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ORIGINAL ARTICLE

Barley grain at Uppåkra, Sweden: evidence for selection in the Iron Age

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Abstract A metric analysis on hulled barley grain from the Iron Age regional centre of Uppåkra and surrounding sites in southern Sweden has identified a variation in the size of the grain found on these archaeological sites. Large, high-quality grain was found more frequently at Uppåkra when compared to sites in the surrounding area, where smaller grain was more frequent. The observed large grain found at Uppåkra was, however, restricted to only a few house contexts, including hall-buildings, while other contexts on the site, such as areas dedicated to craft production, had barley assemblages containing smaller grain, similar to the size range found on the surrounding sites. The intra-site variation between different contexts at Uppåkra points to a degree of sorting for larger grain and that this variation between grain assemblages was the result of selection after the crop processing was completed. The distribution of grain size at Uppåkra shows a pattern that indicates that the high-quality barley grain was indented for specific individuals or households. The different contexts at Uppåkra have together produced a record spanning the first millennium AD, representing almost the whole existence of the site. The evidence for selection of larger grain can be seen in the hall-buildings throughout most of the first millennium AD, although less prominently during the Late Roman Iron Age (AD 200–400), while during the Migration Period (AD 400–550) several houses on the main site Uppåkra had assemblages of large grain size. The distribution of grain size at the regional centre Uppåkra shows a pattern that indicates that the handling of large high-quality barley grain was part of a spatial organization, and such organization is similar to other functions observed on the site. The long-term record of grain size patterns across time shows that a structure for handling grain was already in place during the early phase of the settlement and that it remained for centuries. This study indicates that the affluence otherwise seen at the regional centre Uppåkra from an abundance of high-status objects, could also include agricultural wealth, with extensive access to high-quality grain.

Keywords *Hordeum vulgare* ssp *vulgare* · Hulled barley · Crop processing · Uppåkra · Iron Age · Sweden

Introduction

Archaeological research on the Iron Age regional centre site of Uppåkra has revealed an occupational history lasting over 1,000 years, from approximately 100 BC–AD 1000 (Hårdh 2003a; Fig. 1). This continuous habitation of a settlement is rare in northern Europe at that time and raises questions about its social identity and how it was supplied with food. The site, located in southernmost Sweden, is perceived to have been central in functions for trade, religion and administration in the region (Gustin 1999; Helgesson 2002, 2010; Hårdh 2003b; Larsson 2007). The artifact record from Uppåkra demonstrates both a local artisan-based economy and a well-established network of trade and cultural contacts that expanded across the continent well beyond the local region (Hårdh 1999, 2001,

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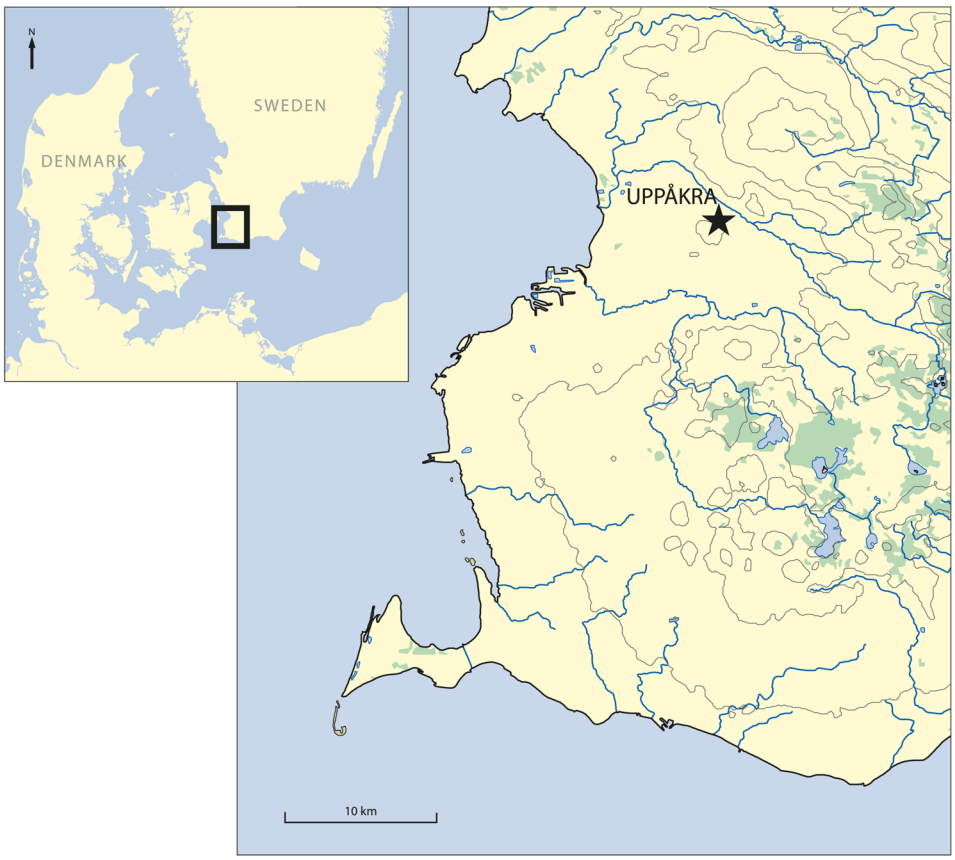

Fig. 1 Location of the regional centre Uppåkra in southern Sweden

2010; Stjernquist 2004; Watt 2004). However, few efforts have been made to understand the role of Uppåkra in the agricultural society, how it organized and managed its food supplies, and whether its affluent role had parallels concerning the handling of staple plant-based food in the area.

Recent archaeobotanical sampling at the regional centre Uppåkra and at seven smaller surrounding sites has produced new data on crops handled in this confined area. The sites in the surrounding area, all located within a distance of 0.5–2.5 km from Uppåkra, are contemporary with the main site at different times (Fig. 2). The good preservation of cultural layers at Uppåkra has in places preserved stratigraphic records from multiple-phase houses (Larsson and Söderberg 2012). These cultural layers, together with several other contexts, provide an opportunity to study not only plant remains from individual phases, but plants handled over a considerable time on the site. The individual smaller sites in the surrounding environs of Uppåkra are, in contrast, rather short-lived, but together they represent the nearby hinterland for the entire Iron Age (Table 1).

Hulled barley, representing the vast majority of cereals on the investigated sites, was subjected to a metric analysis. This study aimed to test if any variation existed in grain size among samples of barley collected from different contexts at the regional centre Uppåkra and from the surrounding sites. Specific questions for this metric study include:

1. If size differences in grain can be identified, is there variability between different cereal assemblages, within the individual sites, and/or between the regional centre Uppåkra and surrounding sites? If so, what does this variation reflect in terms of function and social identity?
2. Given the long habitation at the regional centre Uppåkra, are there any indications from grain size distribution among assemblages to suggest change or stability in the handling of barley over time?

This study uses quantitative and spatial distribution of hulled barley grain to examine if the economic relationship for handling cereals at the regional centre of Uppåkra and surrounding settlements can be explained by variation in grain size. If grain assemblages can be characterized as having larger or smaller grain overall, this can indicate sorting of cereals (Hillman 1981), though it is important to note that a difference in growing conditions can affect grain quality, including grain size (Willcox 2004).

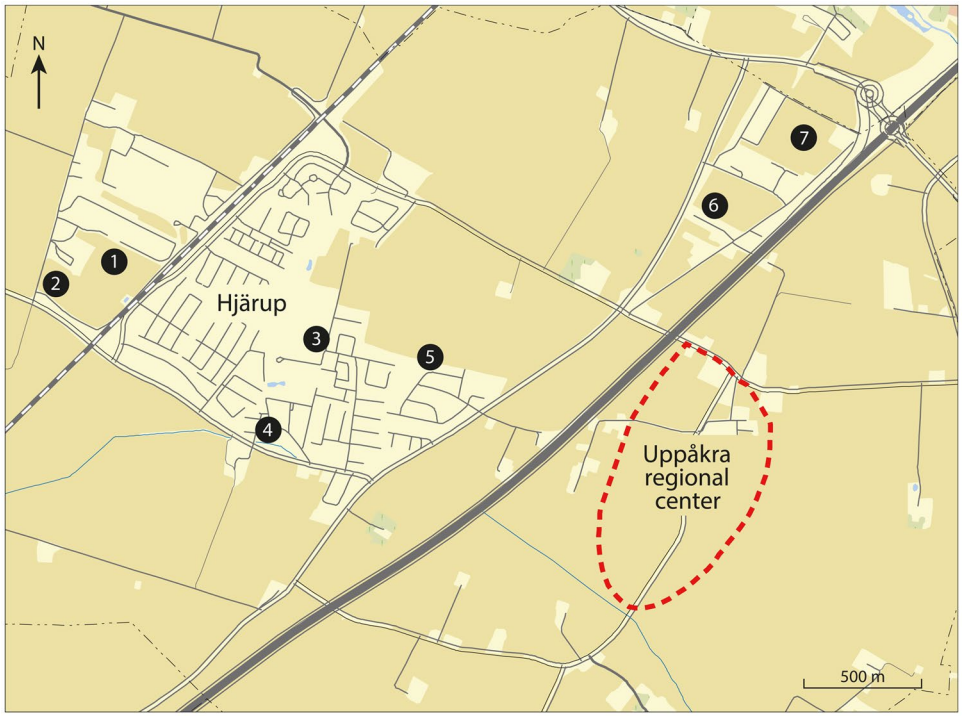

Fig. 2 Sampled sites in the surroundings of the regional centre Uppåkra: (1) Hjärup 7:1, (2) Hjärup 21:36, (3) Hjärup–Åttevägenområdet, (4) Hjärup 9:8, (5) Uppåkra 12:110, (6) Uppåkra 2:14, (7) Uppåkra 2:25

Table 1 Chronology of the Swedish Iron Age

Cultural stage	Chronology
Late Iron Age	
Viking Period	AD 800–1050
Vendel Period	AD 550–800
Migration Period	AD 400–550
Early Iron Age	
Roman Iron Age	
Late Roman Iron Age	AD 200–400
Early Roman Iron Age	AD 1–200
Pre-Roman Iron Age	500–1 BC

Study area

The study area is located in the province of Scania, around the present day villages of Uppåkra and Hjärup, in southern Sweden. The archaeological sites investigated in this study includes the main site, the regional centre Uppåkra (55°40′N 13°10′E) and seven smaller settlements, Uppåkra 12:110, Uppåkra 2:14, Uppåkra 2:25, Hjärup 7:1, Hjärup 9:8, Hjärup 21:36 and Åttevägenområdet, all located within a distance of 0.5–2.5 km, west and north of the regional centre.

Situated between the Öresund Strait to the west and a ridge trending northwest-southeast to the east, the investigated area is set in the middle of a fertile agricultural area. All sites can be found on similar soil types consisting of uniform Quaternary deposits which are dominated by clay till and overlying chalk bedrock. The regional centre Uppåkra was located 7 km away from the coast, with access to the Öresund Strait from the small stream Sege å to the south. The topographical setting is typically a flat landscape at an elevation of 15–25 m a.s.l., while Uppåkra is situated on a slight rise in the landscape, approximately 35 m a.s.l., making it visible from its surrounding areas.

The seven smaller sites in this study are referred to as the ‘surrounding sites’, or the ‘surrounding area’. When a specific site in the surrounding area is discussed, its name and property number is stated, e.g. Uppåkra 2:25, after the Swedish National Heritage registration system of archaeological sites. The main site is referred to as Uppåkra or the regional centre Uppåkra.

Background

Regional centre Uppåkra

An archaeological excavation program of the site began in 1996 and since then the settlement has been estimated to cover about 40 ha (Larsson 2002, 2003). Different areas of the settlement have been the subject of investigation, but the primary focus has been on the central part of the site. This central area has revealed several house structures, for example contexts of hall-like buildings and a ceremonial house, but also weapon deposits. Based on exceptional artifacts found within these layers of both local and foreign origin—such as glassware, a metal beaker, weapons, surgical

instruments and numerous gold-figure foils, but also great accumulations of discarded animal bone from presumed public gatherings—it has been suggested that this area of the site was associated with the social elite, but functioned also as a place of communal use (Larsson 2006; Frølish 2010; Magnell et al. 2013). In particular, the abundance and quality of the metal objects made from bronze, silver and gold, reflect a concentration of wealth suggesting a socially stratified community (Stjernquist 2001). Outside the central part of the site, the artifactual record is still abundant and investigations have uncovered many smaller houses and several areas associated with craft production (Helgesson 1998; Lenntorp and Lindell 2000; Gabler et al. 2013; Lenntorp 2013).

Surrounding sites

Archaeological investigations of Iron Age settlements in the surroundings of the regional centre of Uppåkra have characterized these as being ordinary, farm-based settlements lacking the material wealth seen at the regional centre (Schmidt Sabo et al. 2011; Becker et al. 2012, p 35; Aspeborg et al. 2013, pp 127–131). Visible manifestations otherwise observed at the main site, such as the tell-like build-up of accumulated cultural layers, burial mounds and a ceremonial building are missing from the surrounding sites. Some artifactual evidence suggests however that a few of these settlements had a direct link to the leading elite at Uppåkra through their provision of bronze casting for the wealthier residents of the regional centre (Larsson 2003).

Crop cleaning and its effect on grain assemblages

In pre-industrial agriculture, the harvested cereal crop was processed by threshing, raking, winnowing, pouring, flinging, sieving and hand sorting (e.g. Hillman 1981, 1984; Jones 1984; van der Veen 1992; Viklund 1998, pp 60–63). The aim of processing is to remove contaminants, chaff and weed seeds, to leave clean grain. The crop processing consequently diminishes the proportion of contaminants among the grain. Composition of assemblages from the final stages of the crop processing will therefore be dominated by grain with few contaminants, while those from the earlier stages will contain mostly contaminants. Weed seeds and grain are however removed in a selective manner during processing, large weed seeds can be retained with similar size grains, and those grains of small size may be lost as waste.

To understand the pre-historic composition of ancient plant remains, different models have been used to understand the different stages involved in cleaning the harvested crops and how these processes affected and formed the archaeobotanical assemblages (e.g. Hillman 1973, 1981, 1984; Dennell 1974, 1976; Hubbard 1976; Jones 1984). Hillman (1984) described from ethnographic observations in Turkey how the processing-sequence effected the composition of the products and by-products produced at any stage of the processing. Waste from each stage, by-products, includes removed chaff, smaller weed seeds and small 'tail' grain. The prime products are transitory as they are carried into the next stage of processing, until the final stages when the assemblage contains mostly 'prime' grain. Grain-sized weed seeds retained with prime grain could be removed by hand sorting. Using ethnographic studies of crop processing, the presence or absence of by-products from the early stages of crop processing (winnowing and coarse sieving) was suggested to be indicative in distinguishing between producer and consumer sites (Hillman 1973, 1981, 1984; Jones 1983, 1984). On producer sites (i.e. where the grain was processed and cleaned) there would exist remnants of by-products, in contrast to consumer sites where we might expect to find mostly grain which had completed the cleaning and sorting process.

A model developed by Jones (1985), based on settlements in central-southern England, was in direct contrast to that of Hillman. He proposed that within producer settlements grain would be readily wasted, leading to grain-rich assemblages. Grain on non-producer sites would in contrast be characterized by low quantities of grain, leading to assemblages more abundant in weed seeds and chaff. Campbell (2000) has added to the discussion that the absence of chaff among grain-rich assemblages, particularly on producer sites, is indicative of chaff used as fodder. Based on the stages of handling cereals, Stevens (2003) looked at the type of storage cereals were given at different points of their processing. He explained variation between assemblages as being a result of the processing stage at which the crop was stored. He differentiated between communal storage (storage for clean or semi-clean spikelets), and household storage (storage for partially threshed ears). Models for producer and consumer sites have, however, been seen as rather simplistic. Because these models relate to waste from the later stages of processing, new models have developed which pay attention to taphonomic processes involved in the formation of charred assemblages (van der Veen 1992, pp 91–99; van der Veen and Jones 2006).

Previous studies on grain assemblages have often been based on botanical composition and the presence or absence of chaff and/or weed seeds. They are good methods, but require good preservation of chaff and weed seeds to be correlated to past activities, and also an understanding of the taphonomic processes (van der Veen 2007). In Sweden, archaeobotanical assemblages from Iron Age settlements usually contain scarce amounts of chaff. Several experiments have shown that much of the waste from crop processing survives differently undergoing charring (e.g. Viklund 1998, pp 99–107; Gustafsson 2000). It is therefore problematic to

assume that the proportions of chaff, weed seeds and grain preserved are relative to the proportion that would have existed in the past. Thus, the absence of chaff or weed seeds, or a dominance of cereal grains, cannot be relied on alone as an indication of post-harvest processing (Wilson 1984).

Another method is to study by metric analysis the size of the grain itself from assemblages. Overall grain size in an assemblage or variation of size between assemblages may be indicative of specific stages in grain processing. The advantage of using metrics on grains is that they, almost regardless of size, have the same probability of surviving charring compared to other plant remains, such as chaff and weed seeds. However, some caution needs to be taken regarding the dimension of the grain, as grains are easily distorted during carbonization, which can then affect variation in size distribution. According to Ferrio et al. (2004), the charring process will probably affect size dimensions causing the grain to shrink in length (up to 5%) and puff up in breadth (up to 14%). Experiments have further demonstrated how charring conditions affect distortion of grain depending on the temperature, the amount of oxygen in the atmosphere and the moisture content in and around the grain (Boardman and Jones 1990; Gustafsson 2000).

Materials and methods

Regional centre Uppåkra

Archaeological excavations were combined with archaeobotanical sampling during four field seasons (2010–2013) at Uppåkra (Lenntorp 2009; Söderberg and Piltz-Williams 2012; Söderberg et al. 2014). The investigations focused partly on a house-sequence in the central part of the site (Fig. 3a; Table 2 [1–7]). This sequence, representing cultural layers from a multi-phase building, spans over one millennium (approximately 100 BC–AD 1000), and has in places formed stratigraphic records of about 2 m. From the house-sequence, four stratigraphic profiles—105776, 92518, 93609, 87033 (context 1, 2, 3, 4)—were sampled for archaeobotanical material and radiocarbon dating using a contiguous sampling method (Pearsall 1989). The purpose of this sampling was to study plants handled across time. From the house-sequence, additional samples were collected during the excavation of varying layers belonging to three different houses: House 23 (context 5, 6), House 24 (context 6) and House 22 (context 7). This series of house-phases is commonly referred to as the "hall-buildings" (Larsson and Söderberg 2012).

Outside the central part of the site (Fig. 3b; Table 2 [8–15]), three other areas were investigated: a house layer of House-phase 4 (context 9); an activity area with hearth features at Trench B (context 14); and another

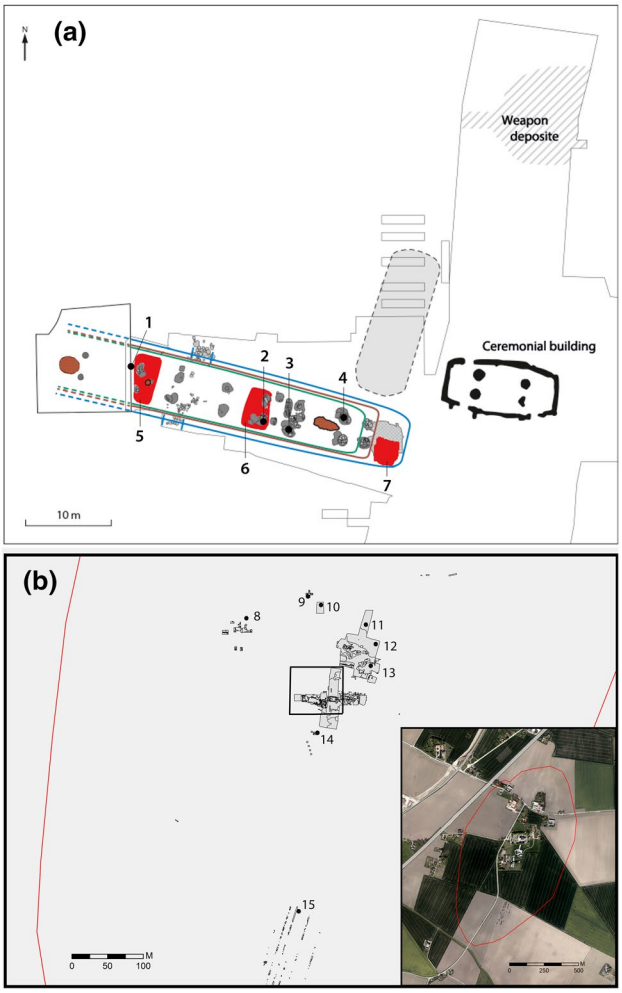

Fig. 3 **a**–**b** Sampling contexts at Upppåkra: **a** from the sequence of houses—hall-buildings, located in the central part of Uppåkra (1–7), **b** from other areas on the site (8–15)

house-sequence—stratigraphic profile 110342 (context 11). In addition, unprocessed soil samples from four previous investigations at the site were available for processing and analysis, and were included in this study. These included an oven feature (context 8) and layers from three houses: Bårhuset (context 10), Pithouse 1 (context 12) and House 11 (context 13) (Ohlsson 1968; Lenntorp and Lindell 2000; Larsson and Lenntorp 2004).

Surrounding sites

Excavation of seven sites in a confined area, west and north of the regional centre Uppåkra, provided archaeobotanical material for the present study (Fig. 2). All sites are interpreted to have been small farm-based settlements (Regnell 1998; Schmidt Sabo et al. 2011; Becker 2012; Becker et al. 2012; Bolander 2012a, b; Aspeborg et al. 2013).

Table 2 Samples of measurements of barley grain from the regional centre Uppåkra and surrounding sites with individual site chronology and corresponding period

Site	Site chronology	Sampled context	Loc.	Early RIA (1–200)	Late RIA (200–400)	Migration Period (400–550)	Vendel Period (550–800)	Viking Period (800–1050)
Main site[a]								
Regional centre Uppåkra	ca 100 BC–AD 1000	Profile 105776 (house sequence)	1	6	4	4	–	–
		Profile 92518 (house sequence)	2	7	3	4	–	–
		Profile 96069 (house sequence)	3	–	1	–	–	–
		Profile 87033 (house sequence)	4	9	–	–	–	–
		House Vifot (house sequence)	5	–	–	1	–	–
		House 23 (house sequence)	5	–	–	–	5	–
		House 23 (house sequence)	6	–	–	–	3	–
		House 24 (house sequence)	6	–	–	9	–	–
		House 22 (house sequence)	7	–	–	–	–	1
		Oven area (oven)	8	–	–	–	2	–
		House-phase 4 (house layer)	9	–	1	–	–	–
		Bårhuset (house layer)	10	–	–	4	–	–
		Profile 110342 (house layers)	11	3	1	5	–	–
		Pithouse 1 (house layer)	12	–	–	2	–	–
		House 11 (house layer)	13	–	–	3	–	–
		Trench B (hearths)	14	6	–	–	–	–
		Artisian area (house layers)	15	2	–	–	–	–
Surrounding sites[b]								
Hjärup 7:1	ca AD 400–550	House, pits	1	–	–	5	–	–
Hjärup 21:36	ca AD 600–800	Pit	2	–	–	–	1	–
Åttevägenområdet	ca AD 1–400	Pits	3	3	–	–	–	–
Hjärup 9:8	ca AD 900–1000	Pit, hearth	4	–	–	–	–	2
Uppåkra 12:110	ca AD 1–300	House	5	1	–	–	–	–
Uppåkra 2:14	ca AD 1–200	House, pithouse	6	2	–	–	–	–
Uppåkra 2:25	ca AD 1–400	Houses, pit	7	4	2	–	–	–
Total number of samples used in *Hordeum* measurments								
Regional center Uppåkra				33	10	32	10	1
Surrounding sites				10	2	5	1	2

[a]Location refers to sampled contexts in Fig. 3a, b

[b]Locations refers to sampled sites and contexts in Fig. 2

Archaeobotanical samples were mostly collected from post-holes of long-houses, pits, ovens and hearth features.

Sample treatment and analysis

Soil samples of around 1–2 l were processed by flotation and sieved manually over a 0.4 mm mesh. With a few exceptions, only charred plant material was preserved and botanical remains were identified using a modern reference collection at the Geology Department of Lund University and at the Swedish National Heritage Board, UV-Syd, Lund. Relevant reference literature was also consulted (Cappers et al. 2006; Jacomet 2006).

Radiocarbon dating

Samples of charred *Hordeum vulgare* ssp *vulgare* caryopses from stratigraphic profiles and other contexts at Uppåkra underwent AMS radiocarbon dating. Results were calibrated using OxCal v3.10 Bronk Ramsey (2005). From sites in the surrounding area, ^{14}C dates were obtained from archaeological reports of Runcis (1998), Schmidt Sabo et al. (2011), Becker (2012), Becker et al. (2012), Bolander (2012a, b) and Aspeborg et al. (2013).

Metric analysis

A metric analysis was used to investigate the size variation, specifically the length (L) and breadth (B), of hulled barley (*H. vulgare* ssp *vulgare*) grain (caryopses). The aim was to establish whether it was possible to identify a size variation in grains and, if so, to distinguish different size distributions between assemblages and between sites. The metric analysis was undertaken on 86 samples of grain from 15 contexts within the regional centre Uppåkra site: seven contexts in the central part of the site (57 samples) and eight contexts from different areas of the site (29 samples). 20 samples of grain were analysed from seven sites in the surrounding area. The length and breadth of grains were measured using a digital live-link camera through a microscope with magnification 6.3–63. The quantity of preserved complete charred barley grains available for metric analysis varied between contexts. The number of grains measured for each sample population aimed, however, to be as alike as possible, to make samples in the study comparable. In 86 samples 20–40 grains were measured, but smaller samples, less than 20 grains constituted 20 samples. Only whole grains were measured. When samples were taken from large assemblages (i.e. those containing hundreds or thousands of grains), a sample splitter was used to avoid any bias.

The median (Md) was calculated for each sample and for L and B separately. The inter-quartile range (IQR), using the first (Q1) and third quartile (Q3), was used to measure dispersion around the median value. The min–max value is included to show the full range of each sample. Mean values were calculated from all individual measurements of grain to compare the results of the regional centre with those of the surrounding sites. A T-test was used to test for differences between the entire distributions of the two data sets (the main site Uppåkra and surrounding sites).

Results

Chronology

Radiocarbon dates from the regional centre Uppåkra have produced chronologies with the earliest occupational layer dating from the 1st century BC continuing up to around AD 1000 (ESM 1). The younger phases of the settlement (AD 650–900s) are represented mostly by fragments of cultural layers, due to impacts from modern agriculture. Sites in the surrounding area produced dates within the time-span of approximately AD 1–1000.

The chronology of the house-sequences represented in the stratigraphic profiles show occupational layers between approximately 100 BC–AD 650. Individual layers from the house-sequences (stratigraphic profiles 105776, 92518, 93609, 87033, 110342) are described according to the type of cultural layer: floor layer (constructed from clay); floor deposit (accumulation of habitation debris); building collapse (mixed debris from house-fires, such as ash, wood charcoal and burnt daub); intermittent layers of fill and levelling; thin lenses of various deposited composition. Until excavations investigate the layers that are represented in the stratigraphic profiles, covering larger surfaces, identification to type of cultural layer and how they relate to each other is preliminary at this stage. Due to larger excavations of layers belonging to the later phases of the house-sequence (hall-buildings), identification of individual houses and their corresponding time periods are provided for three houses: House 24 (AD 400–550), House 23 (AD 550–800) and House 22 (AD 800–1050).

Cereal composition

Archaeobotanical data on crop plants from the stratigraphic profiles and other areas investigated at the regional centre for this study are presented in ESM 2. Results from the surrounding sites are available in excavation reports by Schmidt Sabo et al. (2011), Becker (2012), Becker et al. (2012), Bolander (2012a, b) and Aspeborg et al. (2013).

From the present study and previous archaeobotanical investigations at the regional centre Uppåkra (Hjelmqvist 1955; Regnell 2001; Larsson 2015), hulled barley largely dominated the cereal composition followed by smaller

quantities of emmer wheat, bread wheat, oat, rye, naked barley and broomcorn millet. The large quantity of barley is partly due to finds containing thousands of grains, i.e. the house-sequence of hall-buildings (context 1–7), Bårhuset (context 10), Pithouse 1 (context 12) and House 11 (context 13), all located in the central area of the main site. However, barley grain is also highly represented in most sampled features across the site. This range of cereals corresponds with the cereal compositions found at the sites in the surrounding area and, typically, elsewhere in Iron Age southern Scandinavia (Grabowski 2011). Based on the relative proportion of grain quantity found at individual sites, the archaeobotanical archive from some of the surrounding sites indicates that farmers had a focus on cereal production, particularly barley and/or wheat. Grains of oat, rye and broomcorn millet were also found secondarily. Both at the main site of Uppåkra and on surrounding sites, cereal crops were almost entirely represented by grain, whereas chaff was scarce.

Grain size

Results from the metric analysis (2,705 grains from 106 samples) of the *H. vulgare* ssp *vulgare* assemblages are presented by median values of each sample in Fig. 4. Analyses of individual samples are presented in ESM 3.

The metric analysis of grain populations in the study area shows how both the regional centre Uppåkra and the surrounding sites have contexts with similar grain sizes. However, an intra-site study of the sample populations from the regional centre Uppåkra shows a variation among sampled grain assemblages in which a predominantly larger grain size is identified at only a few contexts. This is the case with samples from the hall-buildings where a tendency for assemblages to have larger grain size was observed. This tendency for handling large grain in the hall-buildings can be seen throughout most of the first millennium AD, while it is less evident from samples dating to the Late Roman Iron Age (AD 200–400). During the Migration period (AD 400–550), three other house contexts (context 10, 12, 13) show sample populations containing larger size grain. Other features on the main site, i.e. around the oven area (context 8), House-phase 4 (context 9), profile 110342 (context 11), Trench B (context 14) and in the artisan area (context 15), had sample populations containing mostly smaller grain.

The sample populations with smaller grain at the main site of Uppåkra corresponded to contexts from the surrounding sites, which also had smaller grain. Six of the surrounding sites had overall sample populations with a small grain size from comparable contexts: households, pit and hearth features. Only Hjärup 9:8 differed from the other surrounding sites in that it had a few sample populations with larger grain, which were taken from hearth and oven features.

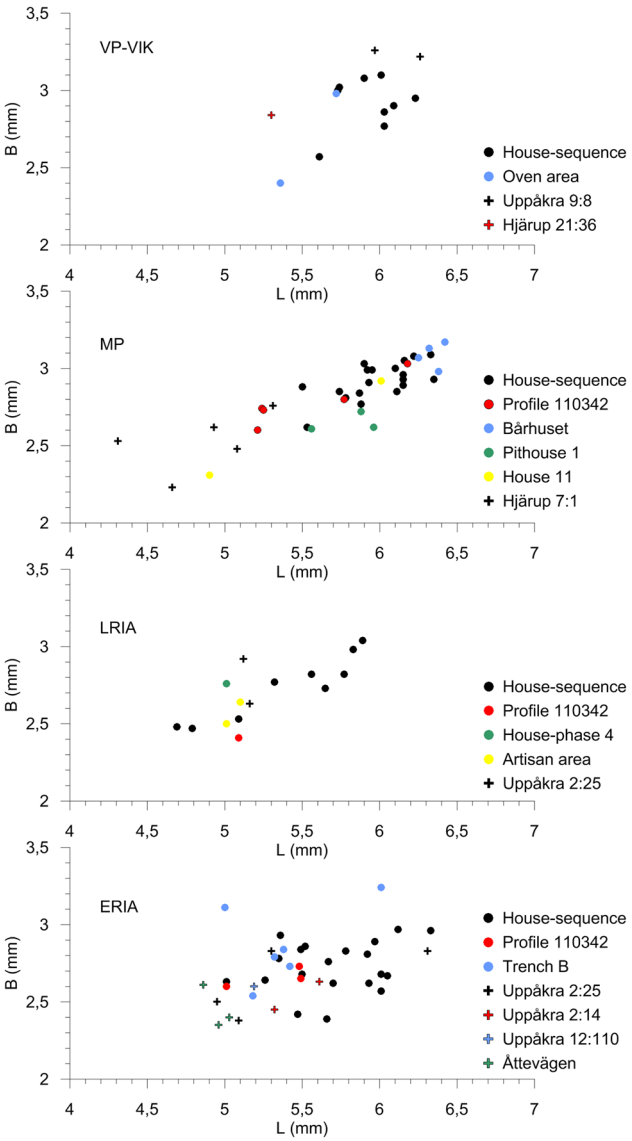

Fig. 4 Measurements of barley grain presented by median values for all sample populations in the study area, separated by context and time periods. *Circles* represent samples from the regional centre Uppåkra, and *crosses* those from the surrounding sites

A comparison of the metric data shows that from the main site of Uppåkra the mean grain size (both length and breadth) is larger overall compared to those from the surrounding sites collectively (Fig. 5). Mean values for grain length (5.83 mm) and breadth (2.83 mm) at Uppåkra are larger compared to the length (5.22 mm) and breadth (2.66 mm) at the surrounding sites (Fig. 6). The total distributions

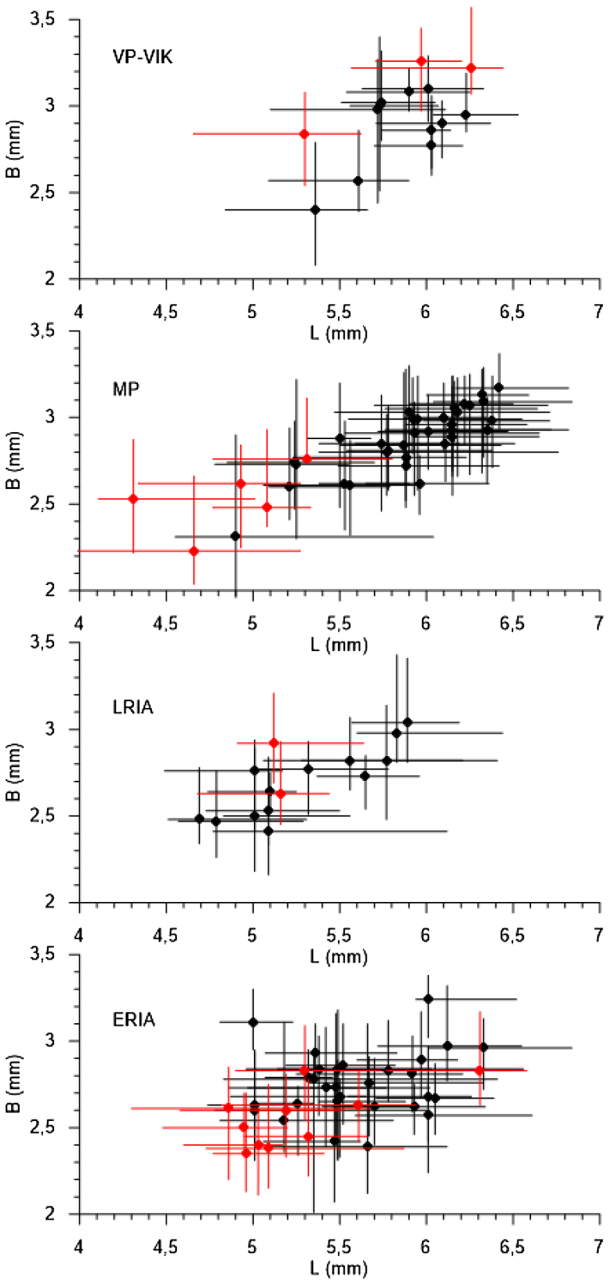

Fig. 5 Measurements of barley grain presented for median and inter-quartile values of all sample populations in the study, separated by context and time periods. *Black* represents the regional centre Uppåkra, and *red* represents the surrounding sites (ERIA includes Uppåkra 2:25, Uppåkra 2:14, Uppåkra 12:110, Åttevägenområdet; LRIA includes Uppåkra 2:25; MP includes Hjärup 7:1; VP-VIK includes Hjärup 21:36, Uppåkra 9:8)

of the two data sets are significantly different ($p < 0.001$). The standard deviation for both the length (0.729) and the breadth (0.433) at Uppåkra is smaller compared to the length (0.796) and breadth (0.488) at the surrounding sites.

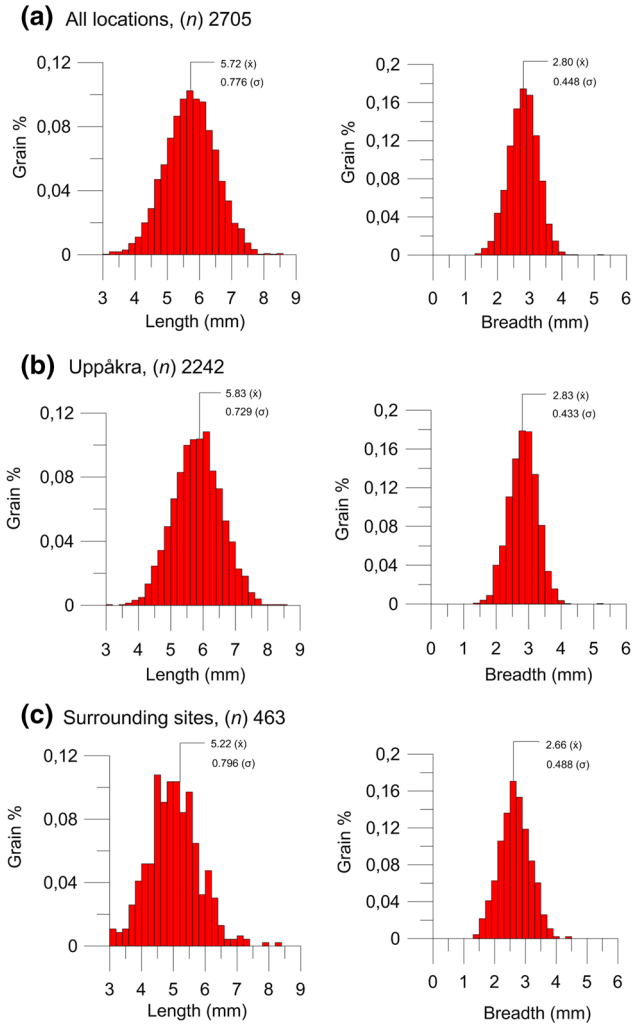

Fig. 6 Size distribution for length and breadth respectively: **a** size distribution of all metric data from the study area; **b** size distribution from all contexts at the regional centre Uppåkra; **c** size distributions from all surrounding sites

Discussion

Barley grain size and contextual variation

Hulled barley was largely the principal cereal crop in Scandinavian Iron Age society and it is not unique to the finds from the investigated sites in this study (Robinson et al. 2009; Grabowski 2011). It reflects foremost the great economic value of this crop; it was consumed in the forms of food and beer, while on the farm other uses of the cereal included the straw and chaff for bedding, and fodder for livestock (Viklund 1998, pp 92, 142–148). Even with far-reaching contacts from trade, basic food consumption of staple produce at the regional centre Uppåkra was still in

accordance to local tradition. The metric analyses presented in this study show, however, that barley assemblages vary in regards to overall size distribution—some assemblages have a composition of large grain whilst others have a small grain size—and that this difference observed in grain size related to contextual difference.

Roman Iron Age (AD 1–400)

Different contexts within the main site of Uppåkra containing barley show a noticeable variation in grain size. Larger grain size was found in different phases of the hall-buildings. Based on the stratigraphic continuity of the hall-buildings (about one millennium), the sheer size of the buildings, the artifacts found within the house layers, and its placement besides a ceremonial house (also made up of a sequence of house layers dating to AD 200s–900s), the hall-buildings are believed to have been a residence for high ranking individuals (Larsson 2011). The location of the hall-buildings is thought to be the central part of the settlement—a part that is also thought to have functioned as a communal area for administrative and religious uses (Larsson 2011). Cereal remains from the hall-buildings show not only a strong dominance of barley, but also a tendency for large grain, a pattern that is observed already during the early phase of the house-sequence, the Early Roman Iron Age.

In contrast to the hall-buildings, other contexts on the settlement dating to the Roman Iron Age show a tendency for handling smaller grain. These contexts include areas with several hearth features and pithouses linked to craft production: Trench B (context 14) and an artisan area (context 15). A partially excavated layer from House-phase 4 was, judging from the scarce and rather ordinary artifacts found within it, thought to be a regular household (Söderberg and Piltz Williams 2012). Contextual information from profile 110342 is less understood, but the sampled layers are interpreted as representing house-phases (Söderberg et al. 2014). Grain size from the aforementioned contexts was of small to medium size, with the exception of large grain found in one sample from a hearth at Trench B.

Four of the surrounding sites (Uppåkra 2:25, Uppåkra 12:110, Uppåkra 2:14, Åttevägenområdet) investigated near to the regional centre Uppåkra were established around the transition from the pre-Roman Iron Age to the Early Roman Iron Age. Samples from these sites were taken from similar contexts: households, pits, and hearth features linked to farmsteads, in which grain assemblages had a tendency to a smaller size of grain. One exception was a sample of large grain observed from Uppåkra 2:25. This came from a pit feature (a refuse pit) close to a household which had previously reported finds of charred seed conglomerates of flax and gold of pleasure (Larsson 2013). This unusual archaeobotanical assemblage (of flax and gold of pleasure) was interpreted as the remains from oil extraction. However, it is unclear why large cereal grain was also found in this context.

From the Late Roman Iron Age, samples are too few to draw any conclusions between the main site Uppåkra and the surrounding sites. Nonetheless, variation in grain size is evident on the main site itself. A variation can be seen in that some households handled smaller sized grain while grain from the hall-buildings, although somewhat varied, contained a tendency for a large grain size. Large grain size was, however, less evident during the Late Roman Iron Age.

Migration Period (AD 400–550)

The difference in grain size is not as apparent between contexts on the main site in the following Migration Period. Grain from the hall-buildings, although somewhat scattered in regards to size, continues to show a tendency to be large in size overall. But during this time period, large grain is seen also in several other house contexts on the site. These contexts are located in an area just northeast of the hall-buildings, thought to be smaller households with associated activity areas of a more ordinary character (Lenntorp 2009). One of these houses, Bårhuset (context 10), partially excavated in 1968, exposed cultural deposits from three consecutive house-phases, all very rich in remains of charred hulled barley grain (Ohlsson 1968). Embedded in one of these layers were the remains of ceramic shards from a large storage vessel (Stjernquist et al. 1968). Only grain from one of these layers was available for the metric analysis, but nonetheless, the layer revealed only grains of a large size. The abundance of grain in the sequential layers of Bårhuset, the large grain size, the overall absence of weed seeds and chaff, and the contextual relationship of the grain to a large ceramic container in one house-phase, found at the site may indicate that the cereals were stored. Because three consecutive grain-rich layers were observed, it is possible that for some time this house was designated for the storage and/or handling of high-quality grain.

Samples from profile 110342 (context 11) typically show a medium-small size range in three consecutive house layers from the early Migration Period, followed by large grain in two succeeding house layers. Grain assemblages of both smaller and larger grain was found in layers from two other houses, slightly northeast of the hall-buildings, Pithouse 1 (context 12) and House 11 (context 13).

The samples from the main site show that during the Migration Period, an increased number of houses contain large sized grain. In contrast, smaller grain remains the typical size range in the surrounding area, and is evident from households and pit features linked to farmsteads belonging to Hjärup 7:1.

Vendel Period–Viking Period (AD 550–1050)

Contexts from the later centuries at the regional centre Uppåkra are few, but the trend for large grain remains in the hall-buildings. On the western side of the site, remains from several oven features were found in an area indicating use for several centuries, dating from the Roman Iron Age to at least the Vendel Period. Through the absence of by-products usually found in smelting contexts, these low-temperature ovens are thought to have functioned as an area designated to bread baking (Regnell 2001). Samples from one of the ovens (dating to the AD 600s) showed the presence of medium grain size.

From the surrounding sites, grain from Hjärup 21:36, dating to the Vendel Period, is of a small size range, while hearth and oven features connected to a somewhat wealthier farmstead at Hjärup 9:8, dating to the Viking Period, showed a large grain size (Schmidt Sabo et al. 2011).

In summary, the distribution of grain size shows a variation across time and space in the study area. Large-sized grain is well represented from the house-sequence of hall-buildings, indicating a tendency for handling larger grain for most of the first millennium AD, although less evidently during the Late Roman Iron Age. During the Migration Period, larger grain is seen in several smaller houses on the main site. From the surrounding sites, only Uppåkra 2:25 and Hjärup 9:8, during the Early Roman Iron Age and Viking Period respectively, show contexts with large grain.

Difference in observed grain size

There are two possible explanation for the difference in grain size observed in the study area. Environmental factors is one explanation, another is selection for high-quality grain after the crop processing was completed.

Environmental factors

The observed differences in grain size may be the outcome of environmental factors reflecting different conditions in the field, depending on variation in soil and fertility. Modern experiments have investigated how environmental variation affects grain quality (weight and size) (Ellis and Marshall 1998; Bingham et al. 2007). These studies have shown the importance of pre- and post-anthesis environmental conditions, that is, the effect that air temperature, moisture levels and nutritional input have on determining grain size. Conditions such as under-ripeness (disease, malnutrition, or premature harvesting) are other factors affecting grain size (Hubbard and Azm 1990). The sites in this study share similar environmental conditions, and Quaternary deposits of clay till are rather uniform in the study area. Any difference in soil fertility would primarily reflect agricultural management, or access to manure.

In the 1930s, the provincial sugar mill company made a comprehensive survey of phosphate levels of the Scanian soil (Arrhenius 1934). Because phosphate is mostly formed by urine and manure, the amount of phosphate in the soil shows not only the most appropriate land for sugar beet cultivation, but it also provides a picture of past human occupation. Uppåkra proved to be, by far, the most phosphate rich area in Scania. This is in part probably due to Uppåkra being a confined habitation area which was continually lived in over a long time. But considering the rich material wealth documented at Uppåkra, it is possible that its prosperity had parallels in agrarian capital, for example, ownership of animals and greater access to manure. According to this line of reasoning, the large grain size at the regional centre may reflect agricultural wealth of its farmers holding well-manured fertile soils.

Selection for high-quality grain

The variation in grain size was alternatively due to selection for high-quality grain after crop processing was completed. No definite groups of grain measurements could be distinguished in the material presented in this study, i.e. assemblages containing only by-products with smaller tail grain or only products of larger prime grain, nor were samples containing rich remains of chaff recovered. A clear distinction should not be expected, however, as archaeological samples may represent a mix of different products and by-products that were originally separated. Furthermore, ethnographical studies by Hillman (1981, 1984) of botanical compositions of processed grain, observed that, regardless of how thoroughly grain was sieved, some small tail grain that could theoretically pass through the sieve would be retained amongst the prime grain after the sieving process was completed. Dimension of grains from the same sample may therefore include measures of both prime grain and tail grain, whilst product composition from the later stages of crop processing will progressively be dominated by prime grain. Additionally, the type of sorting and the mechanism for doing so in the study area is still unclear. It is unknown whether a type of sieve was used, allowing for vertical or horizontal separation of grain size (Jones 1996). Alternatively, grain size could have been separated by flinging, that is by weight; heavier grain landing further from the person throwing the uncleaned grain, leaving the lowest weight class, the tail and mid-grain range, closer to the person (Viklund 1998, pp 60–73).

Measurements of grain from individual samples contained instead a range of grain sizes, and this indicates that the measurements of barley in this study represent prime

grain. According to Hillman (1984), the composition of prime grain could be any grain retained from the last stages of crop processing, and could include a range of grain sizes, but predominantly grains larger than the tail grain, since most of the tail grain was removed along with chaff and small seed weeds during the earlier stages of crop processing. If flinging was used, it would similarly separate the grain into sub-groups of different quality by weight.

Though many sample populations from the regional centre Uppåkra and from the surrounding sites contained prime grain of various size, a few contexts at the main site had, however, sample populations containing lager-sized grain. This included the house-sequence of hall-buildings which showed an overall tendency across time for handling large grain, but also samples from several house contexts dating to the Migration Period, which contained grain averages above the mean values of the main site (L 5.83 mm and B 2.83 mm) and the surrounding sites (L 5.22 mm and B 2.66 mm). Furthermore, the sample populations with large-sized grain coincided with grain rich assemblages (ESM 2). The grain dimensions from this study can be compared to measurements of hulled barley at other Scandinavian Iron Age sites (Table 3). The mean value of the samples from the regional centre Uppåkra was comparable to grain dimensions from Ullandhaug, but from the sites Vallhagar, Trogsta, Overbygård and Gammel Lejre mean values was smaller in comparison. The breadth was, however, greater in some samples from the comparative sites. Alteration that can occur during carbonization of grain can primary causes the length to shrink and the breadth to widen as the grain may puff up (Ferrio et al. 2004). Because the length is smaller in the three comparative sites, it is likely that, in combination with greater breadth, this may be due to the grain slightly puffed up during carbonization.

The measurements from Overbygård is of particular interest, as the context, an underground granary, stored a range of crops, including hulled barley. Separate grain assemblages of processed and unprocessed barley had, however, mean diameter values below that seen at the regional centre Uppåkra. In contrast, at Eketorp a grain deposit in a house, containing approximately 100,000 grains, and the grain-rich find from Sorte Muld showed similarities in grain dimensions to the assemblages with larger grains at the regional centre Uppåkra. These contexts, all deposits of large quantities of grain, are indicative of stored grain, but the mean diameter of the grain points to different stages in the crop process before storage. The processed grain at Overbygård is likely prime grain, whilst the assemblages containing larger grain at the regional centre Uppåkra, Eketorp and Sorte Muld, indicate that selection for large, high-quality grain took place.

Additional information supporting the observed differences in grain size as being the outcome of selection for high-quality grain is provided by the overall mean values, which are higher in grain assemblages from Uppåkra than from surrounding sites. Tentatively, this could reflect more favourable growing conditions for Uppåkra. Though growing conditions could have been advantageous for cereal producers at Uppåkra, the intra-site variation between different contexts at the main site indicates a later stage in handling grain. After completion of crop processing a selection by sieving took place to select the largest grain to go to specific individuals or households at the main site. The rest of the prime grain, smaller but still prime, was used elsewhere.

Table 3 Mean measurements of hulled barley from Scandinavian Iron Age sites

Country	Site	Context	Period	n	Length (mm)	Breadth (mm)	Reference
Sweden	Vallhager	House	MP	50	5.50	2.28	Helbæk (1955)
	Eketorp II	Ringfort/house	MP	100	6.42	3.13	Helbæk (1976)
	Trogsta	House	LRIA/MP	85	5.54	3.14	Wennberg (1986)
Danmark	Overbygård	Granary	ERIA	50[a]	4.8	2.9	Henriksen and Robinson (1996)
		Granary	ERIA	31[a]	4.3	2.5	
		Granary	ERIA	29[a]	4.2	2.4	
		Granary	ERIA	42[b]	4.1	2.2	
		Granary	ERIA	17[b]	4.2	2.4	
	Gammel Lejre	Great hall	VIK	14	5.1	2.8	Robinson (1991)
		Pithouse	VIK	25	5.2	3.1	
	Sorte Muld	House	MP	–	6.3	2.73	Helbæk (1976)
Norway	Ullandhaug	House	MP	50	5.8	2.73	Rindal (2011)

[a]Processed grain

[b]Unprocessed grain

Sorting of cereal grain probably had the intention of selecting and using the best prime grain. This would support the interpretation of the observed variation in grain size in the study area as being due to selection for high-quality grain after crop processing was completed.

Grain size and function at the regional centre Uppåkra

The observed variation in grain size between contexts in the regional centre Uppåkra raises the question of whether grain was separated and used for different purposes. Selection for large high-quality grain could have been intended for several functions, malting in preparation to make beer, seeding or other forms of consumption.

Crop processing traditionally aims to clean the harvested crop from impurities, but can, after the crop processing is complete, include separation of the processed grain to be used for specific purposes. When grain is selected for beer brewing, in modern times as well as in documentation from the medieval period in Scandinavia, a high grain quality is sought, including grain of similar size, preferably large, as this benefits the malting process (Olaus 1555, pp 13, 26; Lee et al. 1989). Uniform grain size is desirable because it allows for an even germination rate, and larger grains have more starch to be converted into sugar during the brewing process (Burger and LaBerge 1985). It is therefore reasonable to think that the larger grain size of barley found, i.e. in the hall-buildings and Bårhuset, was intention for making beer. However, other indications of beer brewing, such as bog myrtle (*Myrica gale*) or hops (*Humulus hupulus*), well known as flavouring and preservative agents in beer (Behre 1999), were not found in any of the house-phases. Nor was there evidence of germinated grain. It can be suggested, therefore, that grain was collected and stored in the buildings, but if it was intended for beer production, this activity took place elsewhere.

Another explanation for the consistent representation of large grain size is the intention of seeding. The importance of selecting high-quality grain aimed for sowing was already emphasized by Roman writers on agriculture (e.g. Columella, *De re rustica* tr. 2009, 2.9.11–12). Uniform grain size permits even seeding, and large grains contain more starch protein in their endosperm, important for fast-growing plants. The seedlings that can withstand early growing season stress produce more extensive root systems and are better able to tolerate low levels of disease (Ransom 2015).

Barley grain intended for everyday consumption, such as for porridge/gruel, soup and bread, probably used mixed prime grain sizes for these purposes. From ethnographic sources, however, this grain could have been divided into further types and stored separately. In terms of human consumption, in historic times the best grain was used for porridge/gruel and beer, and the lowest quality for bread (Viklund 1998, p 105).

Whether high-quality grain in the study area was intended for beer production, seeding, or for other consumption, is not possible to say. The absence of sprouted grain and beer additives in the investigated contexts, however, speaks in favour of the grains being used for seeding or other consumption.

Spatial organization of food supplies

Archaeological investigations at the regional centre Uppåkra have over the years revealed a settlement with an extraordinary site-continuity: 1,100 years (Larsson and Söderberg 2012). Several contexts located in the central part of the settlement, having had a variety of functions (including a ceremonial house, hall-like residence buildings, several multi-phase houses, weapon deposits and different workshop areas for craft production), all show continuity over time, both with respect to how they were used and to their fixed location in the settlement. Together they illustrate spatial organization for specific functions at Uppåkra.

This apparently stable structure also parallels how crops were handled at the site. The overall grain size pattern from the study area indicates that some houses in the regional centre Uppåkra were dedicated to collecting and handling barley, including high-quality grain, particularly the hall-buildings and Bårhuset, while various sizes of grain was primarily found in more ordinary contexts at Uppåkra and on the surrounding sites. Furthermore, sample populations with large grain size, which coincided with the large quantity of barley grain recovered from floor layers, interpreted as being from burnt down houses in the centre of the settlement (Larsson and Söderberg 2012), likely do not represent accumulated spill from daily activities, but rather indicates houses having grain stores set ablaze. The fixed location of these houses on the site, and the continuity of handling barley grain, indicates grain storage or that activities in processing grain can be linked to these houses, and this points to an aspect of how the management of grain was part of a spatial organization at Uppåkra.

Staple food is an important foundation to any given society regardless of size. At larger settlements, such as the regional centre Uppåkra, which was presumably a hierarchical society in which some inhabitants, such as artisans and the social elite, were less involved in agrarian production, maintaining food supplies must have been of particular importance. It is conceivable that in the central area of the main site, perceived to have been the residence of the social elite (Larsson and Söderberg 2012), individuals of high rank not only demanded access to the finest grain quality, but also had control of agricultural produce. This, judging from the assemblages of large grain size observed in some house contexts from Uppåkra, while

mostly absent from house contexts on the surrounding sites, suggests that Uppåkra had greater access to high-quality grain.

Research using strontium isotope analysis of zooarchaeological material from the regional centre Uppåkra has shown parallels to the variation of barley grain size assemblages observed in this study (Price 2013). The isotopic study indicated local values for pigs and sheep/goats at the main site Uppåkra, while some cattle had non-local values. The occurrence of non-local values of cattle was explained by the importing of animals to the site. In another zooarchaeological study from the regional centre Uppåkra, Magnell et al. (2013) observed an intra-site variation in the consumption of meat. In the central area of the site, around the hall-buildings and the ceremonial house, consumption of pork and beef was greater than compared with a southern area on the site that was associated with houses for craft production. Osteological studies from three of the surrounding sites (Uppåkra 12:110, Uppåkra 2:25, Hjärup 7:1) found the meat-rich parts of animals to be significantly underrepresented among the remains of bone, regardless of species. It was argued that meat-rich parts had been "exported" elsewhere, perhaps as food supplies to Uppåkra (Bolander 2012b; Cardell in; Becker et al. 2012; Cardell in; Aspeborg et al. 2013). Since taphonomic aspects of these osteological assemblages were not discussed, some caution is needed, however, when explaining the movement of animal products, as factors concerning preservation and reduction processes may have affected the bone assemblages on the aforementioned sites.

Even if Uppåkra is perceived as a major centre in the region (e.g. Helgesson 2002), and perhaps also a consumer site per se, it probably carried on some agrarian production, but was still dependent on surrounding farms for food supplies. The spatial pattern of grain size across the study area not only indicates that Uppåkra had greater access to high-quality grain, but that economic relationships may have existed between Uppåkra and surrounding settlements, in which grain was transported from the periphery to the regional centre. To be resilient and to provide sustainability over time, a system for handling produce, and perhaps also production of food, can be seen as a central constituent for the wealth and longevity of a settlement. A system for production, storing and redistributing grain for consumption and propagation would have been important to secure lucrative crop production for the area, and to reduce the hardship and social unrest from starvation during periods of food crises caused by crop failure (Erdkamp 2009, pp 281–283). The distribution of agrarian produce in the study area, of both grain and from bone material, suggests the regional centre had some principal control in the area over food supplies.

Conclusions

This metric study on hulled barley has observed a difference in grain size in the study area. Hulled barley assemblages with smaller grain size characterize several contexts at the regional centre Uppåkra, and are comparable to grain size found on the surrounding sites. Large grain size was identified foremost in some house contexts in the central part of Uppåkra, an area with communal spaces and buildings, and was associated with the social elite. In this area, a tendency for handling large grain can be traced in a sequence of hall-buildings during most of the first millennium AD, while it is less noticeable during the Late Roman Iron Age (AD 200–400). During the Migration Period (AD 400–550), several houses in the central part of Uppåkra show handling of larger sized-grain. The observed difference in grain size between contexts points to a selection for larger grain taking place after crop processing was completed.

The overall distribution of larger and smaller grain in the study area and across time indicates that high-quality grain was primarily handled at designated contexts at the regional centre Uppåkra. This possibly reflects a demand by Uppåkra for barley grain, including high-quality grain that was consistent over time. Given the powerful status and administrative role Uppåkra is believed to have had in the region (e.g. Helgesson 2002), it is conceivable that Uppåkra also had a role in accessing agrarian production among farmers by collecting, storing and redistributing grain in the agricultural community. Tentatively, the role of Uppåkra as a regional centre could thus be linked to economic relations in agricultural production and produce with nearby farming settlements.

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