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RESEARCH REPORT

Cereal cultivation in east-central Jutland during the Iron Age, 500 BC–AD 1100

Radoslaw Grabowski*

Department of Historical, Philosophical and Religious Studies, Environmental Archaeology Laboratory, Umeå University, SE-90187 Umeå, Sweden

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This article aims at presenting a cereal cultivation history for the Iron Age (500 BC–AD 1100) in east-central Jutland (Vejle and Århus County).

The developments in cereal cultivation are presented based on recent investigations of material from the Iron Age sites of Gedved Vest and Kristinebjerg Øst, as well as a compilation of 10 previously analysed sites.

The combined data show that barley (*Hordeum vulgare*) was the dominant cereal throughout the period, with a seemingly rapid shift from naked barley (*Hordeum vulgare* var *nudum*) to hulled barley (*Hordeum vulgare* var *vulgare*) around the year 1 BC/AD. Rye (*Secale cereale*) is present in archaeobotanical assemblages throughout the period, but secure evidence of its cultivation exist only from the end of the second century AD onward. From the fourth century AD onward, the record indicates that rye may have been utilised as a dominant crop alongside barley.

The cultivation of subdominant cereals, hulled wheats (*Triticum dicoccum/spelta/monococcum*), naked bread wheat (*Triticum aestivum*) and oat (*Avena sativa*), is also discussed. A reappearance of naked barley during the fourth to sixth century AD is also elaborated upon.

Agricultural strategies are assessed based on the material and an interpretation is put forward that cultivation from the fifth century BC to at least the third century AD took place on manured, spring sown fields, which were slowly rotated between cultivation and fallow. The shift toward crop-rotation of barley and rye is also investigated; tenuous evidence of which are dated to the late second century AD and secure evidence occurring from the ninth century onward.

The article also addresses issues of archaeobotanical interpretation, and a way of increasing the resolution of archaeobotanical investigations is illustrated by examples from Gedved Vest where plant macrofossil analysis was combined with geochemical (phosphate analysis and analysis of soil organic matter) and geophysical (magnetic susceptibility) methods.

Keywords: cereal cultivation; Iron Age; Jutland; Denmark; south Scandinavia; archaeobotany; plant macrofossil analysis; phosphate analysis; magnetic susceptibility; settlement archaeology

Introduction

Since its introduction, around 4000 BC, cereal cultivation has been one of the primary components of the subsistence economies of southern Scandinavia.

The discipline of archaeobotany, with a history of research in south Scandinavia spanning over a hundred years, has since its very beginning pursued the study of cereal cultivation as one of its main research areas (Robinson 1994, Grabowski 2011, and therein presented historiography). The ongoing accumulation of archaeobotanical data has provided archaeology with numerous insights about cereal cultivation and its links to other facets of prehistoric societies.

The always fragmented nature of the archaeological record, as well as the changing geographic, methodological and theoretical focus of archaeologists has, however, resulted in the insights of archaeobotanical research being unevenly distributed. This particularly applies to geographic and chronological coverage, with some areas and periods being notably underrepresented in scientific publications (Robinson *et al.* 2009, Grabowski 2011). There are also numerous phenomena connected to cereal cultivation which, although being well researched, are still in need of further data gathering, interpretation and discussion.

Aims

The primary aim of this article is to present a cereal cultivation history for east-central Jutland covering the Iron Age, that is circa 500 BC–AD 1100.

The main investigation area has been delineated to the former amts (counties) of Vejle and Århus. This area has previously been noted as an underrepresented region in archaeobotanical research (Robinson *et al.* 2009).

Within the PhD-project of which this article is part, two sites have recently been analysed at the Environmental Archaeology Laboratory at Umeå University:

(1) HOM 2247 Gedved Vest, a large site with settlement continuity spanning from period V/VI of the Bronze Age to the Viking Age.

*Email: radoslaw.grabowski@arke.umu.se

(2) VKH 7087 Kristinebjerg Øst, with one analysed house dating to approximately AD 800.

The data from these sites is used as the main empirical material of the presented study, along with a compilation of all hitherto analysed relevant archaeobotanical assemblages from the investigation area (see Table 1).

A second aim of this article is to discuss and address some of the complexity inherent to archaeobotanical inference in Scandinavian prehistoric settlement contexts. The analysis of Gedved Vest is therefore also presented as a case example of how archaeobotany may be correlated against geochemical and geophysical methods in order to achieve a better understanding of the material under study (see also Grabowski and Linderholm 2013).

Previous research

General overview of interpretations of Iron Age cereal agriculture in southern Scandinavia

Results from archaeobotanical investigations have over the last hundred years been accumulating in the form of reports of analysed sites and single finds of specific interest, interspersed by occasional attempts at regional syntheses of available data (e.g. Hjelmqvist 1979, Engelmark *et al.* 1992, Robinson 1994, Regnell 2002, Robinson *et al.* 2009, Grabowski 2011, Jensen and Andreasen 2011). Numerous studies from the former category have provided in-depth insights into specific aspects of cereal cultivation, while the latter category has allowed for identification of larger scale geographic and/or chronological trends.

Generalising broadly, south Scandinavian cereal cultivation may be seen as having gone through two main transformations during the last two millennia of prehistory, that is *c*. 1000 BC–AD 1100.

Early Iron Age: intensification of cultivation, possible beginning of manuring, and the establishment of hulled barley as a dominating crop

Cereal cultivation during the latter part of the Bronze Age and the earliest phases of the Iron Age was developed from a long agricultural tradition established during the Neolithic. This earlier agriculture was based on two main groups of cereals: barley of the naked variety (*Hordeum vulgare* var *nudum*) and hulled wheats; emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*) and spelt (*Triticum spelta*) (Robinson 1994, 2003, Engelmark and Viklund 2008, Andreasen 2009).

Evidence about the modes of cultivation during the Neolithic and early Bronze Age is scarcer than for most periods, and what has been obtained is often difficult to interpret. Numerous interpretations of available data have proposed that the abovementioned crops were cultivated on unmanured fields within a framework of an area-extensive agriculture utilising wandering fields in a woodland meadow setting otherwise used for animal grazing (Hedeager and Kristiansen 1988, Gustafsson 1998, Robinson 2000, Göransson 2001, Welinder 2004, p. 136, Andreasen 2009). Arguments for such cultivation are the availability of land during the early periods of agriculture and a lack of traces from permanent or semi-permanent cultivation in the landscape-archaeological record dating to the Neolithic and early Bronze Age. This perception has, however, increasingly been questioned based on new data, some researchers calling for the possibility of both permanent fields and manuring already during the Neolithic (for Scandinavia see Regnell and Sjögren 2006, p. 134 and therein cited references). Combining the current sources of evidence, one may argue for a Neolithic and early Bronze Age agriculture utilising both area-extensive and more permanent solutions in a flexible manner, adapting to local ecological and social conditions.

The first of the mentioned agricultural transformations was a shift away from the presumed area-extensive way of cultivating crops towards more permanent fields typical of the mid Iron Age. Physical evidence of more permanent cultivation can be seen in the archaeological record in the form of fossil fields, areas with stone clearance cairns (primarily in southern Sweden), field enclosures and changing settlement patterns (Hatt 1949, Lagerås and Bartholin 2003, Welinder 2004, p. 136f, Widgren 2010).

This transformation appears on a general level to have coincided with some major changes in the choice of crop species. The hulled wheats appear by the beginning of the Iron Age to have assumed a distinctly marginal role, together with naked bread wheat (*Triticum aestivum*) which, although present from the early Neolithic onward, always appears to have been cultivated on a limited scale. Naked barley also decreased, seemingly being replaced by the hulled variety (*Hordeum vulgare* var *vulgare*), which over the course of the Iron Age became the dominating crop (Engelmark *et al.* 1992, Robinson 1994, Robinson *et al.* 2009).

Numerous interpretative models have been proposed on the intensification of cereal cultivation at the shift from the Bronze to the Iron Age, about the changing role of crops and about the possible causal links between these phenomena (for a detailed overview of the recent discussion see Hedeager and Kristiansen 1988, Lagerås and Regnell 1999, Regnell 2002, Mikkelsen and Nørbach 2003, Robinson 2003, Regnell and Sjögren 2006, Robinson *et al.* 2009, Grabowski 2011). Most important is perhaps the discussion surrounding the timing of when manuring was introduced and its possible link to hulled barley.

Engelmark *et al.* (1992) proposed that the two phenomena are interconnected based on hulled barley's better tolerance to over-manuring and the suitability of its straw

Table 1. List of previously performed archaeobotanical analyses in east-central Jutland with a summary of the results.

Site no	Site/feature name	Context type	Chronology	Plant finds other than cereal grains	Reference
1	Randers, Frederiksdalvej, Pit CET	Pit with presumably mixed secondary/tertiary depositions.	Stratigraphically, pre-Roman Iron Age (*c.* 500 BC–AD).	Spring-annual arable weeds, *Camelina sativa*, grassland and wetland plants, heather and hazelnuts.	Robinson and Petersen (1994)
2	FHM 4862, Grenåvej, House 2	Longhouse, most likely not burnt. Samples derive from two roof-supporting postholes.	Typologically, early pre-Roman Iron Age (*c.* 500–250 BC) and 14C: 749–208 BC (2σ).	*Persicaria lapathifolia* (spring annual arable weed).	Andreasen (2008), Moesgård Database
2	FHM 4862, Grenåvej, Pits	Cluster of pits, presumably containing mixed secondary and tertiary deposits.	Typologically and by association to other settlement remains, early pre-roman Iron Age (*c.* 500–250 BC).	Spring-annual arable weeds, *Camelina sativa, Linum usitatissimum*, grassland and wetland plants and hazelnuts.	Andreasen (2008), Moesgård Database
3	Århus, Børglumvej, House I	Longhouse, most likely not burnt.	Typologically (house type and pottery), later pre-Roman Iron Age (*c.* 200 BC–AD).	Spring-annual arable weeds, possible grassland taxa and heather.	Aaby *et al.* (1994)
4	Århus Søndervold, House CME	Pit-house, presumably burnt.	Typologically, later Viking Age (*c.* 900–1100).	Spring-annual arable weeds and autumn-annual and perennial arable weeds.	Fredskild *et al.* (1971)
4	Århus Søndervold, House OU	Pit-house, presumably burnt.	Typologically, later Viking Age (*c.* 900–1100).	Single *Poaceae* seed.	Fredskild *et al.* (1971)
6	SBM 983, Kildebjerg I, Kiln K21	Kiln, deposit from active period of feature, may consist of repeated carbonisation events over an undefined period of time.	Typologically and by association to other settlement remains, pre-Roman Iron Age (*c.* 500 BC–AD).	Spring-annual arable weeds, *Camelina sativa* (large find, hundreds of seeds meted into 'lumps') and single find of *Carex* sp.	Jensen and Mikkelsen (2006), Moesgård Database
6	SBM 983, Kildebjerg I, Pit A4851	Pit with presumably mixed secondary/tertiary depositions.	Typologically and by association to other settlement remains, pre-Roman Iron Age (*c.* 500 BC–AD).	Spring-annual arable weeds, possible grassland taxa and *Lolium perenne.*	Jensen and Mikkelsen (2006), Moesgård Database
7	SBM 1101, Golf 11, House K11	Longhouse, unknown whether burnt or unburnt, only a single sampled posthole.	Typologically, late Roman Iron Age (*c.* AD 200–400) and 14C: AD 255–532 (2σ).	Spring-annual arable weeds, hazelnuts.	Andreasen (2011, 2011), Moesgård Database
7	SBM 1101, Golf 11, Iron furnace JP484	Iron extraction furnace.	Typologically *c.* 200 AD–1000 and C14: AD 133–326 (2σ).	Spring- and autumn-annual arable weeds, *Lolium perenne,* cereal straw (cf. *Secale*).	Andreasen (2011, 2011), Moesgård Database

(*continued*)

Table 1. (*Continued*).

Site no	Site/feature name	Context type	Chronology	Plant finds other than cereal grains	Reference
7	SBM 1101, Golf 11, Iron furnace JP485	Iron extraction furnace.	Typologically *c.* 200 AD–1000 and C14: AD 255–405 (2σ).	Spring- and autumn-annual arable weeds, *Lolium perenne,* cereal straw (cf. *Secale*).	Andreasen (2011, 2011), Moesgård Database
8	HOM 1892, Galgehøj, Pit A3402	Pit, presumably containing mixed secondary and tertiary deposits; however, a major portion of the deposit appears to derive from accidentally charred, cleaned, barley cache deposited post-burning inside the pit.	Association to surrounding settlement and pottery, early pre-Roman Iron Age (*c.* 500–250) and 14C: 387–50 BC (2σ).	Spring-annual arable weeds.	Jensen (2009a), Moesgård Database
9	HOM 2288, Møllersmindevej, Pit A317	Pit with presumably mixed secondary/tertiary depositions.	Pottery, early pre-Roman Iron Age (*c.* 500–250 BC) and 14C: 405–207 BC (2σ).	Spring-annual arable weeds, *Camelina sativa, Linum usitatissimum*, grassland and wetland plants.	Jensen (2009b), Moesgård Database
10	HOM 2295, Kværnbæksgård, Pits	Numerous pits with presumably mixed secondary/tertiary depositions	Pottery, pre-Roman Iron Age (*c.* 500 BC–AD).	Spring-annual arable weeds, grassland and wetland plants and hazelnuts.	Grabowski (2009), Moesgård Database
5	MKH 1588, Viuf Vesterby 2, Pit-house III	Deposit inside pit-house. Unknown whether burnt or unburnt. Unknown whether grain is a primary, secondary or tertiary deposit.	Typologically and through settlement context, Viking Age (*c.* AD 550–1100) and 14C: AD 888–1024 (1σ?).	Spring-sown arable weeds.	Andreasen (2010), Moesgård Database

Notes: The compositions of cereal grain finds from the listed sites are presented in Figure 2. The site numbers in this list correspond to the ones in Figures 1 and 2. For detailed data on the composition of each assemblage, refer to Supplementary material 1.

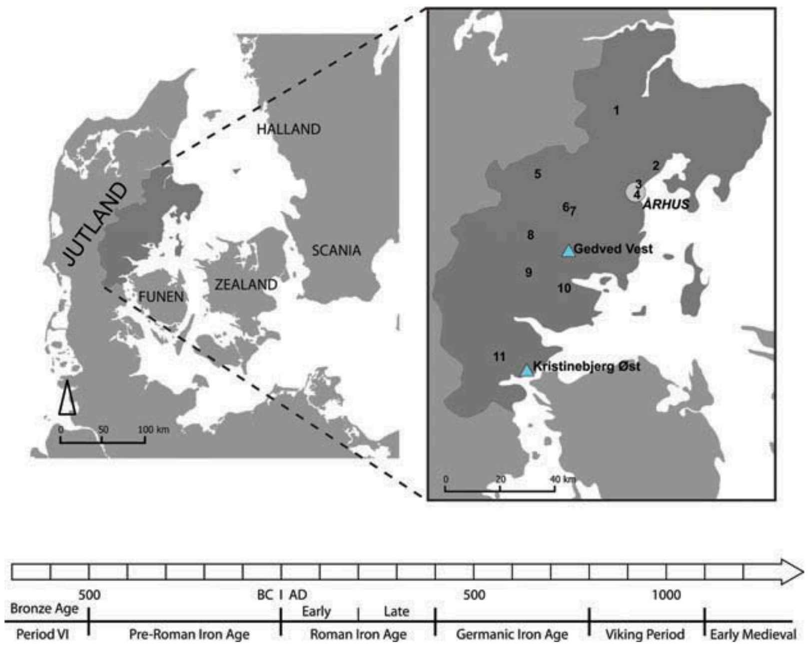

Figure 1. Map of southern Scandinavia, showing regions mentioned in the text as well as an outline of the main investigation area. The close-up map shows the location of the analysed sites of Gedved Vest and Kristinebjerg Øst, as well as sites from which previously analysed archaeobotanical assemblages have been compiled (numbers 1–10, cf. Table 1).

as animal fodder. A correlation between the appearance of hulled barley and nitrophilous weeds (preferring manured soils) in archaeobotanical assemblages and the contemporaneity between hulled barley and byre-indicating evidences in settlement-archaeological data have been proposed as a link between the two phenomena.

The identification of byres and other stabling indicators in the settlement-archaeological record is, however, an active and not completely resolved topic amongst archaeologists and may be seen as a weak link in the Engelmark's model (e.g. Viklund *et al.* 1998, Carlie 1999, Lagerås and Regnell 1999, Ethelberg 2000, Streiffert 2001, Peterson 2006).

The manure-hulled barley connection has also been questioned on the basis of some of its theoretical assumptions; the most commonly cited being whether the increase of nitrophilous weeds truly indicates changing field conditions rather than altered harvesting and processing techniques (e.g. Lagerås and Regnell 1999, Robinson 2003, Regnell and Sjögren 2006). A hypothetical, but archaeologically unsubstantiated, change from hand plucking of cereals close to ears to sickle-based harvesting close to the ground (in order to bring in the straw as fodder) may for example have radically changed the quantities of weeds, making their way into the charred archaeobotanical assemblages. Thus, manuring could have been in use prior to the end of the Bronze Age, invisible in the archaeobotanical carbonised material (Regnell and Sjögren 2006).

The use of weeds as indicators for field conditions on anything more than a general level has also been put into question (Bogaard *et al.* 2013). An alternative approach utilising analysis of the isotopic signature of carbonised cereal grains has been presented as an alternative method of investigation and may in the near future begin to complement the indications obtained from analysis of weed finds. These analyses are, however, in the early stages of method development and application on prehistoric archaeological material and thus currently unable to provide solid clues about the timing of manure introduction in south Scandinavia (Bogaard *et al.* 2013, Kanstrup *et al.* 2013).

The growing corpus of archaeobotanical results also challenges the connection between hulled barley and manuring because the transition from the naked to the hulled variety appears to have been less rapid and later in many parts of southern Scandinavia than in Scania: the region that provided the empirical material for the hulled barley–manure hypothesis. Currently available evidence indicates that hulled barley was introduced on a large scale at the end of the Bronze Age in Scania and Zealand, areas where it dominates most but by no means all botanical assemblages already during pre-Roman Iron Age. In other areas such as northernmost and southernmost Jutland, Halland and, to some extent, also Funen, however, naked barley appears to remain in cultivation as one of the primary crops well into the Roman Iron Age, long past the date when other segments of the archaeological record indicate at least partial use of animal stabling and manuring (Engelmark *et al.* 1992, Robinson 2003, Robinson *et al.* 2009, Grabowski 2011, Jensen and Andreasen 2011).

Other proposed hypotheses for the introduction and eventual domination of hulled barley include resistance to increasing humidity and other environmental change (Helbæk 1957), suitability for beer brewing (Mikkelsen and Nørbach 2003), tolerance to more efficient but forceful harvesting techniques with new iron implements (naked barley grains are comparatively loose, which may result in significant loss of grain if they are harvested forcefully; Hillman 1984, Mikkelsen and Nørbach 2003) and changing food habits (Skoglund 1999). All of these hypotheses are difficult to substantiate on the basis of currently available data, neither can they be refuted, and must therefore be considered as possible causal factors in future research.

Regardless of which choices and processes prompted the shift away from hulled wheats and naked barley, it is clear from the investigated material that hulled barley by the middle of Roman Iron age was the main crop across the south Scandinavian region (Robinson *et al.* 2009, Grabowski 2011). The weed flora accompanying the cereals in archaeobotanical assemblages, as well as other types of archaeological data, also indicate that manured, so called *permanent*, fields were in use across most of the region (Engelmark *et al.* 1992, Gustafsson 1998, Robinson 2003).

The term *permanent field cultivation*, commonly used in archaeobotanical literature (e.g. Engelmark *et al.* 1992, Gustafsson 1998, Grabowski 2011), is perhaps slightly misleading and could for the sake of clarity be termed as a *slow rotation semi-permanent cultivation utilising manure*.

Manuring of the Iron Age fields would have allowed for a replenishing of the nutrient content, extending their active use to several years or possibly decades. Eventually, however, cultivation would most likely have become unsustainable because of increasing problems with weed and insect infestation (Engelmark *et al.* 1992). A presumed solution to this problem would have been a slow rotation of fields between active use and fallow. The fallow fields in such a system could have been utilised as pasture or meadow spaces, providing a portion of the fodder necessary to feed the manure producing animals. Additional sources of fodder could have been obtained from wetlands unsuitable for cultivation and from leaf fodder from coppiced or pollarded trees.

It should be noted that the archaeological evidence from the first halves of the Iron Age in most of southern Scandinavia does not indicate a fully developed infield–outfield system, such as that known from later periods, although some tendencies towards a division of the landscape along similar lines may already have begun (Fabech and Ringtved 2009). It is likely that the rotation of fields between active use and fallow would have created a patchy and somewhat extensive distribution of cultivated land and foddering space. A source of evidence for this may be seen in the physical traces of the fields themselves. The remnants of the so called *celtic fields* in Sweden and Denmark have often been discussed from the perspective of ownership, inheritance and land regulation (e.g. Hatt 1949, Widgren 1997, p. 32, Holst *et al.* 2010), but their size and distribution may also be a partial result of a rather complex sequence of clearance, use and fallow, each cycle spanning several decades (cf. Lang 2007, p. 105). At the very least, any regulated division of land in connection to inheritance events must have taken into account the quality of the fields as productive units within the existing agricultural system. The stone clearance fields common in some areas of southern Sweden can be interpreted along similar lines and have been proposed as indicators for a semi-permanent cultivation (e.g. Lagerås and Bartholin 2003, Widgren 2003).

Late Iron Age: appearance of crop-rotation, infields–outfields and rye as new staple of south Scandinavian agriculture

The introduction of a more defined infield–outfield landscape organisation was presumably one of the main components of the second transformation of Iron Age cereal agriculture.

Historical as well as archaeological evidence shows that agriculture at the beginning of the medieval period was distinctly different from that practiced during the middle of the Iron Age (Myrdal 1999, Fabech and Ringtved 2009). The infield–outfield concept can broadly be defined as a binary division of land into an intensively worked space close to the settlement, containing the majority of the cultivation and fodder generating areas (primarily meadows for hay gathering), and a less intensively used surrounding area utilised for grazing, fodder collection, wood resources and gathering of wild plants (Christiansen 1978, Fabech and Ringtved 2009). It should, however, be noted that the prehistoric record in south Scandinavia shows significant variation with regard to archaeological remains, indicating management of the landscape along infield–outfield principles (Pedersen and Widgren 2004, Fabech and Ringtved 2009). Näsman (2009, p. 106), among others, argues that:

> *One should be open to the possibility that a distinct infield–outfield system was only established on better soils, and that a more loosely structured grazing practice continued in western Denmark (my translation).*

A possible scenario is that the trend toward a division of land into spaces utilised at varying intensity and the thereof resulting fixation of cultivation (and possibly also settlement) took place at varying pace in different parts of the south Scandinavian region. The resulting landscape arrangements would as a result range from distinctly developed infields–outfields to a loose adaptation of the same principles in which earlier strategies could have remained more or less intact or where alternatives to strict infields–outfields could be developed.

Because the infield–outfield concept requires a more fixed and permanent siting of arable fields than the preceding semi-mobile agriculture, the problems with nutrient depletion and weed-pest infestations must, however, be solved by new cultivation strategies. Strategies that became dominating across southern Scandinavia throughout the entire medieval period were various versions of crop-rotation systems. In such systems, the problem of increasing infestation was solved by dividing the arable land into sections. Some of these were cultivated with spring sown crops, in Scandinavia traditionally hulled barley, while others were used for autumn sown crops. Commonly, a period of fallow was also incorporated in each rotation cycle. The alternation between spring and autumn sowing in such system disturbs the life cycles of the pests, decreasing their competitiveness on the fields, while the period of fallow followed by intensive tilling destroys the root systems of existing weeds (Engelmark *et al.* 1992, Mikkelsen and Nørbach 2003, p. 132).

The crops cultivated by the farmers of the early and middle Iron Age were most likely all spring sown, an indication deduced by the predominance of spring annual arable weeds in the archaeobotanical assemblages (Engelmark *et al.* 1992, Viklund 1998, Andreasen 2009). Therefore, in order to function, the three-partite rotation of the medieval period necessitated the introduction of an autumn sown crop. This role was filled by rye (*Secale cereale*), which towards the end of the Iron Age and throughout the medieval period complemented hulled barley as the staple crop of the region. Ryes' lower demand on soil nutrient content also meant that the fields only needed to be fertilised once per rotation cycle as opposed to each year, or every couple of years, when cultivated exclusively with hulled barley (Engelmark 1989, Mikkelsen and Nørbach 2003).

Similarly to the first of the mentioned agrarian transformations, the introduction of autumn rye, crop-rotation and infield–outfield organisation is not easy to date and trace across the region. Archaeobotanically, the presence of rye has been one of the most widely used indicators, although it is far from an unproblematic one. This is because rye initially spread to the south Scandinavian region as a weed, growing unintentionally with planted crops. This is reflected in the archaeobotanical material as small inclusions of rye grains in assemblages, otherwise interpreted as clean barley or wheat harvests; the earliest occurrences dating to the end of the Bronze Age (Behre 1992, Robinson 2003, Regnell and Sjögren 2006).

After this initial period of weed presence, rye may have been grown for a period of time as an independent crop, in ways similar to the dominating barley, that is spring sown and not within a fully developed rotation system.

Behre (1992) suggests that it was ryes' ability to compete on lower nutrient fields that prompted the Iron Age farmers to adopt it as a crop in the first place. If ryes' ability to outcompete other cereals on certain types of soils was as obvious as presumed by Behre, the initial period of independent cultivation may have provided Iron Age farmers with observations necessary for the formulation of concepts and botanical understanding necessary for its subsequent inclusion in a crop-rotation regime. Alternatively, if crop-rotation was inspired from areas outside the south Scandinavian region, the initial period of cultivation may have demonstrated the suitability of rye cultivation under the specific conditions prevailing in southern Scandinavia. Although difficult to prove by archaeobotanical means, rye could through experimentation and experience have ended up being grown on either soils, which were too poor or sandy for barley and wheat cultivation, or on fields in a stage of the slow rotation sequence best suitable to its requirements (Engelmark *et al.* 1992).

The presumed independent cultivation of rye is one of the reasons why the introduction of rye–barley rotation is difficult to delineate in time and space. Traditionally, the presence of rye in quantities on par to those of barley has been proposed as evidence for crop-rotation (Engelmark *et al.* 1992, Regnell 2002). The interpretative problem lies in the fact that the archaeobotanical record in most cases is the end result of complex formational and taphonomic processes. In many cases, the record is an amalgamation of events, which cannot be separated by means of available methodology. Thus, it is impossible to say whether an approximately similar amount of rye and barley on a site truly represents the conditions in the fields.

For that reason, two additional archaeobotanical strategies have been used to distinguish autumn sown rye. The first is identification of weed taxa, which are historically and ethnographically documented in autumn cultivation. The two most commonly cited species are *Agrostemma githago* and *Centaurea cyanus*. The first of these appears in south Scandinavian assemblages from the sixth century AD, while the second appears at the end of the Viking Age and the beginning of the medieval period (Jessen and Lind 1922, Grabowski 2011). A third species cited in literature is *Bromus secalinus*, which thrives in autumn sown rye fields (Kroll 1987, Mikkelsen and Nørbach 2003). This species is, however, also tolerant to other environments and appears even to have been periodically cultivated for its seeds. It is recovered from various archaeobotanical contexts throughout most of prehistory, thus making it a problematic indicator for delineating the beginning of autumn sowing (Hillman 1981, Korsmo *et al.* 1981, Engelmark *et al.* 1992, Gustafsson 1998, Robinson 2002, Regnell and Sjögren 2006).

Based on the reasoning above, the beginnings of crop-rotation and autumn sowing, and by extension possibly the shift to an infield–outfield landscape utilisation, have been placed to sixth to seventh century at its earliest, with clear evidence being available from eighth to tenth centuries onward.

Recent findings from Denmark have, however, put the above model into doubt by questioning the link between *Agrostemma githago* and *Centaurea cyanus* and the earliest autumn rye cultivation. Neither of these species is native to Scandinavia, and although they have historically been linked to autumn sowing, there is no evidence that this was the case in prehistory. Mikkelsen, for example, argues that these species may very well have been introduced to the region after crop-rotation was established as a result of an unrelated process, possibly the growing grain trade in the Baltic region, which presumably started at the very end of the Iron Age (Henriksen 2003, Mikkelsen and Nørbach 2003).

Recent studies have therefore attempted to circumvent some of the problems of archaeobotanical material from settlement contexts by analysis of a specific type of feature, namely the iron extraction furnace.

In such furnaces, organic material, occasionally cereal straw, was used in the smelting procedure. On occasion, unprocessed cereals were utilised, presumably collected in nearby fields directly prior to use. This appears in the material as finds of complete cereal plants, often with soil still clinging to the roots, accompanied by a clearly unsorted weed material. Since the iron extraction furnaces were single-use features, Mikkelsen argues that the unprocessed cereal material found within some of them must represent single harvests. Statistical analysis of such features containing clean barley and clean rye finds have shown that the weed flora differs significantly for each respective crop, something that would not be the case if they were both spring grown within the same slow rotation system. By means of statistical analyses, Mikkelsen has defined new criteria for identification of autumn sowing from weed data, one based on changed numerical relationships between existing taxa rather than the appearance of completely new species. Some of the increasing species defined as particularly important are *Rumex acetosella, Lolium perenne* and *Triplospermum perforatum* and *Polygonum* aviculare. The furnaces which produced indications for autumn sowing have, on basis of site typology, artefacts and ^{14}C-data, been interpreted as being in use around AD 380–540. Mikkelsen thus argues for an establishment of autumn rye and crop-rotation as early as the Roman Iron Age (Mikkelsen and Nørbach 2003).

The identification of autumn sown rye and crop-rotation through analysis of iron furnaces is, however, not without problems. Although the majority of the furnaces analysed by Mikkelsen contained unthreshed material, this is not always the case. If furnaces are interpreted as being filled with processed straw, the same limitations of archaeobotanical interpretation apply to this material as to any derived from settlement contexts. Furthermore, the practice of filling furnace pits with cereal straw is limited in space and time; all the hitherto analysed furnaces are located in southern Jutland and all are dated to the Roman and Germanic Iron Age. This chronological and geographic distribution makes it difficult to evaluate the representativity of the results on more than a local scale. That caution is needed can be argued by reference to the most basic of archaeobotanical data, namely the relative percentages between cereal species. There is a discernable trend of rye appearing in larger quantities early on in western and southern Jutland and in Halland, but later in Scania, Zealand and to some extent Funen (Regnell 2002, Robinson *et al.* 2009, Grabowski 2011, Jensen 2012). Thus, the interpretation of early crop-rotation based on material from iron furnaces in south Jutland may well be true for that particular area, where it corresponds with the rye–barley numbers, while the model of a late introduction could still apply to other parts of the south Scandinavian region.

Previous plant macrofossil analyses in east-central Jutland

As previously mentioned, east-central Jutland is one of the underrepresented regions in archaeobotanical publications (Robinson *et al.* 2009). During the last decade, however, a number of sites have been analysed.

To avoid inclusion of archaeobotanical material with poor representativity, a condition for including a previously analysed assemblage in this study was that it should contain at least 50 carbonised plant remains (see discussion in Robinson *et al.* (2009, p. 121)). This resulted in the compilation of 15 unique assemblages (i.e. spatially and chronologically delineated botanical units, for example: a single house, a specific pit, etc.) distributed across 10 sites.

The material is unevenly distributed throughout the Iron Age, with nine contexts dating to pre-Roman Iron Age, three to late Roman and early Germanic period and three to the Viking Age.

Pre-Roman Iron Age

The material from pre-Roman Iron Age shows that naked barley dominates in seven out of nine assemblages.

The hulled variety of barley was only retrieved in larger quantities in two assemblages, both derived from

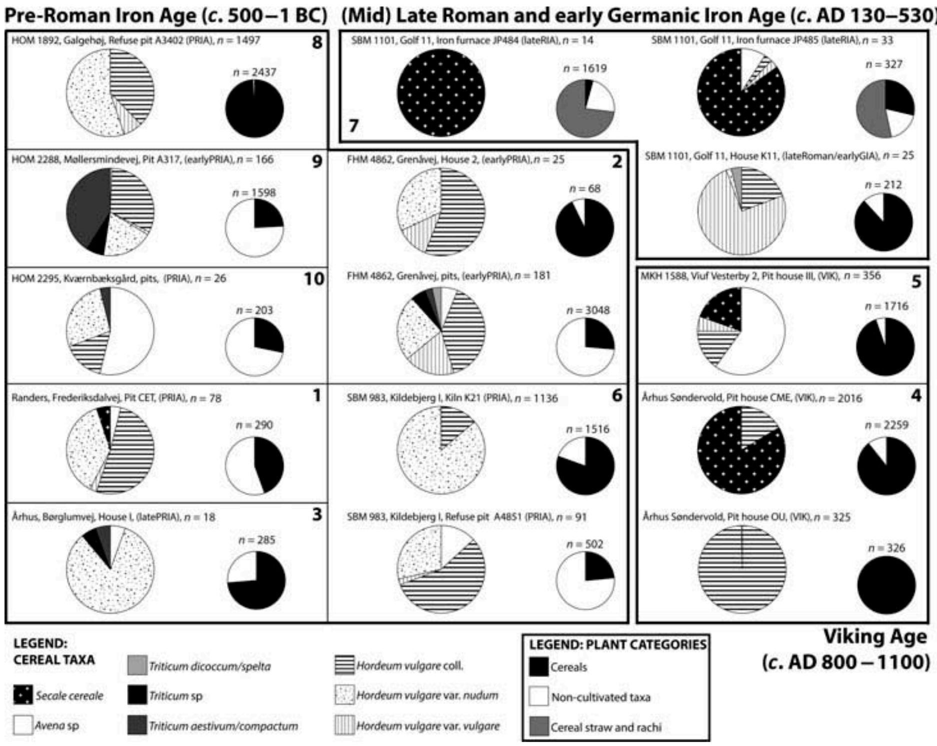

Figure 2. Overview of archaeobotanical assemblages from east-central Jutland dating to the Iron Age. The assemblages are presented grouped into three chronological segments: pre-Roman Iron Age 500 BC–AD 1, mid/late Roman and early Germanic Iron Age AD 130–530 and Viking Age AD 800–1100. The composition of each assemblage is presented as ratios between cereals, weeds and straw/chaff (small pie chart, representing entire sample) and ratios of identified cereal species (large pie-chart, identified cereal fraction only).

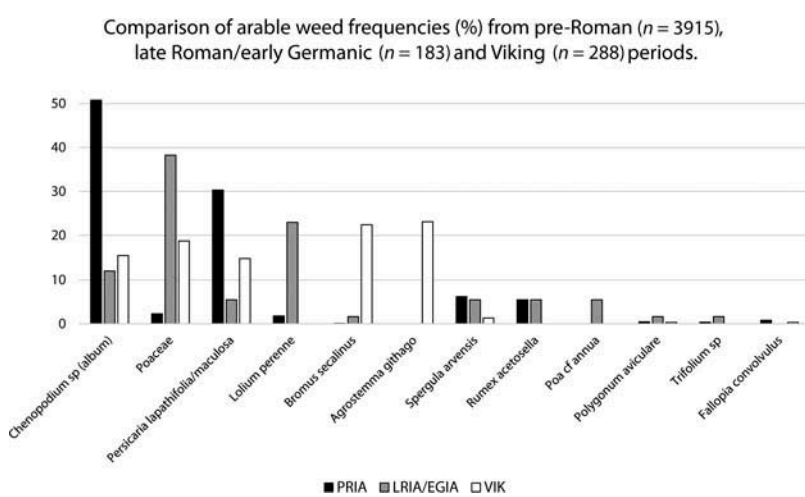

Figure 3. Weed frequencies over the course of the Iron Age in the compiled archaeobotanical assemblages from east-central Jutland. The material is, similarly to Figure 2, divided into three chronological segments representing pre-Roman, mid/late Roman and early Germanic Iron Age, and the Viking period.

the site of Grenåvej. The contexts in which the hulled barley was found are of different type; one assemblage deriving from two postholes of an unburnt longhouse, the second from a cluster of refuse pits. This distribution in contexts formed by two unrelated events may indicate that the hulled barley was a significant crop on this site, rather than being the result of an isolated and unrepresentative circumstance.

Other sites where hulled barley was retrieved were Galgehøj, Møllersmindevej, Randers Frederiksdalvej and

Kildebjerg, where it was found as small inclusions of no more than a few percent. Since most of these finds derive from presumably mixed contexts, such as refuse pits and unburnt houses, interpretation of the origins of these finds is problematic. They may represent cultivation of the crop on a very small scale, but could perhaps also be explained as unplanned inclusions in naked barley cultivation. Since hulled barley was likely cultivated during this period on at least some sites, as indicated by the material from Grenåvej, it is possible that the crops used in the region were not completely pure. An admixture of hulled barley in naked barley seed would have been almost impossible to remove through sieving or similar techniques because the two plants are morphologically almost identical. Any purification would therefore have been undertaken by hand (Hillman 1984, Jones and Halstead 1995), a time consuming process which may have prompted the acceptance of a level of crop mixing in otherwise monocultural cultivation. That this is possibly the case may perhaps be seen in the assemblage from Galgehøj, where hulled barley made up 13% of the barley grains determined down to variety. Although derived from a pit, the sampled layer contained such a high concentration of clean grain that it was interpreted as belonging to an accidentally burnt crop cache, which was deposited in its entirety inside the pit, presumably representing a single harvest (Jensen 2009a, p. 3f).

The third most commonly appearing cereal was oat (*Avena* sp.). Oat is a problematic plant for archaeobotanists since it occurs in arable environments both as a cultivated crop (*Avena sativa*) and as a weed (*Avena fatua/strigosa*). Distinction between these species can be made only if the floret bases are preserved (Jacomet *et al.* 2006), which is rarely the case in carbonised assemblages. Therefore, the definition between cultivated and wild oats has previously mainly been made by identification of large and clean finds. This is a problematic approach, since small scale cultivation of oat could theoretically have taken place whilst being archaeobotanically interpreted as weed presence due to low frequencies in the material.

In the record from east-central Jutland, oat appears in six out of nine pre-Roman assemblages. In all contexts but one, the oat appeared as a small inclusion only. The only percentually large find was derived from Kværnbækgård where oat made up >50% of the cereal total. The entire assemblage of cereals determined down to species was, however, comprised of only 26 grains, and despite the high percentage, this find cannot be used as evidence for cultivation.

Wheat was present in four out of nine assemblages. Three of the occurrences were very insubstantial and may indicate either limited purposeful cultivation or accidental inclusion in other crops. In the fourth assemblage, at Møllersmindevej, naked bread wheat made up just under 50% of the total species-determined assemblage, which as a whole consisted of 166 grains. The material was retrieved from a pit in which material presumably accumulated over a longer period of time and is thus of unknown representative value. Still this comparatively large find of wheat may indicate limited cultivation in the region.

Late Roman and early Germanic Iron Age

After approximately 1 AD, there is a gap in the archaeobotanical material from east-central Jutland.

Dating to the latter part of Roman Iron Age and the beginning of the Germanic period are three contexts from the site of SBM 1101 Golf 11.

Two of the contexts comprise of iron extraction furnaces, while the third was recovered from a presumably unburnt longhouse. All three contexts differ strikingly from the ones dates to the pre-Roman Iron Age.

In House K11, almost all identified grains consisted of barley and the ones which were in a good state of preservation were predominantly determined to the hulled variety. This shows that the transition from naked to hulled barley most likely was completed by fourth and fifth centuries AD as the house provided a cal. 2σ ^{14}C-date spanning AD 255–532.

The iron furnaces were possibly somewhat older, providing cal. 2σ-dates of AD 133–326 and 255–405, respectively. The composition of the botanical material recovered from them differed drastically from the house. The amount of recovered grains was small in both furnaces, but was dominated by rye. The presence of rye was also indicated by large amounts of straw fragments. These were determined as likely belonging to rye (cf *Secale cereale*). The combination of grain and straw finds must be seen as a convincing indication that rye was independently cultivated at this site. Therefore, cultivation of rye in this area should, based on available data, be seen as commencing at the latest during the second or third century AD.

Since the barley and rye were recovered from two unrelated contexts, it is impossible to interpret how they were cultivated in relation to each other. Rye may have been cultivated on independent fields, in certain stages of a slow rotation agriculture or even in some form of crop-rotation. The presence of *Lolium perenne*, interpreted by Mikkelsen as an autumn rye indicator, in one of the furnaces could be a tenuous indication of rotation. Since the species was only found in one of the furnaces and since the material is so small as to prohibit further in-depth analysis, the issue must, however, be seen as unresolved.

Germanic Iron Age and Viking Period

After the transition from late Roman to Germanic Iron Age, there is another gap in the material, the chronologically subsequent assemblages dating to the Viking Period.

All three of these assemblages were derived from pit houses. Two of these, from Søndervold in Århus, have been typologically dated to the Viking Age. The third, from Viuf Vesterby, has been radiocarbon dated to AD 888–1024 (1σ?, BP-date not reported). The three assemblages are in this overview considered as contemporaneous.

The material from both houses at Søndervold consisted of large and clean finds of grain indicating storage. Interestingly, each house was dominated by a different crop; house CME contained mostly rye with approximately 20% barley, while house OU contained an almost clean barley crop with only a single grain of rye. The find in house OU was also almost completely clean of weed inclusions, indicating a well processed produce, the only inclusion being a single grass seed (*Poaceae*). The weeds in house CME were somewhat more numerous and very informative as they contained *Agrostemma githago*, which has already been discussed as an autumn rye indicator, and *Centaurea jacea*, which has a life cycle similar to that of autumn sown rye. The comparatively large presence of rye brome also points towards this store being autumn sown. Thus, the find from Søndervold is a clear indication that not only rye was cultivated, but also crop-rotation was in use. A point of caution is, however, the archaeological context of the find. Since Århus Søndervold represents an urban setting, it is possible that the cultivation of the recovered plants took place somewhere else than in the Århus area, as extensive trade networks are most likely to have existed during this late period of the Iron Age (see e.g. numerous articles in Mortensen and Rasmussen (1991)).

The functional interpretation of the material from Viuf Vesterby was somewhat ambiguous. Its composition and siting inside the house did not provide clear evidence about its formation. It is thus unclear whether it is a storage find carbonised in situ or whether it ended up in the house fills as a secondary or tertiary deposit. Andreasen (2010) also explored the possibility of the material being brought into the house as floor covering, although without reaching a conclusion. Regardless of its origins, this assemblage provides some information about possible agrarian practices.

Hulled barley and rye were present in almost equal proportions. This could indicate crop-rotation. The presence of *Lolium perenne* adds further support to this interpretation, which would be chronologically consistent with the results from Søndervold.

More important, however, is the fact that the assemblage was dominated not by barley and rye, but by oat, and that some of the oat husks were preserved sufficiently to allow their identification as *Avena sativa*. Thus, Pit House III from Viuf Vesterby provides the first, and so far only, evidence of oat cultivation in east-central Jutland during the Iron Age.

Weed finds

The large number of weed taxa and their diversity with regards to seed production, dispersal modes and seed preservation qualities make this type of archaeobotanical remains more complex to assess than cereal finds, although under certain conditions weeds may also be more informative than the cultivated plants.

The composition of weed seeds in archaeobotanical assemblages cannot be seen as representative for the actual flora of the fields. Rather, the weeds should be used qualitative proxies providing general insights about field conditions (Engelmark 1989).

The material from east-central Jutland is also small, with only the finds from pre-Roman Iron Age occurring in larger quantities.

With these reservations in mind, a summary of the most commonly occurring weeds (Figure 3) shows three tendencies.

The first of these is one of continuity. Nitrophilous weeds, interpreted previously as indicators for manured fields (Engelmark 1989), such as *Chenopodium album* and *Persicaria lapathifolia/maculosa* are among some of the most commonly appearing taxa in the assemblages from all periods. They do decrease in the graph during the late Roman/early Germanic and Viking periods, but this decrease should be seen in light of the graph showing relative occurrences within each period, the decrease in the graph corresponding to an increase in taxa not present during the first period.

The new taxa are *Lolium perenne, Agrostemma githago* and *Bromus secalinus.* All three have been previously interpreted as possible indicators for autumn sowing (Kroll 1987, Mikkelsen and Nørbach 2003).

Lolium perenne increases sharply in the graph already from later Roman Iron Age, but this increase is based on a single material only, the iron extraction furnace from SBM 1101 Golf 11. The uncertainty of its representativity for autumn sowing has already been discussed above.

The finds of *Agrostemma githago* and *Bromus secalinus* increase during the Viking period and have also been previously mentioned as much more secure indications of crop-rotation.

There is also a trend of decrease in the material, seen mainly in *Spergula arvensis* and *Rumex acetosella*. These taxa are associated with lower-nutrient soils, and their decrease could possibly indicate that poor soils were used to a lesser extent during the latter part of the Iron Age. The material is, however, far too limited to substantiate such a hypothesis.

Archaeobotanical interpretation: issues and possibilities

As seen from the overview above, the archaeobotanical material has provided numerous insights into how cereal cultivation may have been practiced during the Iron Age. It has, however, also illustrated numerous aspects of complexity inherent to studies based on carbonised plant material.

The plant macrofossil analyses at Gedved Vest and, to a lesser degree Kristinebjerg Øst, were therefore planned not only as means of providing additional input to the corpus of archaeobotanical data, but also to attempt to test and evaluate analytical strategies, which may enhance the interpretation of carbonised materials from settlement sites (Grabowski and Linderholm 2013).

Complexities of the archaeobotanical source material

The archaeobotanical study of cereal agriculture during south Scandinavian prehistory has to date been primarily based on analysis of carbonized plant macrofossils from rural settlement contexts (Engelmark and Viklund 2008, Robinson *et al.* 2009). Although the technical aspect of plant macrofossil analysis is comparatively straightforward, the interpretation of this material presents a high degree of complexity due to a number of factors.

The composition of archaeobotanical assemblages is the result of both anthropogenic and natural transforming processes (Schiffer 1972, 1976).

Non-human filters include the properties of the plants themselves, particularly those which affect their chances of preservation through carbonisation. They also encompass the dynamics of the sediments into which botanical material is deposited (Engelmark 1989, Boardman and Jones 1990, Gustafsson 2000, Branch *et al.* 2005).

The anthropogenic filters shape the archaeobotanical material mainly as a result of the sequential actions involved in refining harvested or collected plants into usable end products (Dennell 1976, Hillman 1981, 1984, Jones 1987, Viklund 1998). This series of transformations is termed as *operational sequence* (cf. *chaîne opératoire,* Schlanger 2005, *behavioural chains,* Schiffer 1975, *systemic and archaeological context,* 1972).

Unlike many types of material culture, which are created by joining components into artefacts, plant resource operation is commonly characterised by separation of material retrieved jointly from a specific habitat into separate units intended for different utilisation.

Figure 4 shows a typical operational sequence of cereal processing. As the harvested crop progresses along the sequence, actions such as threshing, winnowing, flinging, sieving and hand sorting achieve both the removal of weeds and the separation of the harvested crop into functional units (Hillman 1981, 1984, Viklund 1998).

In theory, the original material collected in its growth biotope may through these actions be subdivided into a number of separate assemblages. Cleaned grains may be stored and eventually consumed. Weed residues from cereal cleaning may be used as fuel, left in situ or re-deposited in a number of ways as an effect of waste management. There are also some indications in the archaeobotanical material that weeds were, at least on occasion, collected and consumed (e.g. Behre 2007). Other parts such as the ears of cereals may be treated similarly to the weeds, while the straw may be used as fuel, as animal fodder, in construction and manufacture, and so on.

Important for archaeobotanical interpretation is the fact that some actions are more or less unavoidable for a given crop and that these have to be performed in a specific sequence, for example threshing prior to winnowing and flinging and coarse sieving prior to fine sieving (cf. Jones 1984).

Botanical material can be preserved by carbonisation at numerous stages of the operational sequence (Hillman 1981, 1984), but the nature and chances of the carbonisation events are also variable. Active use of fire, for example during parching in order to loosen the glumes, presents

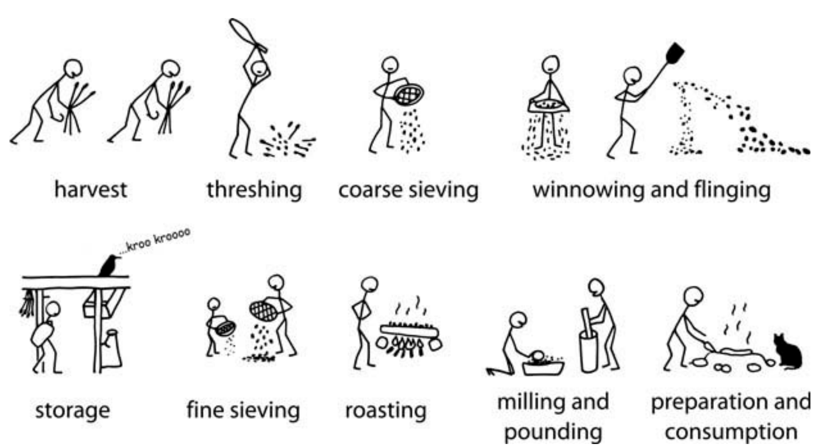

Figure 4. A schematic illustration showing a possible operational sequence of cereal processing. After Hillman (1981) and Viklund (1998).

an increased chance of carbonisation. Small portions of botanical material may become charred in connection to everyday accidents around heat sources, resulting in the accumulation of plant remains over longer, often archaeologically undefinable, periods of time. In contrast, uncontrolled fires may occasionally result in the carbonisation of large quantities of plant material: assemblages representative of singular events (Viklund 1998).

Once carbonised, most plants are no longer of use to humans. Thus, the process of carbonisation results in an irreversible movement of the material from an operational to an archaeological context (cf. Schiffer 1972). This may occur through abandonment of the material at the location of its carbonisation or consist of numerous stages of deposition and re-deposition (see Figure 5).

Based on the reasoning above, most archaeobotanical research performed since the 1970s has acknowledged that a good foundation for archaeobotanical interpretation may often only be attained through delineation of the operational context of the investigated assemblages (e.g. Hillman 1981, 1984, Jones 1984, Van der Veen 2007).

Defining the operational context of botanical assemblages presents several challenges. The exact structure of the operational sequences performed during prehistory is rarely known, although clues may be attained from ethnographic studies and historical documentation. Ultimately, the operational sequences must be inferred from the prehistoric record itself, either through analysis of the internal compositional variation within the botanical material under study, by correlation to non-botanical archaeological data (feature morphology, artefacts, etc.), or through analysis of the sediment matrix from which the material was recovered by additional non-botanical methods. Another problem is that it may be impossible to identify some stages and fully define the sequence. The available methodology may not be able to attain a sufficient level of resolution to separate one stage from another. The various stages themselves may also have created more or less suitable conditions for preservation of botanical material. Some stages may be significantly underrepresented or even lacking completely in the material, others may be impossible to separate from each other because of the phenomenon of *equifinality*; that is similarities in archaeobotanical outcome may not always represent similarities in starting conditions or operation.

The known aspects of Iron Age settlement structure indicate that plant resource refinement, as well as numerous other activities, were confined to specific areas. Thus, the definition of the functionality of spaces is an important step in delineating the operational context of a related plant assemblage. The assemblage itself may, however, also provide clues about the functionality of the space from which it was recovered. Therefore, the process of delineating functional spaces and defining an operational botanical context may be seen as a multidirectional interpretive process.

Multiproxy functional analysis as a way of evaluating carbonised botanical assemblages

At the Environmental Archaeology Laboratory at Umeå University in Sweden, botanical analysis has been integrated into a more comprehensive multiproxy strategy where archaeobotany is correlated against a set of geochemical and geophysical methods (Grabowski and Linderholm 2013). These analyses are performed either on separate samples, collected from the same archaeological contexts, or on sub-samples extracted from the soil which is sampled for plant macrofossil analysis.

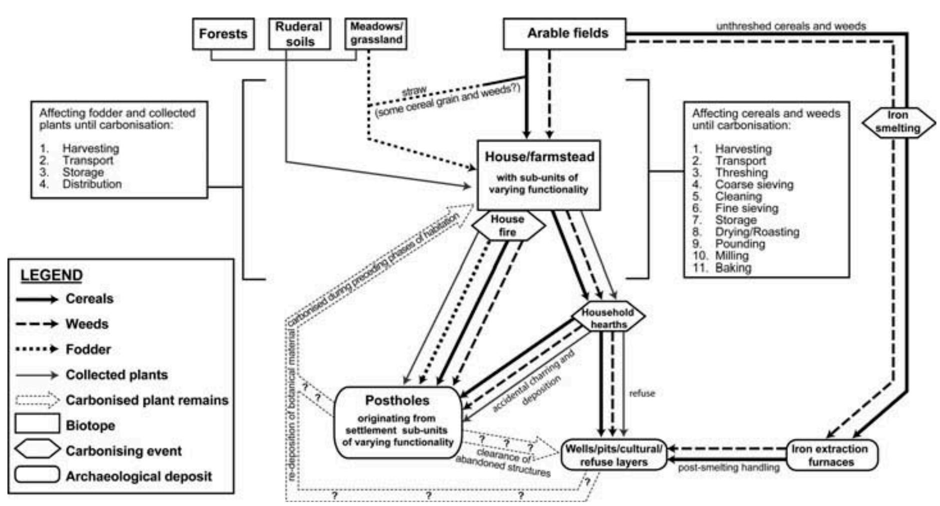

Figure 5. Flow chart showing the plausible pathways of movement, deposition and re-deposition of carbonised botanical material at an Iron Age settlement site (the herein presented chart being modelled on HOM 2247, Gedved Vest).

The development, previous application and technical specifics of the method are described in a separate article (Grabowski and Linderholm 2013, and therein cited references).

In short, the procedure can be described as follows:

Plant macrofossil analysis is performed on material retrieved through floatation (0.25 mm smallest mesh size). The theoretical preposition is that different actions of plant utilisation will result in variable botanical compositions. Under favourable conditions, this variation should be indicative of the operational context of cultivated plants and/or functionality of the space from which the samples were retrieved. This is presumed to apply in particular to samples from postholes, since the depressions created by the removal or destruction of posts should have filled up quickly with eroding sediment. This process is assumed to have created protective environments for botanical assemblages indicative of activities performed around the posts.

Magnetic Susceptibility analysis is performed on the samples to differentiate between soils previously exposed or not exposed to heat. In some cases, the field evidence is inconclusive about whether a context, such as a house, is burnt or not. A definition of this aspect is important for archaeobotanical interpretation, since it illuminates the formation process of the material and gives an indication of whether it is resulting from an accumulation over a longer period of time or whether it represents a singular event.

Phosphate analysis is used to delineate areas of increased input of phosphorous material. This material can originate from numerous sources. Therefore, a separation is made between phosphates bound in inorganic and organic compounds. Concentrations of inorganic phosphates are presumed to be indicative of household waste, primarily bones, while organically bound phosphates are presumed to be indicative of manure. In visualisations of phosphate data, it is sometimes illustrative to also express the relation between organically and inorganically bound phosphates (phosphate quota), with higher quota corresponding to higher levels of organically bound phosphorous material.

Loss on ignition is performed to measure the organic content in the samples. High organic content may be indicative of a number of different types of depositions. One of these is long term input of manure. In this study, the results were correlated to those of the phosphate analysis in order to provide evidence about the presence or absence of manure.

Material

HOM 2247, Gedved Vest

Site overview

Gedved Vest is situated in east-central Jutland, 33 km south-west of Århus and 8 km north of Horsens. The site was investigated between 2008 and 2010 by Horsens Museum in connection with an industrial development project (Hansen 2012).

The area is characterised by a gently undulating topography. The relatively flat topography of the site is mirrored by a comparatively homogenous geology. The subsoil was primarily made up of glacial silty clays with admixtures of sand and gravel. The overlaying topsoil was made up of clayey loam.

The excavation of Gedved Vest resulted in the documentation of a large amount of archaeological features, mostly of settlement character (postholes, pits, wells, enclosures, refuse/activity layers, etc.). More than 350 constructions were recorded on the site, many of which have been ^{14}C dated, showing activity from the latter half of the Bronze Age (oldest dates at 808–551 BC, cal 2σ) to the Viking Age (AD 885–1013, cal 2σ). The radiocarbon data corresponds well with the typological chronology established during excavation (Hansen 2012). For a plan of the site see Figure 6.

Presented contexts

A total of 879 samples were retrieved from Gedved Vest. Botanical analysis was performed on all samples. Geochemical and geophysical methods were thereafter strategically applied to features qualitatively assessed as suitable cases for the identification of operational cereal processing context and functionality of settlement spaces.

The space constraints of the article format do not allow for a presentation of all results from Gedved Vest. Instead, the presentation focuses on cases where functionality and/or operational context was to some extent elucidated. This applies in total to 12 assemblages from 10 archaeological features. Since these contexts were not evenly distributed in time, the herein presented data spans approximately AD 1–550.

The illustrations below present data only relevant to the discussion of the material. A full table with archaeobotanical and geochemical/geophysical data is presented as Supplementary material 2 (Table 2).

Kristinebjerg Øst

Site overview

Kristinebjerg Øst, situated a few kilometers from Little Belt, between the towns of Kolding and Fredericia, was excavated between 2007 and 2009 by Vejle Museum. The excavations, which were performed in connection with rezoning of the area, resulted in the identification of archaeological remains dating to the Neolithic and the Iron Age, as well as the medieval and modern periods (Bjerregård and Iversen 2013).

Table 2. ^{14}C-datings from Gedved Vest for the archaeological features presented in the article.

Locality	House	Lab nr	Dated material	Age ^{14}C	Cal 1σ	Cal 2 σ
21	A11402	Poz-44610	cf Secale cereale	1905 ± 30 BP	AD 26–128	AD 25–212
		Poz-44611	Secale cereale	2015 ± 30 BP	47 BC to AD 23	97 BC to AD 64
		Poz-44612	Hordeum vulgare var vulgare	1925 ± 30 BP	AD 53–124	AD 2–134
	A11404	Poz-44614	Secale cereale	1900 ± 30 BP	AD 69–130	AD 28–214
		Poz-44,615	Hordeum vulgare var vulgare	1850 ± 35 BP	AD 126–223	AD 79–240
		Poz-44616	Hordeum vulgare var vulgare	1895 ± 30 BP	AD 70–132	AD 33–215
	A11412	Poz-44617	Hordeum vulgare var vulgare	1910 ± 30 BP	AD 67–126	AD 21–210
		Poz-44618	Hordeum vulgare var vulgare	1875 ± 30 BP	AD 78–210	AD 70–225
		Poz-44619	Hordeum vulgare var vulgare	1845 ± 30 BP	AD 130–215	AD 85–239
09-Nov	A11312	Poz-44684	Hordeum vulgare var vulgare	1565 ± 35 BP	AD 436–561	AD 428–582
		Poz-44658	Hordeum vulgare var vulgare	1585 ± 35 BP	AD 383–529	AD 342–535
		Poz-44686	Hordeum vulgare coll	1585 ± 30 BP	AD 415–532	AD 397–540
	A11320	Poz-44687	Hordeum vulgare	1625 ± 30 BP	AD 392–531	AD 352–537
		Poz-44688	Hordeum vulgare var vulgare	1590 ± 30 BP	AD 426–533	AD 411–534
		Poz-44689	Hordeum vulgare	1625 ± 30 BP	AD 392–531	AD 352–537
13	A11220	Poz-44700	Hordeum vulgare var vulgare	1620 ± 30 BP	AD 397–532	AD 357–539
		Poz-44702	Hordeum vulgare var vulgare	1605 ± 30 BP	AD 415–532	AD 397–540
		Poz-44703	Secale cereale	1656 ± 35 BP	AD 434–540	AD 434–540
	A11071	Poz-44722	Hordeum vulgare var vulgare	1550 ± 35 BP	AD 435–555	AD 424–584
		Poz-44723	Secale cereale	1575 ± 30 BP	AD 435–535	AD 417–552
19	A11107	Poz-44717	Hordeum vulgare coll	1545 ± 30 BP	AD 436–561	AD 428–582
		Poz-44718	Hordeum vulgare coll	1635 ± 30 BP	AD 383–529	AD 342–535
		Poz-44719	Hordeum vulgare var vulgare	1605 ± 30 BP	AD 415–532	AD 397–540
	A11123	Poz-44724	Secale cereale	1505 ± 35 BP	AD 536–610	AD 435–639
		Poz-44725	Hordeum vulgare var vulgare	1485 ± 35 BP	AD 548–613	AD 443–649
		Poz-44726	Secale cereale	1565 ± 30 BP	AD 434–540	AD 422–561

Note: See also the ^{14}C calibration graph in Supplementary material 3.

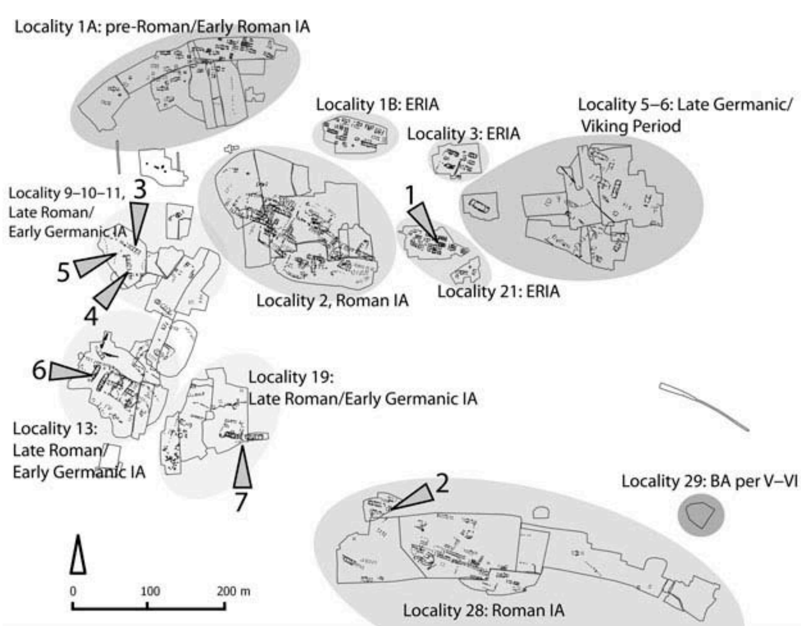

Figure 6. Site plan of Gedved Vest, showing the location of the context presented in the article. 1, locality 21 (houses A11402, A11404 and A11412); 2, pit A35875; 3, house A11312; 4, house A11320; 5, well A30223; 6, house A11220; 7, Locality 19 (houses A11107 and A11123).

The site topography was characterised by a gently undulating moraine landscape, with an underlying soil consisting primarily of sandy clay.

House DG

In the western part of the site, a concentration of 12 houses from the Viking Age was excavated. Chronological control of these houses has been achieved through house and artefact typology.

Several of the houses were sampled for archaeobotanical studies but preliminary analysis of the material showed that only one building, house DG, contained substantial amounts of carbonised plant remains.

House DG is one of the smaller buildings dated to the Viking period. The typology of the building indicates a date around AD 800. It has been interpreted as a likely barn or outhouse to one of the larger longhouses situated nearby (Bjerregård and Iversen 2012).

Only archaeobotanical analysis was performed on the material from house DG since the samples were floated on site and no soil remained for additional analyses. Complete data from the analysis of house DG is available in Supplementary material 4.

Analysis of Gedved Vest

Functional interpretation of Locality 21: houses A11402, A11404 and A11412

Locality 21 consisted of a cluster of at least 32 houses of varying sizes, typologically dating to the early Roman Iron Age. Many of these structures overlapped, indicating recurring phases of construction, reconstruction and renovation. Since the individual postholes of the houses only occasionally cut each other, it is impossible to reconstruct a relative chronological sequence for these phases.

Among these houses, three stood out during excavation with clear traces of house fires; A11402, A11404 and A11412. These were the only houses which were sampled during excavation. On the basis of their size and siting in relation to larger ‘habitation-type’ longhouses, the three constructions have been interpreted as outhouses. All three appear to have had at least three separate phases, and in all three cases, only one phase appears to have been destroyed by fire. The presumed burning of the houses was evidenced during excavation as highly charcoal rich fills, with significant inclusions of burnt clay and charred grain.

Relating to Figure 5, which shows the possible pathways of a botanical material on an Iron Age site, Locality 21 does not present an optimal case for archaeobotanical studies, as there is a possibility of material moving between chronological phases due to redisposition of soil.

Because of this complex archaeological situation, geochemical and geophysical analyses were not performed on this locality, and the interpretation below is based solely on botanical data.

There were, however, also factors favouring the inclusion of this material into the study.

First, each of the overlapping houses appears to have been constructed similarly to its predecessor, resulting in dimensionally comparable structures on top of each other. Such similarity may be an indication of a functional continuity. Any mixing of plant material between chronological phases should thus not affect the final interpretation of function.

Second, the excavators noted that the postholes of the sampled houses had much darker and charcoal rich fills than those of the overlapping structures. This observation was confirmed during the archaeobotanical analysis. Locality 21 displays the by far highest concentrations of carbonised plant material on Gedved Vest (57.5 remains/litre compared to an average of 13.4). The fact that the three sampled houses were burned and the overlapping ones were not may be argued to have created an assemblage where the majority of the botanical remains likely originated from the burning event. Identified patterns should therefore reflect the contents of the structures at the time of the fire. A signal from activities before the fire is likely embedded in the material as well, but its effects on the composition of this assemblage should be limited.

All three houses have been ^{14}C-dated, providing similar cal. 2σ-spans, ranging from AD 2 to 240. Only one sample out of nine provided a slightly divergent date of 97 BC to AD 64. These structures could have been contemporaneous and possibly destroyed as the result of the same event.

Figure 7 illustrating the results of the archaeobotanical analysis shows striking differences between the three structures. Most obvious is the diametrically opposite relationship between cereals and non-cultivated taxa in A11402 and A11412. In the former house, non-arable plants (predominantly arable weeds) make up 80% of the material, oil plants 10% and cereals 10%. In the latter, house cereals comprise over 90% of the material with a small inclusion of oil plants and almost no weeds. This indicates that these two structures, regardless of whether they are contemporaneous or not, filled a different role in the processing of cereal produce. The most readily available explanation is that A11402 was used either as a cereal cleaning space or a space where cereal cleaning residues were stored, resulting in an accumulation of weeds not meant for human consumption, while A11412 was a storage space for cleaned grain at the end of the operational sequence.

House A11404 is somewhat more difficult to interpret. The relationship between cereals and non-cultivated taxa is 80–20%, respectively. This mixing of the two categories

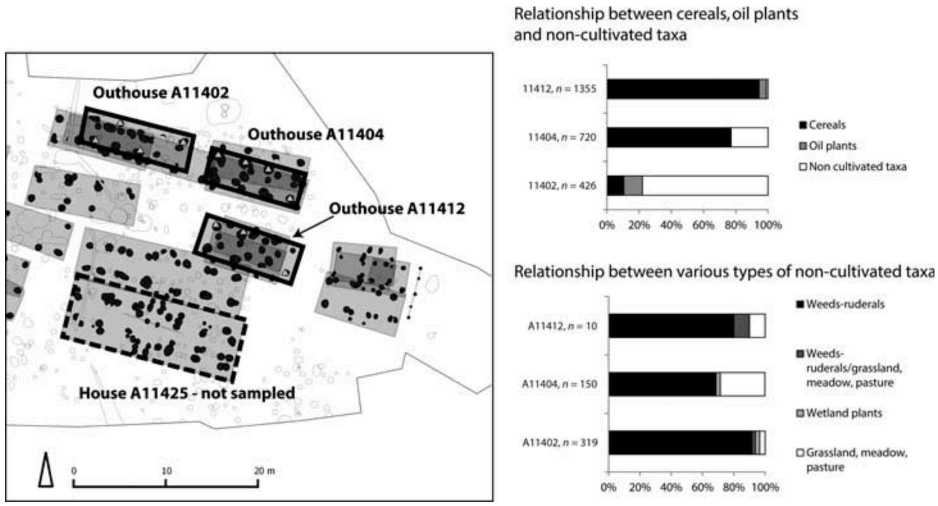

Figure 7. Site plan of locality 21 at Gedved Vest and the composition of the archaeobotanical material from houses A11402, A11404 and A11412.

of plant material could indicate a more diverse functionality of the house. It could also, in the event of all three houses being contemporaneous, indicate intermediate storage of partially cleaned grain. A third explanation may possibly be seen in the composition of the non-arable category of plants. Both in A11402 and A11412, this category was composed almost exclusively of weeds-ruderals. In A11404, the weeds still dominate, but there is also a presence of possible fodder plants, amounting to 30%. Accordingly, an alternative interpretation of this structure could be that it was a fodder storage space and that the fodder comprised of both meadow plants, such as grasses and weeds, and cereal straw with some grains still attached. There is also the possibility that all of the above-mentioned functions were true and that the house was used in a flexible manner.

Functional interpretation of Locality 28: pit A35875

A35875 was a small pit, 64 cm in diameter and 50 cm in depth (Figure 8). Three layers were identified inside the pit, two rich in carbonised material, possibly indicating primary use, and an uppermost layer which appears to have eroded into the pit after abandonment.

Pottery fragments of Roman Iron Age-type were found inside the pit and two adjacent features, a longhouse and an iron extraction furnace, have provided ^{14}C-dates with a span of AD 70–409 cal. 2σ.

Only macrofossil analysis was performed on the samples from A35875.

The results of the analysis show distinctly different composition of each of the sampled layers. The uppermost fill (A) contained few plant seeds or charcoal. This supports an interpretation that the layer represents infilling of the pit after its active phase. Layer (B) contained a large concentration of charcoal, but a comparatively limited amount of plant seeds, while the lowermost layer (C) showed a reverse situation with a smaller amount of charcoal but high concentrations of plant seeds.

The relationship between plant categories in this pit was 12% cereals to 88% non-cultivated taxa. The former category was made up predominantly of grains, but several rachis fragments were also recovered. The latter category consisted almost exclusively of arable weeds.

Based on the available data, a plausible interpretation of the feature could be that it was some form of hearth where both wood and cereal material was used as fuel. The distribution of the charcoal above the cereals may possibly indicate that the latter was used as kindling and that this material was a residue from cereal threshing and cleaning, indicated by the predominance of weeds and the presence of inedible cereal parts such as the rachi. The fact that the layers display clearly divergent botanical signatures also indicates that the entire material most likely represents a single firing event, with limited succeeding mixing or disturbance. It is unclear, however, whether the feature was a one-use construction or whether it was utilised repeatedly and cleaned prior to its final use.

Functional interpretation of Locality 9–11: houses A11312 and A11320 and well A30223

Locality 9–11 was another cluster of settlement remains identified during the excavation of Gedved Vest. The cluster was typologically and artefactually dated to late Roman and early Germanic Iron Age.

Two longhouses, A11312 and A11320, were sampled in sufficient detail to allow for an in-depth interpretation based on analysis of posthole fills (Figure 9). Because of the relatively clean siting of both houses, all methods

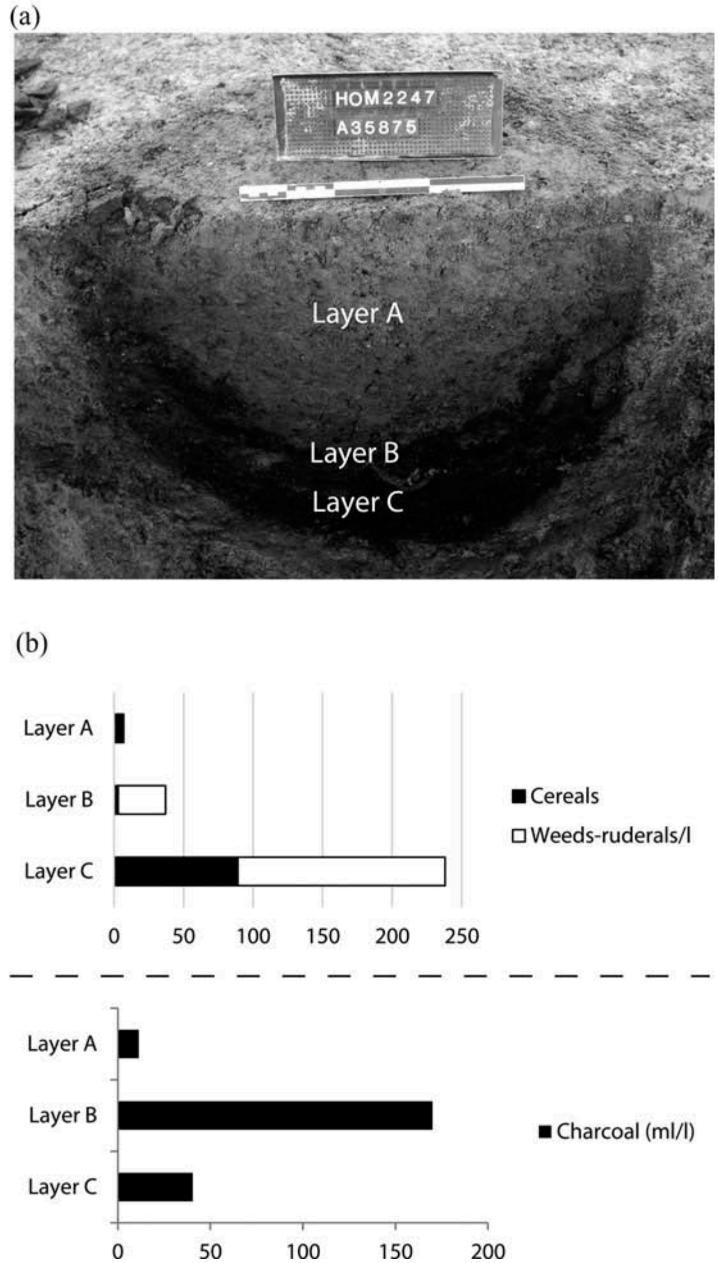

Figure 8. Photograph of pit A35875 at Gedved Vest (a) and the composition of the archaeobotanical material in the three layers documented and sampled inside the feature (b).

outlined in the method section above were applied on the material. Both houses were ^{14}C-dated, showing a cal. 2σ-span of AD 342–582 for A11312 and AD 352–537 for A11320, corresponding with the preliminary typological designation of the locality. In this presentation, the houses are treated as roughly contemporaneous.

A well, A30223, situated in close proximity to both houses, was also sampled and analysed in detail (Figure 11). The well has not been securely dated by relative or absolute methods, but its special siting indicates a likely association to one or both houses.

Magnetic susceptibility analysis of the postholes indicates that both houses were burnt. This is supported by the archaeobotanical results, which show presence of carbonised material along the entire length of both constructions, with the exception of a single posthole pair at the easternmost end of A11312.

Although present in all sections of the houses, the botanical material shows a heterogeneous composition in different parts of both houses.

In A11312, there is a clear separation between finds of arable weeds and cereals. The former are concentrated to

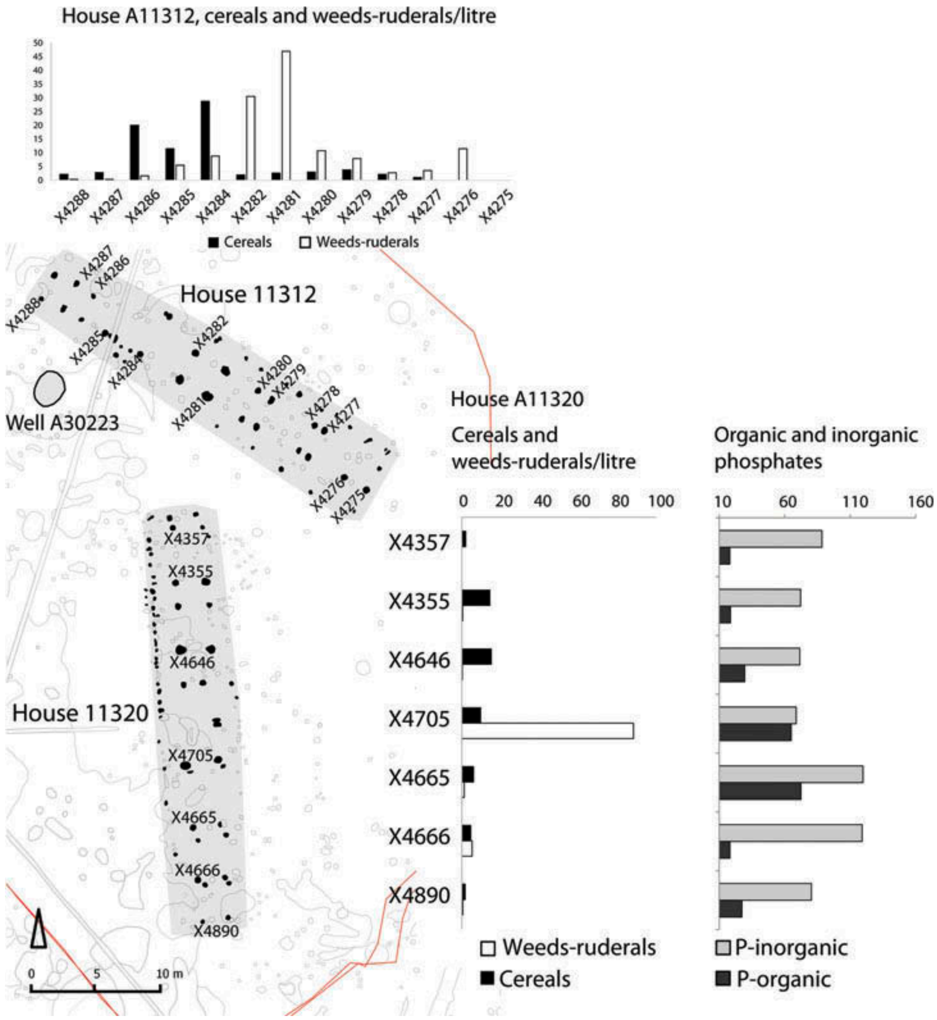

Figure 9. Site plan of locality 9–11 at Gedved Vest and results of the multiproxy analyses of houses A11312 and A11320, showing the composition of the recovered archaeobotanical material for both houses and the results of geochemical analyses for house A11320.

an area around two posthole pairs (X4282–4281), while the latter were found further west, around posthole pairs X4286, X4285 and X4284.

A similar pattern was detected in A11320, where the cereals were predominantly found in the northern part of the house, around posthole pairs X4355 and X4646, while almost all weed finds were recovered from posthole pair X4705, situated directly to the south.

This pattern may be interpreted as an indication for the presence of two areas with different function in each house, the finds of more or less clean cereals indicating cereal stores and possibly a kitchen/living spaces and the weeds indicating cereal cleaning areas.

To test this hypothesis, measurements of the cereal grains from each respective area were performed. All known cereal sorting procedures, such as sieving, winnowing and flinging, are based on weight, size and the aerodynamic properties of the plant remains. Thus, in theory, the cereal grains meant for consumption or cultivation should be larger and heavier than those which may have been discarded during cereal cleaning. The results of the measurements, presented in Figure 10, show that the cereals in the presumed cereal cleaning spaces were on average a full millimetre shorter than those in the presumed storage areas, with a smaller but notable difference in height and width. Although a difference of only 1 mm could, if presented on its own, be interpreted in numerous ways, for example as a difference in sieve size used in the processing of different cereal caches, in relation to the results from the other measurements applied at Locality 9–11, the results seem to indicate different stages of operation and not separate assemblages processed differently.

It should be noted that the cereal finds in the presumed storage sections, although consisting of clean grain, were not comparable in quantity or concentration to carbonised

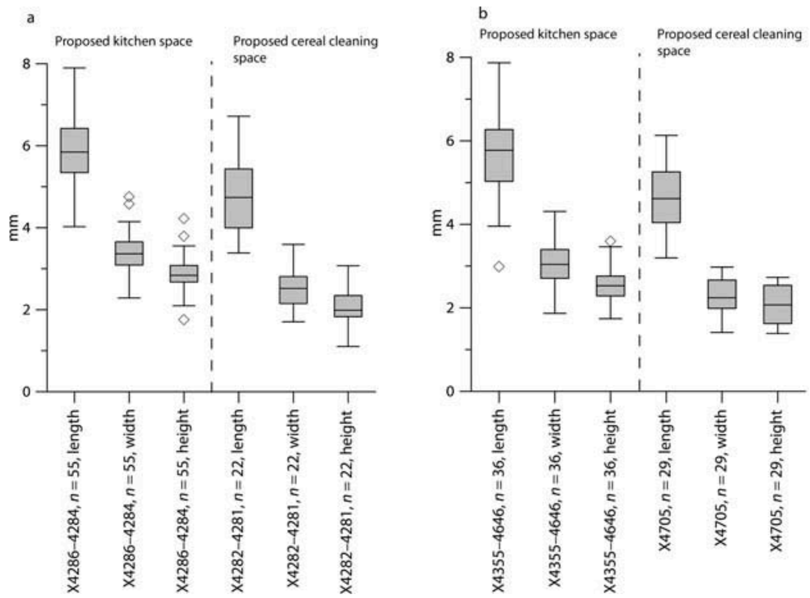

Figure 10. Grain sizes in the proposed cereal cleaning areas and kitchen/storage spaces, respectively, of houses A11312 (a), and A11320 (b).

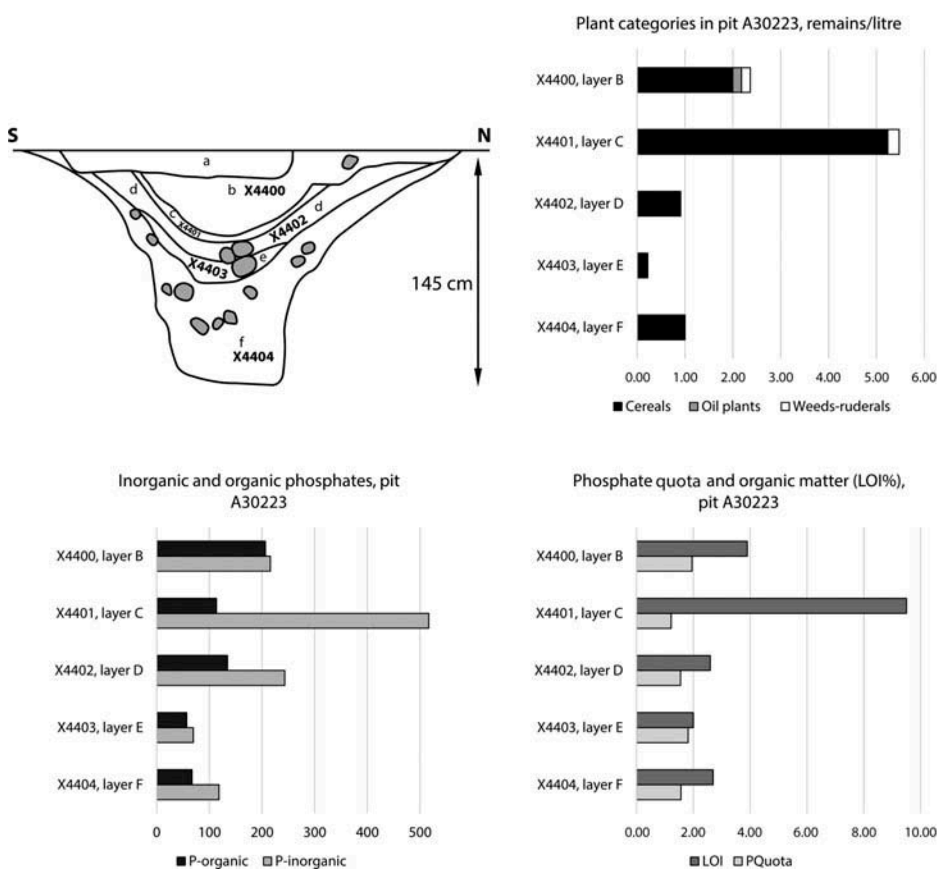

Figure 11. Section drawing of well A11320 and the results of the archaeobotanical and geochemical analyses.

bulk storage finds from other parts of south Scandinavia, or even to house A11412 presented above. It is therefore possible that the main cereal store of the farmsteads represented by houses A11312 and A11320 were situated somewhere else, possibly in an outhouse, and that the material presented herein represents smaller caches of grain brought into the houses in connection with final processing and consumption.

The phosphate and loss-on-ignition measurements in these houses showed diverging results. In A11312, the LOI and phosphate levels were relatively even along the entire length of the house. In house A11320, two different areas could be defined, one corresponding spatially to the finds of cereal grains in the northern part of the house, where almost all phosphate was bound in inorganic compounds most likely representing animal refuse (bones), and one with high levels of organic phosphate and organic matter (LOI) localize to the southern half.

Thus, a possible functional interpretation of A11320, based on herein presented data, is that it contained a byre in the southern half and a cereal storage and likely kitchen area in the north, with a cereal cleaning space situated in-between.

The interpretation for A11312 is similar, with a cereal storage space and kitchen in the west and a cereal cleaning area in the middle, but no evidence of a byre space.

Well A30223 consisted of six layers, of which all but the topmost were sampled and analysed. The results from all methods are strikingly consistent. Low concentrations of plants as well as limited evidence for input of phosphate rich material in the lower layers D, E and F indicate that these layers represent deposition due to the collapse of the walls of the well. These layers were also noted during excavation as containing large stones, which could originally have belonged to some form of lining or structural support. In layer C, the amount of recovered botanical remains increases sharply (consisting almost exclusively of cereal grains), as does the amount of organic matter (LOI) and the amount of inorganically bound phosphates. In the chronologically subsequent layer (B), the input of anthropogenic material decreases again.

A plausible interpretation for this pattern is that the well was, during its lifespan, kept clean with limited input of waste and rubbish. After its abandonment, the well began to collapse (layers D–F) and was after some time taken into secondary use as a refuse pit. The dominance of cereal grains in layer C along with a phosphate signature consistent with animal matter indicates that this waste most likely derived from kitchen activities. It should also be noted that A30223 is situated less than 3 m from the presumed kitchen section of A11312, literally within throwing distance.

The overview of the two houses and the well at Locality 9–11 have thus resulted in the identification of several functional spaces as well as two, or arguably three, categories of operationally delineated botanical material: cereal cleaning residues in houses A11312 and A11320 and end-stage grain finds in the kitchen areas of the same houses as well as well A30223.

Functional interpretation of Locality 13: house A11220

Locality 13 consisted of a cluster of structures of varying size, as well as remains of wells, pits and post-built enclosures, most of which have been ^{14}C-dated or typologically estimated as belonging to the late Roman and early Germanic Iron Age.

One house, A11220, was sampled in sufficient detail to allow for an in-depth functional analysis (Figure 12).

Three ^{14}C-samples were analysed from this house, showing a 2σ-span of AD 357–540, which corresponds to the general chronological interpretation of Locality 13.

The house was a longhouse, approximately 27 by 7 m, aligned along a southwest-northeast axis. The house structure was well preserved in comparison to most houses at Gedved Vest, allowing for a documentation of not only the

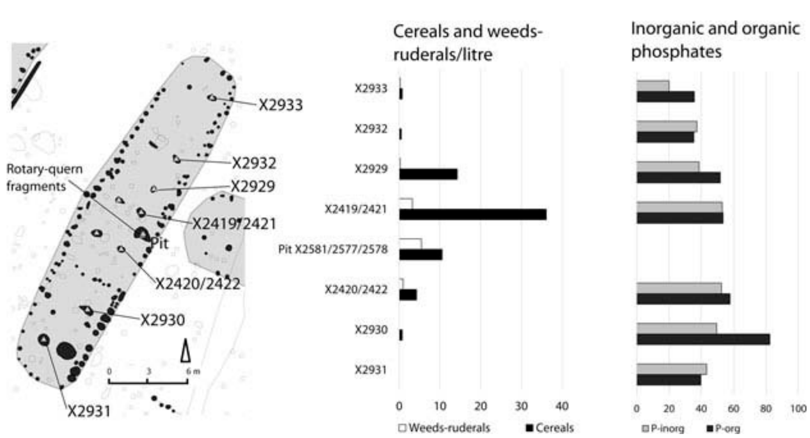

Figure 12. Plan of house A11220 at Gedved Vest and the results of the archaeobotanical and geochemical analyses.

largest roof-supporting postholes, but also details of the walls and internal divisions. The internal arrangement of postholes indicated that at least one wall had been present inside the house, separating the southernmost third from the rest of the building. Another internal detail interpreted as being connected to the house was a pit at the centre of the structure, which contained parts of a rotary quern. This find resulted in the preliminary interpretation of this space as a milling area.

The magnetic susceptibility measurements of the samples from A11220 show that the soil was most probably not exposed to heat, indicating an unburnt structure.

The distribution of botanical material in the house strengthens this interpretation, showing only one area with significant concentrations of carbonised remains. These remains consisted predominantly of cereals, with a smaller admixture of weeds and ruderals, and were recovered from the centre of the house: from the pit with the rotary quern and the posthole pairs on either side of it.

This combination of material evidences strengthens the interpretation of the centre of the house being a mill, but also expands it. In an unburnt house, carbonisation of botanical material should in theory take place primarily around heat sources such as hearths. In most such cases, the carbonisation is accidental and usually limited in volume. The concentration of cereals at the centre of A11220 is, however, comparable to finds from burnt structures, indicating that charring occurred not only of grains which accidentally fell or where thrown into a fire, but rather of a larger cache of grain. Relating to the presumed operational sequence of grain processing (Figure 4), established on the basis of ethnographic, historical and archaeological evidence, a possible explanation may be that this part of the house was not only used for grinding grain into flour, but also for the preceding stage of roasting: one of the few stages involving both fire and large quantities of grain.

The phosphate analysis of this house sheds further evidence about its internal functional arrangement. Both the central and the southern third of the house show higher phosphate levels than the northernmost section. The southernmost section does, however, also display elevated levels of organically bound phosphates around posthole pair X2930.

Summing up the evidences from house A11220, a functional interpretation may thus be that the southernmost third was a byre with animals, or at least a manure storage space. The central space was most likely an area where milling took place, as well as roasting. The comparatively high levels of phosphate may also indicate deposition of various type of animal and organic waste. Thus, this area may also have functioned as a kitchen and possibly also as a living space.

The northernmost space is clean of both botanical remains and phosphates and may have been used for activities which do not leave traces detectable by the methods applied in this study.

Functional interpretation of Locality 19: houses A11107 and A11123

Houses A11107 and A11123 were two longhouses discovered in close proximity to one another at the edge of Locality 19 (Figure 13).

Three ^{14}C-samples from each structure were analyzed, showing a calibrated 2σ-span of AD 342–582 for A11107 and AD 434–649 for A11123.

Based on the large and similar size of these two houses, as well as the fact that A11123 provided slightly earlier ^{14}C-dates than A11107, these houses were preliminarily interpreted as two separate farmsteads; A11107 proposed as the direct successor to A11123 (Hansen 2012). It should be noted, however, that the ^{14}C-data does not preclude these houses being contemporaneous.

The chronological background for houses A11107 and A11123 necessitates the consideration of two possible interpretative scenarios: either that the houses were contemporaneous and possibly part of a single farmstead unit or that they were chronologically separate but, based on their constructional similarities and spatial association, possibly representing succeeding phases of occupation.

Because of the large amount of analysed postholes, the material from these two houses is presented grouped into 12 sections.

The magnetic susceptibility analysis indicates that both houses were destroyed by fire. This indication is supported by the comparatively high concentrations of carbonised plant material in all sections of the houses.

A review of plant concentrations in individual postholes shows that some postholes of A11107 did not contain any carbonised material. This is presumably a result of the constructional history of the building. The plan of the house shows numerous postholes clustered in close proximity to one another. This phenomenon is commonly observed on Scandinavian Iron Age sites and is usually interpreted as the consequence of house maintenance. When a post began to rot, it would be replaced by a new one, resulting in a new posthole next to its predecessor. Since A11107 was probably destroyed by fire, a plausible interpretation is that the ‘empty’ postholes were sealed prior to the fire event.

A comparison between A11107 and A11123 shows that cereals were dominating in all sections of the former house except for no 5. The relation between cereals and non-cultivated plants in this house was 88–12%. The reverse is true for A11123 where non-cultivated (primarily weed-ruderal) taxa dominated all sections except for no 8. The total assemblage of the house shows a relation of cereals to non-cultivated plants of 28–72%. This result

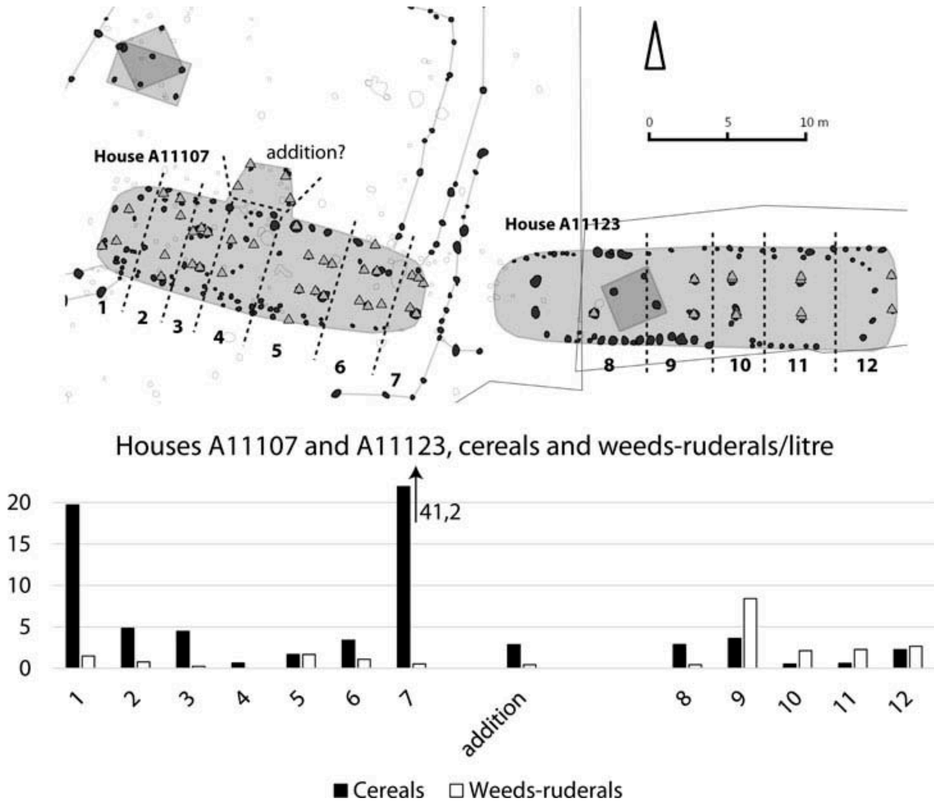

Figure 13. Plan of houses A11107 and A11123 and the results of the archaeobotanical analysis. Note that the samples from the houses have, for the sake of presentation, been grouped into 12 sections.

alone indicates a difference in functionality. A possible interpretation of the variations in the plant assemblages is that A11107 contained predominantly stored grain, from the later stages of operation, while A11123 contained a cereal cleaning space where weeds and cereal residue could accumulate.

Another result indicating different functionality of these buildings was obtained from the phosphate analysis and loss on ignition measurements (Figure 15). The total phosphate levels were higher in house A11107, while the fraction of organic phosphate as well as soil organic matter was higher in A11123. The close proximity of these two houses, as well as the uniform underlying soil conditions, suggests that this variation should be interpreted as a result of anthropogenic processes rather than natural variation. In this particular case, a plausible explanation is that A11123 housed a byre for farm animals, or at least a storage space for manure, while A11107, with high concentrations of inorganic phosphate, could have housed a space where animal products were processed, the most probable alternative being that it contained a kitchen.

Another difference between these houses is the average size of the cereal grains (Figure 15). Grains from A11107 were longer, thicker and broader than those from A11123. The smaller size of the grains in the latter house may represent grain which was sorted out of the main cereal assemblage along with weeds. The grain measurements are thus in agreement with the above interpretation of plant macrofossils, phosphates and LOI.

The multiproxy analysis indicates that these two houses were used for different activities and that they were possibly contemporaneous. The latter interpretation is based on the fact that each structure displays complementary functional aspects expected on an Iron Age farm.

The cultivated crops at Gedved Vest

The functional analysis of archaeological features shows that, with the applied methodology, the botanical material from Gedved Vest can be classified into at least two broad operational categories.

Residues from cereal cleaning were identified in outhouse A11402, pit A35875, specific sections of houses A11312 and A11320, as well as longhouse A11123. The material in these houses may be argued to provide a good foundation for studying the composition of arable weeds at Gedved Vest, since it should be less sorted and modified by human action than weeds in storage finds.

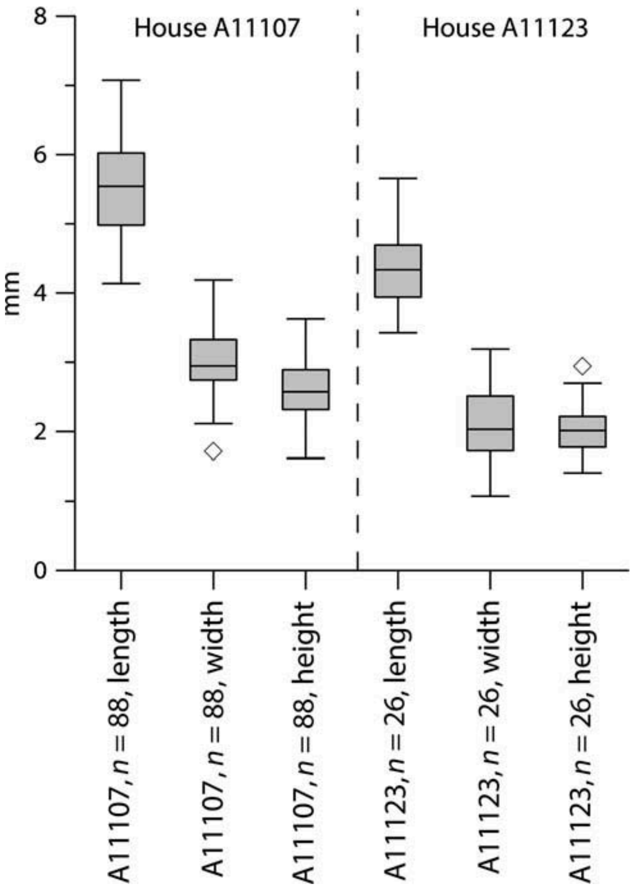

Figure 14. Grain sizes in A11107 and A11123.

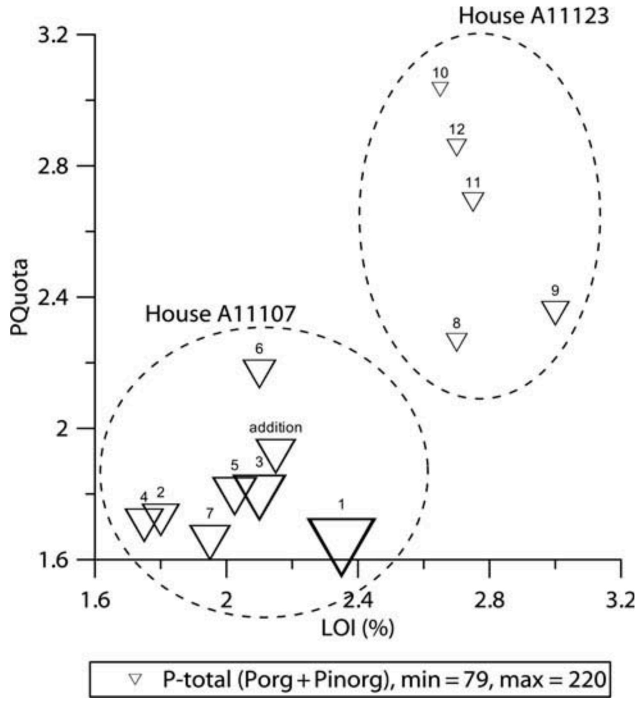

Figure 15. Results of the geochemical analyses of house A11107 and A11123 expressed as a 'bubble graph'. The *Y*-axis shows the relationship between inorganic and organic phosphate (higher quota = more organic P), the *X*-axis shows the amount of organic matter in the samples, as measured by loss on ignition, and the size of the triangles corresponds to the total amount of measured phosphate.

Cereal finds of storage and/or consumption character, in the later stages of cereal processing, were obtained from outhouse A11412, specific spaces in A11312, A11320 and A11220, in pit A30223 and also the entire longhouse A11107. This material is interpreted as providing a good indication of which plants were desired or acceptable for final consumption.

A somewhat ambiguous material, of cereals, weeds and fodder plants, was also recovered from longhouse A11404.

Figure 16 displays the relative cereal composition in the various operational categories (*Y*-axis) sorted in chronological order (*X*-axis). The chronological span of the figure is early Roman Iron Age to late Roman/early Germanic Iron Age. As such, Gedved Vest contributes to filling in a significant gap in archaeobotanical data identified in the overview of previously analysed sites.

The figure provides several insights into the cultivation history of this site.

There appears to be a significant stability in the choices of cereals at Gedved Vest. The assemblages interpreted as meant for consumption all show a distinct dominance of hulled barley. The barley finds dominate already in the earliest assemblages. If Gedved Vest is representative for the region, this could, in combination of the results of the other investigated sites from east-central Jutland, indicate that the shift from naked to hulled barley occurred around the turn of the first millennium AD. If this is the case, this could mean that this region follows a trend similar to Funen, situated to the east (Jensen and Andreasen 2011, Jensen 2012), while diverging from the main trend observed in southern, western and northern Jutland.

Naked barley, although being mostly replaced by the hulled variety, does not disappear entirely. It is present in small amounts in house A11404 and A11312. These occurrences are, however, so small that they could be interpreted as impurities in crop stocks rather than purposeful cultivation. More interesting is perhaps the somewhat larger occurrence in houses A11220 and A11107, both houses displaying almost identical composition of their end-stage cereal assemblages. In the latter case, naked barley comprised only 6% of the cereal material in the house, but a full 50% in the two adjoining postholes from which it was recovered. This indicates small scale cultivation and separate storage of this cereal at the shift from Roman to Germanic Iron Age. This result is interesting as it once again points toward a trend of crop

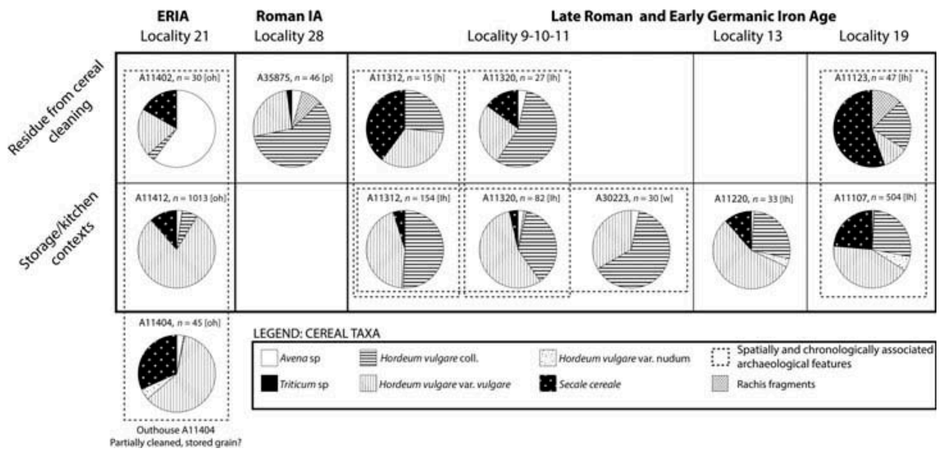

Figure 16. Overview of archaeobotanical assemblages from Gedved Vest. The assemblages are ordered to operational context along the *Y*- and chronologically along the *X*-axis. The type of assemblage is noted next to each assemblage: oh = outhouse, lh = longhouse, p = pit and w = well. Spatially and chronologically associated features are bounded by a broken line.

choices similar to Funen where naked barley is replaced by hulled barley but, deeming from the results of recent investigations, reappears on a small scale during this period (Jensen 2012).

Wheat does not appear to have been grown at Gedved Vest. The occurrences of wheat occur predominantly at Locality 28 and 2, both dated to the Roman Iron Age, but never as more than single occurrences.

Oat was most likely not cultivated either. Oat appears occasionally in the material, but always in very small quantities. Only three grains on the entire site could be determined down to species and these were all *Avena fatua.* Another indication that oat was not cultivated is that appears predominantly in assemblages interpreted as cereal cleaning residues, indicating that it was actively sorted away from the material meant for consumption.

Finally, the assemblages from Gedved Vest contain notable presence of rye. This presence displays a pattern of higher occurrence in cereal cleaning assemblages than in those interpreted as storage and/or consumption finds. For example, rye made up only 4% of the cereal category in the storage find in house A11312 but 40% in the cereal cleaning residue. A similar trend was seen in house A11320 with 3.5% rye in the kitchen space and 15% in the cereal cleaning residue, while longhouse A11107 at Locality 19, interpreted as a habitation space, contained 21%, while the nearby house A11123, interpreted as a barn, showed rye presence of 45%.

Thus, there is a trend of rye presence throughout the investigated periods, increasing somewhat in the later periods, but also of rye generally being localised to areas with cleaning residues rather than spaces with end-stage grain. An exception to this pattern is house A11404 at Locality 21. Being dated to the early Roman Iron Age and interpreted as at least partially cleaned grain, this assemblage stands out as an early and numerous find of rye at Gedved Vest.

The tendency of rye appearing in cereal cleaning residues rather than storage/consumption finds could be the result of rye being a free-threshing cereal, and thus more prone to detaching from the straw than the hulled barley. It could, however, also be, to some extent, an effect of a conscious removal of rye from barley seed.

Based on the results presented in Figure 16, it is difficult to determine how it was cultivated on the site and also when purposeful cultivation may have begun. The complexity involved in such interpretation, as well as the possibility that it may have been consciously removed from the assemblages, is discussed in the summary chapter of this article below.

The weeds at Gedved Vest

Figure 17 presents the relations between weed taxa from the investigated periods of Gedved Vest. This figure is based solely on material from assemblages interpreted as cereal cleaning residues, based on the reasoning that these assemblages should contain the most 'complete' weed compositions in relation to what was presumably growing in the fields. The presence of both small/light- and medium-sized/medium weight weeds in all of the interpreted cereal cleaning residues is furthermore interpreted to represent not one but probably several stages of cleaning, for example coarse sieving, followed by flinging or winnowing (cf. Viklund 1998, p. 63).

The results in the figure are similar to the overview of weed-finds in east-central Jutland as a whole (Figure 2). Arable weeds preferring manured environments, such as *Chenopodium album* and *Persicaria lapathifolia*, dominate the material, but are complemented by species

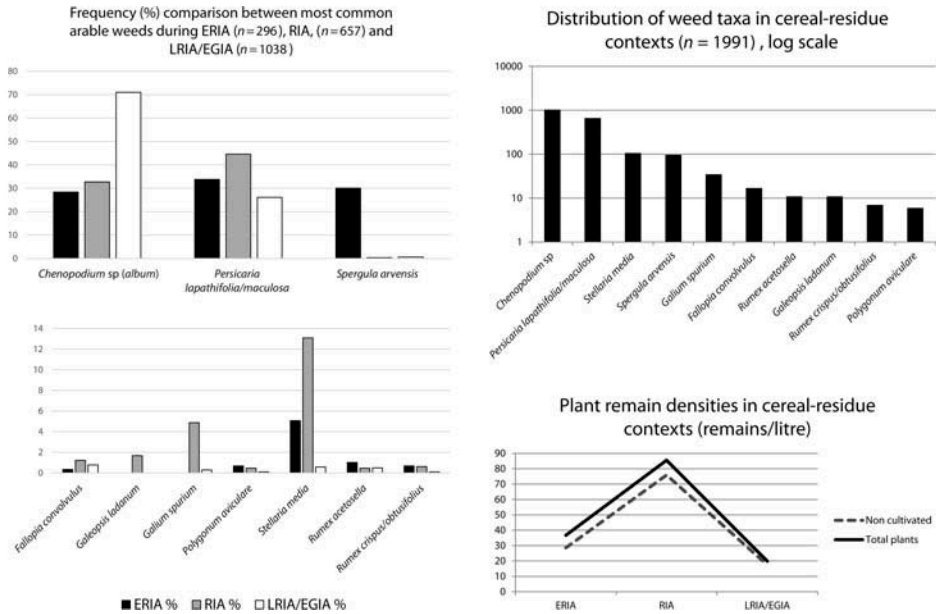

Figure 17. Weed frequencies at Gedved Vest. The material is divided into three chronological categories: early Roman Iron Age (*c*. AD 1–200), Roman Iron Age (*c*. AD 100–400) and late Roman/early Germanic Iron Age (*c*. AD 350–600 [650 in house A11123]).

tolerant of lower nutrient environments such as *Polygonum aviculare, Spergula arvensis* and *Rumex acetosella*. Similarly to the region-wide overview of weed finds, the low-nutrient species appear to decrease sharply over the course of the Iron Age. This could possibly add support for the previously mentioned hypothesis that poor soils were used to a lesser degree during the latter part of the Iron Age or that the manuring regimes became more consistent.

There were no weeds indicative of autumn sowing in the material.

Fodder plants at Gedved Vest?

In the herein presented, overview of botanical material from Gedved Vest references have been made repeatedly to arable weeds and cereals. Hypothetically, however, an Iron Age site should contain botanical material from other biotopes as well, such as fodder plants or collected taxa.

With the exception of house A11404, which contained a moderate presence of grassland species possibly indicative of hay, remarkably few traces of foddering were found at Gedved Vest.

A possible explanation for this fact could be that storage of fodder within the domestic spaces of the settlement was limited. Karin Viklund (1998) has previously noted a distinct difference in the amount of fodder plants in southern and northern Sweden, respectively, arguing for the possibility that the animals in the south were only stalled for short periods of time each year. The milder climate in southern Scandinavia could have allowed for outdoor grazing to a much higher degree than in northern Scandinavia. Interestingly, the analysis of Locality 9–11 showed that only one of two analysed houses contained a phosphate signature consistent with a byre space. This could therefore perhaps be an indication that stalling of animals was not practiced in all farmsteads of the settlement or at least that it in some cases was limited.

Since most of the investigated houses were burnt, there is also a possibility that the houses burned during a time of the year when little or no fodder was stored indoors or that fodder was generally not stored inside the longhouses but maybe in smaller ancillary constructions.

A third possibility could be that the grasslands were mostly used for pasture and that the animals were fed with alternative fodder sources during the stalling period. One such source could be leaf fodder from pollarded trees. Such material would result in a carbonised botanical signature consisting of charcoal and would thus be essentially impossible to distinguish from charcoal derived from the structure of burnt houses.

Analysis of Kristinebjerg Øst

Functional analysis of house DG

House DG was already during excavation noted for its large amounts of charcoal and visible cereal grains indicating destruction by fire (J. Westermann, personal communication, September 2013). This was confirmed by the archaeobotanical analysis, which showed high concentrations of cereals in all sampled postholes and wall-trenches.

The botanical material consisted of almost pure grain. After subsampling, the large samples , a total of 3168 plant remains, were recovered from the house. Out of these, only 143 belonged to non-cultivated taxa. It may thus be concluded that this material represents well cleaned stored grain.

The grain was present in all parts of the house, indicating that the entire area of the house was used for cereal storage. This function does not, however, preclude that the structure had other functions since the cereals could have been stored on a loft (cf discussion in Rowley-Conwy (2000)). Such ancillary function would, however, not have involved plant material traceable through standard archaeobotanical methodology.

Cereals in house DG

The grain assemblage in house DG was composed of four crops: hulled barley, rye, bread wheat and oat. Interestingly, all of these were found in separate parts of the house, thus indicating both monoculture cultivation and separate storage. As seen in Figure 18, only the mixing of crops appears to have occurred at the boundaries between the crop concentrations, possibly resulting from movement of grain during the destruction event. The otherwise intact signature of separate storage indicates limited disturbance after the event.

The cleaned nature of the grain means that the diagnostic floret bases of oat were missing in the material, but the clean large find indicates that it was cultivated at this site, since wild oat would likely not be collected and stored in large quantities. This is also chronologically consistent with the data from previous investigations in east-central Jutland, such as Viuf Vesterby.

The finds of hulled barley and rye are also consistent with previously established understanding of late Iron Age cultivation in Denmark.

Finds of weeds indicating autumn sowing, such as *Agrostemma githago* and *Bromus secalinus* together with the concentration of rye, also indicate crop-rotation of these species.

Most interesting, however, is the large find of bread wheat. This is thus far the only secure storage find of this crop in the region and one of a few in the entire south Scandinavian region. As such, it is a rare material providing evidence about how this crop may have fitted into the existing agricultural system.

A review of the weeds accompanying the wheat in house DG (Figure 19 and supplementary material 4) shows that it likely is grown on manured fields, indicated by presence of *Fallopia convolvulus, Galium spurium, Persicaria lapathifolia/maculosa* and *Stellaria media*. The concentration of wheat did, however, also contain the majority of the *Agrostemma githago* finds from house DG. Although there is a possibility that this occurrence is contaminations deriving from rye cultivation, the evidences pointing toward a minimal disturbance of house DG after the burning also necessitate the consideration that it was growing in the fields together with the wheat. If this is the case, this may indicate that the wheat was

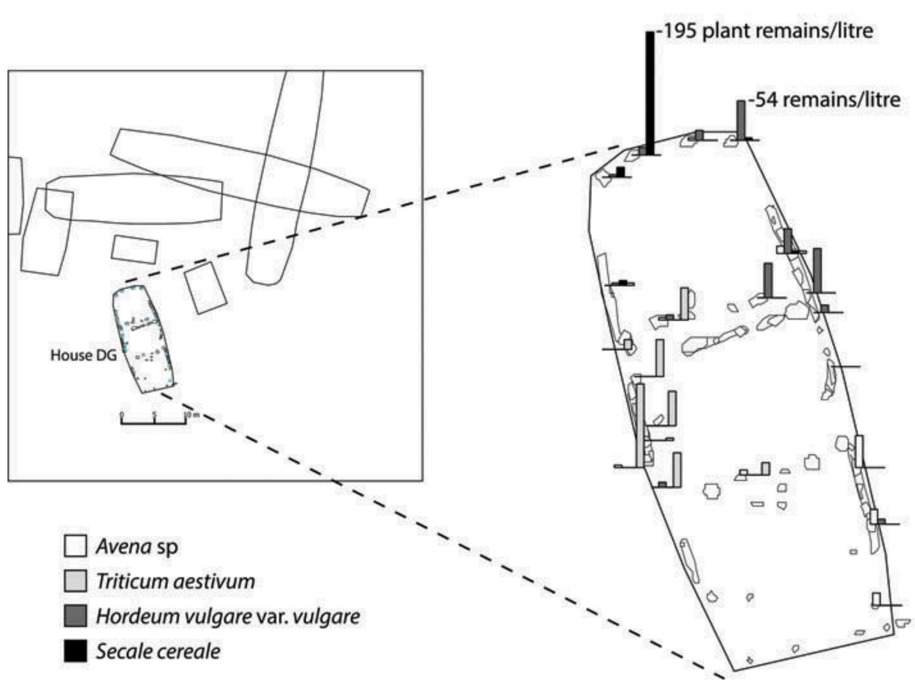

Figure 18. Site plan of Kristinebjerg Øst and close-up of house DG showing the distribution of cereals.

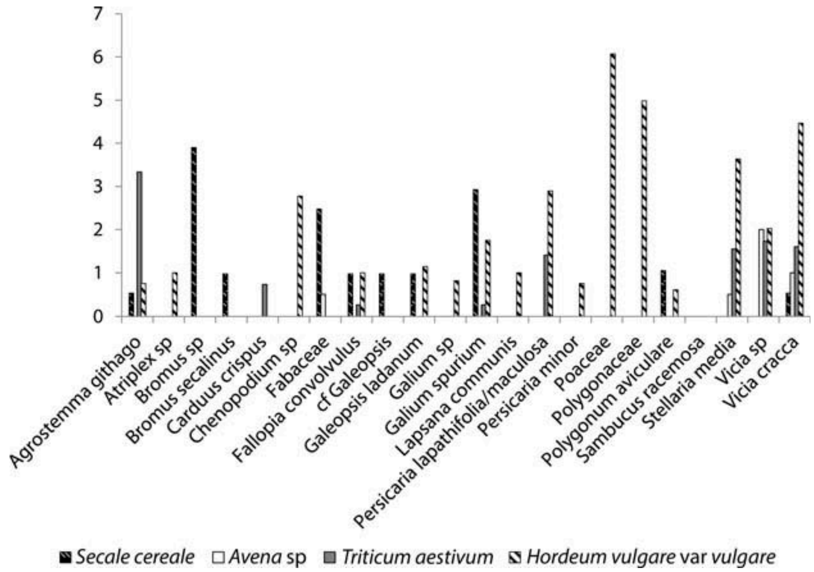

Figure 19. Graph showing the number of various weed taxa in each of the four concentrations of cereals containing relatively clean rye, hulled barley, bread wheat and oat, respectively.

autumn sown similarly to rye. The higher nutritional demand of wheat may, however, have necessitated a slightly different manuring regime for wheat than for rye. This find of wheat thus opens up for the possibility that the rotation agriculture of late south Scandinavian Iron Age may have been more complex than previously indicated by archaeobotanical finds. In the least, the possibility of wheat being autumn sown should be considered in future research as more large finds of bread wheat become available.

Interpreted cereal cultivation history of east-central Jutland based on currently available data

The chronological span of the material presented in this article from previously performed archaeobotanical analyses, coupled with the recently acquired results from Gedved Vest and Kristnebjerg Øst, allows for the establishment of a region-specific cultivation historical overview for the Iron Age in east-central Jutland. This cultivation-historical outline is illustrated in Figure 20.

Consistent with previously proposed models for other areas of south Scandinavia, the Iron Age agriculture in the investigated region appears to have been distinctly dependent on barley, which dominates or makes up a fundamental component of almost all botanical assemblages. The compiled data for east-central Jutland also indicates that the transition from naked to hulled barley, previously mentioned as occurring at different times in various parts of south Scandinavia, can be dated to around the first century AD. Comparing this result to the adjoining regions, east-central Jutland appears to follow a trend more reminiscent of Funen than the rest of Jutland.

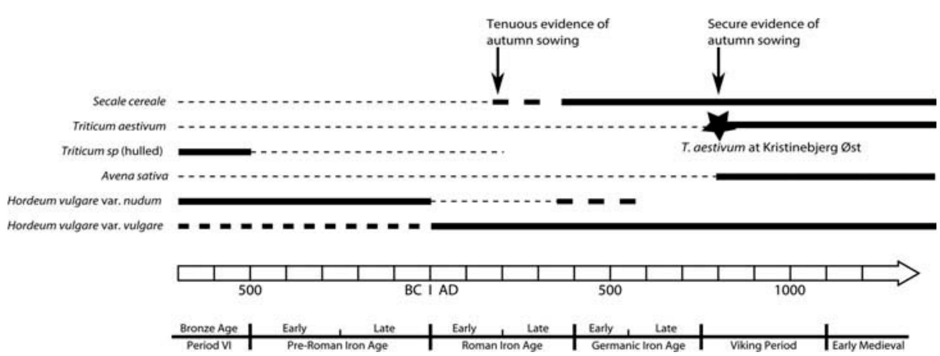

Figure 20. An attempt to visualise the cereal cultivation history of east-central Jutland, based on a qualitative assessment of material from Gedved Vest, Kristinebjerg Øst and the eleven previously analysed sites. Thin broken line, possible cultivation; thick broken line, secure evidence of cultivation but, based on current data, limited in scale; Thick unbroken line, clear evidence for cultivation; star, marking, for the region, the exceptional bread wheat find at Kristinebjerg Øst.

That the main barley cultivation, already at the start of the Iron Age, was performed on manured fields also appears to be clearly indicated by the investigated material. The weed flora (presented in Figures 3, 17 and 19) is similar in almost all assemblages, with nitrophilous, manure indicating weeds being among the most numerous taxa throughout the investigated period.

There are, however, also dissimilarities in the weed material dating to different periods of the Iron Age, the most significant being the decrease over time in taxa which thrive predominantly on poorer soils, such as *Spergula arvensis, Rumex acetosella* and *Polygonum aviculare*, and an increase in taxa indicating autumn sowing such as *Agrostemma githago*. Both of these changes are consistent with a proposed model of early and mid-Iron Age semi-mobile cultivation gradually being transformed into a more fixed infield–outfield utilisation of landscape, where the infields were cultivated in accordance to crop-rotation principles.

The exact dating of this transformation is, however, elusive. The weed assemblages are at this stage not sufficient in quantity and chronological coverage to date the process satisfactorily. Thus, the best archaeobotanical indication for the establishment of crop-rotation, and by extension the presumed infields–outfields, must be sought through a convincing identification of autumn sown crops. In the case of south Scandinavia, the most significant of these crops is rye.

Strong evidence for autumn sowing of rye were found at Kristinebjerg Øst, analysed in connection to the project of which this article is a part, and on the previously analysed site of Århus Søndervold. There was also a more uncertain indication of autumn sowing at the site of Viuf Vesterby. All of these sites are dated to AD 800 or later.

The only earlier clean finds of rye were reported from the site of SBM 1101 Golf 11, where it was recovered from two iron smelting furnaces. There is, however, no way of confirming or disproving whether this rye was autumn sown or not, a situation common to many analysed sites in south Scandinavia.

There are several aspects to rye which make it a particularly difficult plant to interpret.

The first of these is that rye most likely spread to northern Europe as a weed in other cultivation. This weed was, however, not a wild progenitor of cultivated rye, but rather a cultural plant in its own right; a plant that had developed all traits of cultivated cereals in order to increase its chances of dispersal by human action. Therefore, weed rye and cultivated rye are impossible to distinguish by morphology; they are not separate species, but rather different utilisations of the same plant (Behre 1992).

Second, the fact that weed rye already possessed the traits of cultivated cereals distinguishes it from many other weeds by not being necessarily harmful to the cultivation as a whole. Behre notes that farmers in some documented cases display a tolerance to weed inclusion of rye:

> *All over Anatolia and also in north Iran, north Iraq and north Syria, non-brittle types of rye are conspicuous, tolerated weeds in wheat agriculture. They are usually not weeded out by the farmer, and are harvested and threshed together with the wheat* (Behre 1992, p. 149).

Another relevant study of the mixing of crops has been presented by Jones and Halstead (1995). In their publication of the attitudes of the farmers on the Greek island of Amorgos towards monocultural cultivation, maslins (cultivation of several species on a single plot) and the thereof deriving produce, the authors showed that the perception of the purity of a crop was not fixed, but could both be assessed differently by individual farmers – some being more careful in their processing than others – and also influenced by the context in which the plant was utilised; a 'pure assemblage' being judged variously in situations of foddering, consumption, trade and selection of seed for sowing.

The complexity of situations in which rye may have figured during the Iron Age could have been comparable to the cases observed and documented by ethnographers.

In a case such as Gedved Vest, rye could have been grown on separate fields, utilising soils unsuitable for barley. It could also have been utilised on fields which had previously supported barley cultivation, but were being transformed into fallow. The rye could also have grown as a weed in spring sown barley fields.

Another factor to take into consideration is that rye could have had more than merely culinary uses. In an ethnobotanical overview of rye use in Denmark, Brøndegaard (1979) lists many types of craft and manufacture utilising rye straw, ranging from basketry to roof thatching, while in Sweden rye has been documented as being cultivated on small plots in barley dominated areas, its straw used as binding material for the harvested sheaves of the main crop (Dahlstedt 1999).

The factors outlined above makes it necessary to consider whether rye should be discussed in terms of a *weed* versus *cultivated crop* at all, at least when referring to the period preceding its adaptation into a rotation system. The conceptual spectrum of the Iron Age farmers may not necessarily have been one of a binary division into a wanted or unwanted plant. Rye could have been perceived as an individually unique botanical phenomenon, not a weed and not a cereal crop, but rather a species with properties which could be utilised flexibly in order to meet both the needs and desires of the farming community as well as the preconditions for agriculture, such as access to manure and soils in a state suitable for cultivation. Such a situation would account for the difficulty of establishing a precise date for its large scale cultivation.

On a site such as Gedved Vest, flexible utilisation would account for the chronological variations in occurrence; rye being present during the earliest Roman period, disappearing during mid and late Roman Iron Age and reappearing at the shift to the Germanic period.

A flexible utilisation of rye would also account for the trend of rye appearing in some but not all end-stage assemblages from Gedved Vest and for the higher frequencies in cereal cleaning residues, since these could possibly be an amalgamated result of its free-threshing nature and occasional conscious removal from barley stock in which a high level of purity was desired.

Overall, one could argue that rye, even after a review of numerous assemblages, remains a difficult plant to interpret; its mode of cultivation being mostly speculative. The certain conclusions regarding rye are that it played a role in Iron Age agriculture in the investigated region from as early as the first century AD and that its significance likely increased over time. Independent cultivation is indicated from the second and third centuries AD by the iron smelting finds at SBM 1101 Golf 11, while crop-rotation is convincingly identified from the Viking Age onward.

Oat, similar to rye, most likely appeared in south Scandinavia as a weed. Although the weed species *Avena fatua* and *Avena strigosa* differ from the cultivated *Avena sativa* in terms of some morphological traits, these traits have not been preserved in any assemblages except at Viuf Vesterby, where some grains were positively determined as the cultivated species. At Kristinebjerg Øst, the clean and large find, although not positively determined down to species, also indicates cultivated oat. Both sites are dated to the Viking Age. All earlier finds from east-central Jutland are numerically small, pointing to weed inclusion rather than cultivation. This result is somewhat unexpected as assemblages of oat have been interpreted as cultivated in other parts of Denmark from as early as the pre-Roman Iron Age (Robinson *et al.* 2009). Therefore, although oat cultivation cannot be securely established in this region before the Viking Age, one should be cautious about precluding its cultivation prior to the end of the Iron Age. A factor to take into consideration is that oat has historically, at least in some areas, been linked to the feeding of animals, primarily horses (Langdon 1982, Myrdal 1999). If this was true for the prehistoric periods as well, oat may be significantly underrepresented in the archaeobotanical record, since it would likely run a smaller chance of becoming charred by accidental contact with household fires. If the fodder was not stored in structures containing hearths, it would also run a smaller chance of preservation due to accidental house fires.

The modes of oat cultivation cannot be deduced from the small finds presented herein, but historically it has been cultivated both as a spring sown crop in three crop-rotation systems and on permanent slow rotation fields, either independently or following barley. Oat is more resistant to humidity than other cereals, and historical references for Halland have documented the latter method as being applied on wet soils, where little other cultivation was possible (Mikkelsen and Nørbach 2003, Pedersen and Widgren 2004, Grabowski 2011, p. 490 and there listed references).

The last of the four main crops identified in the archaeobotanical material from east-central Jutland is wheat. The various types of wheat have a long history in south Scandinavia; the hulled varieties being in cultivation for several thousand years during the Neolithic and the Bronze Age as a staple in human subsistence, and the naked bread wheat, with its ability to provide fine flour for yeasted white bread, seemingly being cultivated as a secondary crop and known in historical medieval documentation and oral tradition as something of a luxury or special-event product (Grabowski 2011,p. 492 and there listed references).

During the Iron Age, however, wheat is another crop presence eluding a comprehensive interpretation. It occurs constantly throughout most periods and both hulled and naked types are present in the material, although the hulled wheats do gradually disappear over the course of the Iron Age. The sparse presence in botanical assemblages makes it difficult to discuss possible modes of cultivation for wheat or its role in the rotation-systems established at the end of the Iron Age. The find from Kristinebjerg Øst must in this context be seen as significant, since the weed flora accompanying the wheat points towards autumn sowing. The size of the material at Kristinebjerg Øst also indicates that it was, at least on this site of significance, comparable to barley and rye. It is impossible to determine, however, whether this significance is representative for a wider area or even the site from which it was recovered, since the burnt house DG most likely represents a single event in the history of the site. Future archaeobotanical finds of wheat should therefore seek to understand both the relative importance of wheat to other cultivation and attempts to establish whether it was autumn or spring sown.

Concluding remarks

The overview of previously conducted archaeobotanical analyses presented at the beginning of this article focused on a discussion of two previously identified transformations of cereal cultivation over the course of the Iron Age: first from an extensive agriculture of hulled wheats and naked barley on possibly unmanured fields to an intensified cultivation of hulled barley on manured fields, shifting at unknown intervals between cultivation and fallow, and second, one from the intensified but still semi-mobile cultivation of hulled barley to rotation of spring sown hulled barley and autumn rye within a more fixed infield–outfield system.

The initial overview showed that the archaeobotanical material seems to support such a sequence of developments, but only when viewed at the general level of the entire region. The accumulation of archaeobotanical results from analysed and published sites increasingly accentuates differences between various parts of south Scandinavia as much as similarities.

The addition of data from Gedved Vest and Kristinebjerg Øst further accentuates this view, showing, in combination with the previous analyses, that the cereal cultivation history of east-central Jutland followed a general set of developments observed in archaeological data for the south Scandinavian region as a whole, while, on closer inspection, displaying several area specific traits. This particularly applies to the timing of some agrarian transformations, such as the establishment of hulled barley as a primary crop and the establishment of crop-rotation.

As a consequence, the asynchrony and geographic dispersal of the deduced agricultural strategies can be used to question whether Iron Age agriculture should be conceptualised in terms of phases and transformations at all or whether the entire period could be seen as one complex and drawn out process of agrarian intensification and invention culminating in the agricultural system of the medieval period.

In a discussion about Iron Age agrarian landscape developments, based on archaeological and geographic data, Pedersen and Widgren have previously argued that:

> *Agriculture was everywhere based on a combination of crop and animal husbandry. Most farmsteads had three-aisled longhouses with stabled livestock* [and] *manured fields.* […] *The produce from the fields made up at least half the food.* […] *Arable fields provide approximately 10 times more energy per unit of space than pastures or meadows. Therefore, crop husbandry played an important role even in the most livestock oriented areas* […].
>
> *To some extent one can therefore speak of a typical Iron Age farm.* […] *However,* [if one travelled through the Iron Age countryside] *one would see a richly varied landscape. House types and enclosure materials varied between regions. Enclosure systems formed different patterns in the different areas. In that sense there was no typical Iron Age farm* (2004, p. 270, my translation).

In a subsequent discussion, Widgren (2000) further elaborated this view by defining the natural conditions of each region, the locally prevailing culture and social structure, and the global context of south Scandinavia as three perspectives necessary for an understanding of the development of Iron Age landscapes.

It is my conclusion that the herein presented study conforms to the perception of Iron Age agrarian societies as both regionally structured and simultaneously following local developmental trajectories. I also fully agree that numerous perspectives are necessary to extend the value of archaeological studies beyond observation and towards interpretation and understanding; an understanding to which I hope this article contributes with its archaeobotanical perspective.

Supplemental data

Supplemental data for this article is available via the supplemental tab on the article's online page at http://dx.doi.org/10.1080/21662282.2014.920127

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