine algas 19. sajandil ning juba 20. sajandi alguses ilmusid ka esimesed arheoloogilisel materjalil põhinevad uurimused, ent fütoliitide uurimise tõeline õitseng on toimunud viimase paarikümne aasta jooksul.

Fossiilset õietolmu geoloogilistest kihistustest uuriti samuti juba 19. sajandil, ent selle potentsiaal realiseerus alles 1916. aastal, kui Lennart von Post pani aluse tänapäevasele kvantitatiivsele õietolmuanalüüsile. Sellest ajast alates on õietolmuanalüüsi peamised uurimisvaldkonnad olnud biostratigraafia, paleoökoloogia ning taimkatte ja kliima muutused. Alates 1980. aastatest on õietolmu uuritud ka arheoloogilistest kontekstidest, nagu koproliidid, matmispaigad, hoonete asemed ja savinõud, kuid see valdkond on pälvinud võrdlemisi vähe tähelepanu.

Fütoliite, tärkliseteri ja õietolmu kogutakse erinevatest arheoloogilistest allikatest, sealhulgas pinnasest, savinõude kõrbekihist, hambakivist, koproliitidest ja esemete pinnalt.

Õietolmu analüüs Eestis sai alguse 1920. aastatel, mil palünoloogide kaasabil asuti dateerima kiviaegseid asulakohti. Nõukogude ajal nihkus fookus taimkatte ja kliima muutuste uurimisele. Alates 1980. aastatest keskenduti inimmõju ja varase viljelusmajanduse märkidele õietolmuandmetes, mis viis tiheda koostööni arheoloogide ja palünoloogide vahel. Teraviljade tüüpi õietolmu esinemist puursüdamikes on tõlgendatud kui märki põllumajandusest, ent viimastel aastatel on meetodi kitsaskohtade üle tekkinud arutelu.

Arheoloogilise tärklise ja fütoliitide uurimine on Eestis alles lapsekingades. Pinnaseproovidest võetud fütoliite ja õietolmu on analüüsitud rahvusvaheliste projektide raames ja ka välisekspertide poolt, näiteks Karksi ordulinnuse ja Jägala Jõesuu proovidest. Eesti laborites ei ole siiani arheoloogilisest pinnasest tärklist ja fütoliite eraldatud, kuid esimesed uuringud savinõude kõrbekihist ning hambakivist leitud tärklise ja fütoliitide kohta on juba ilmunud. Lätis, Leedus ja Soomes on mikrojäänuste uurimine samuti algusjärgus ning seni on ilmunud vaid üksikud käsitlused fütoliitide ja tärklise leidudest keraamika kõrbekihis ja hambakivis. Seevastu Rootsis, Taanis ja Norras on mikrojäänuste uuringud – nii hambakivist, tööriistade pinnalt kui ka kõrbekihist – olnud märksa järjepidevamad.

Peamised murekohad Eesti arheobotaanika uurimisseisus võib kokku võtta järgmiselt:

1. Eesti arheoloogiliste muististe arheobotaaniline teadmus on väga ebaühtlane ning valdav osa informatsioonist pärineb kesk- ja uusaegsetest linnadest. Pinnaseproovide võtmise kohustuse puudumine suurendab ebavõrdsust veelgi.

Mineviku taimekasutusest diakroonilise pildi saamiseks, nii üle-eestiliselt kui ka erinevatest Eesti piirkondadest, on oluline lisada kõigi arheoloogiliste kaevamiste minimaalsete nõuete hulka ka pinnaseproovide kogumine. Samuti tuleks välja töötada selge proovide võtmise strateegia, mis aitaks tagada proove erinevate perioodide muististelt.

2. Pinnaseproove erinevate taimsete jäänuste tuvastamiseks (nt õietolm, tärklis, fütoliidid ja karpoloogilised jäänused) on siiani võetud väga vähe. Sellised juhtumid on üksikud, näiteks nn Riia eeslinn Tartus (Küüni 5 ja 7), Karksi ordulinnus, Pulli asulakoht ja Vabaduse väljaku asulakoht Tallinnas. Karksis näitas õietolmuanalüüs teraviljade tüüpi õietolmu suurt osakaalu. Kuna teraviljad isetolmlejatena eraldavad vähe õietolmu, siis järeldati, et õietolm pärines tõenäolisemalt teraviljade töötlemise kohast, mitte läheduses paiknenud põldudelt.

Erinevatel taimsetel jäänustel on erinevad eelised ja kitsaskohad, mis puudutavad nende säilimist, taksonoomilise määramise täpsust ja potentsiaali uurimisküsimustele vastamiseks. Näiteks on karpoloogilised jäänused, mille säilivus on kõige kehvem, samas kõige paremini liigini määratavad. Fütoliitide puhul, mis säilivad igas keskkonnas, on seni perekonnani määratavad vaid mõned enamlevinud kultuurtaimed. Sageli on ühe fütoliidi kuju iseloomulik mitmele erinevale taimeperekonnale. Seda arvesse võttes on oluline uurida mikro- ja makrojäänuseid kombineeritult, et suurendada väljakaevamistelt saadava informatsiooni hulka ja teha kindlamaid järeldusi mineviku taimekasutuse kohta.

3. Mineviku taimekasutuse mõistmiseks on tähtis järjepidevalt analüüsida ka teistest keskkondadest, näiteks hambakivist, keraamikast ja muude esemete pinnalt ja seest võetud proove. Eesti vähesed uurimistööd on keskendunud savinõude kõrbekihist ja hambakivist pärit mikrojäänustele eelkõige toitumise analüüsimise ja toidutaimede otsimise eesmärgil. Samas võib mikrojäänuste analüüs osutada ka toidutootmise protsessidele; näiteks võivad kõrbekihtidest ja hambakivist leitud puiduosakesed viidata kütteks kasutatud puidule, puidust potikaantele või segamiseks kasutatud kulpidele-okstele.

Taimede makro- ja mikrojäänuste potentsiaal arheoloogias on tohutu, kuid edusammud peaksid algama väikeste sammudega. Oluline on tekitada stabiilne arv arheobotaanikaga tegelevaid teadlasi ja integreerida arheobotaanika õppekavadesse. Tugev koostöö ülikoolide, muinsuskaitseameti ja erinevate akadeemiliste distsipliinide vahel on hädavajalik. Tuleks välja töötada protokollid proovide võtmiseks ja leidude hoiustamiseks, et tagada mikrojäänuste ja biomolekulaarsete analüüside võimalus.