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ORIGINAL ARTICLE

New evidence on the southeast Baltic Late Bronze Age agrarian intensification and the earliest AMS dates of *Lens culinaris* and *Vicia faba*

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Abstract
This article explores the Late Bronze Age agrarian intensification in the south-east Baltic. In recent years several studies have illustrated that to date there is no solid evidence on Neolithic farming and that the agricultural history of the region was probably distinctly different in comparison to other parts of northern Europe. The recently excavated Kukuliškiai settlement (887–406 cal BC) in coastal Lithuania provides new data, which contribute to the discussion on the development of early farming in the south-east Baltic. Archaeobotanical analysis revealed that local Late Bronze Age communities cultivated a wide range of cereals and pulses, with consumption of wild plants being of minor importance. We also report the earliest finds of *Lens culinaris* in the region and the earliest AMS ^{14}C dates on grains of *Vicia faba* and *Avena* sp. The composition of botanical assemblages also has some indications of manuring and landscape maintenance, presenting a possibility of permanent fields. Finally, we suggest that adoption and intensification of farming alongside other social, economic and technological innovations could have reached the region from the Nordic and Lusatian cultures via the Baltic Sea communication network.

Keywords South-east Baltic · Late Bronze Age · Agriculture · Lithuania · Archaeobotany

Introduction

Transition from the Early Bronze Age (EBA) to the Late Bronze Age (hereinafter LBA; around 1100 BC, after Hornstrup et al. 2012) in northern Europe was marked by series of changes in social structure and economy, and major opening up of the forested landscape followed by the creation of extensive grassland areas (Tesch 1991; Robinson 2003). Some parts of the region have also seen a significant agricultural intensification as illustrated by interdisciplinary research, such as the Ystad project in south Sweden (Berglund 1991; Larsson et al. 1992). This was a period of agricultural experimentation, intensification and expansion. The extensive agriculture, which existed in southern Scandinavia during the Neolithic and early part of the Bronze Age, was abandoned in favour of more intensified agriculture aiming towards surplus production (Björhem and Säfvestad 1993; Gustafsson 1998).

However, across different parts of northern (N) Europe this process was not uniform. Over the last decade several studies have revealed that some of the most problematic regions lie at the eastern and south-eastern fringes of the Baltic Sea. The concepts of pre-Bronze Age farming in Finland (Lahtinen and Rowley-Conwy 2013) and the south-east Baltic (Piličiauskas 2016; Piličiauskas et al. 2017a, b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018) have been successfully challenged. Current evidence indicates that the earliest Neolithic cultures in the south-east (SE) Baltic, the Corded Ware culture (CWC) and the Globular Amphora culture (GAC), only brought in animal husbandry without farming (Piličiauskas et al. 2017b; Piličiauskas 2018). The earliest securely dated direct evidence on crop cultivation in the region is currently dated to the end of the EBA with

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no direct evidence for continuity until the re-appearance of crops in the LBA (Piličiauskas et al. 2017a, b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018).

New archaeobotanical finds from a recently excavated Kukuliškiai LBA site in coastal Lithuania shed some new light on this discussion. Kukuliškiai presents a chronologically closed case limited to a single Bronze Age horizon, an exceptionally rare case in the SE Baltic. It contains one of the richest and best preserved archaeobotanical assemblages in the region. This dataset allows us to expand our understanding of the initial crop package in the region. It also suggests that the adoption of farming in Lithuania coincides with other major LBA social, economic and technological developments. Using the new evidence, we seek to provide more insight into the transition to agricultural dependence in the SE Baltic and to contribute to a better understanding of the complex processes taking place across N Europe during the LBA.

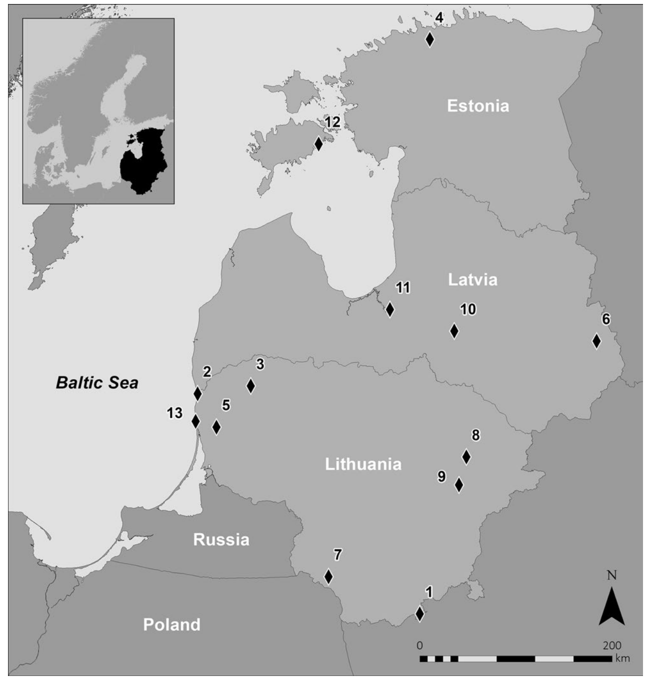

Fig. 1 Map of sites mentioned in the text: 1 Duba and Palesa Lakes, 2 Šventoji, 3 Šarnelė, 4 Iru, 5 Kvietiniai, 6 Kreiči, 7 Turlojiškė, 8 Narkūnai, 9 Luokesa 1, 10 Mūkakalns, 11 Kivutkalns, 12 Asva, 13 Kukuliškiai

A review of the earliest evidence on crop cultivation in the SE Baltic

The Neolithic (3200/2800–1700 BC)

The chronology used here is based on the appearance of the GAC (Piličiauskas et al. 2017b) and CWC (Piličiauskas 2018). Until recent years dating the beginning of farming in Lithuania and the rest of the east (E) and south-east Baltic relied heavily and often almost exclusively on pollen records. Palynological data from the lakes of Duba and Palesa in south (S) Lithuania (Fig. 1) suggested the arrival of the earliest cultivated plants as early as the fifth millennium BC (Stančikaitė et al. 2002; Antanaitis-Jacobs and Stančikaitė 2004; Stančikaitė 2013), based on recordings of the earliest Cerealia-type pollen. Pollen records from Estonia and Finland also testify to plant cultivation already by the sixth-fifth millennium BC (e.g. Poska 2001; Alenius et al. 2013). However, recent studies have pointed out some methodological and interpretational shortcomings of such an approach. Lahtinen and Rowley-Conwy (2013) have convincingly illustrated several major problems with pollen records and have successfully challenged the hypothesis of Neolithic farming in Finland. Similarly, palaeoethnobotanical and archaeological evidence from the E Baltic has been re-evaluated on several occasions (e.g. Piličiauskas 2016; Piliciauskas et al. 2017b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018) and all attempts have reached nearly identical conclusions. They concluded the existence of fundamental flaws in the application of dating methodologies and suggested that the arrival of farming should not be extrapolated from isolated instances of supposed Cerealia-type pollen.

In addition to pollen, archaeological literature also mentions several cases of cultivated plant macroremains being found on Neolithic sites in the SE Baltic. Finds have been reported from the Lithuanian sites of Šventoji and Šarnelė (Rimantienė 1979, 1992, 1996, 2005; Butrimas 1996). The re-examination of the original excavation material now stored in the National Museum of Lithuania revealed that reported finds had originally been misidentified and, in fact, belong to wild species (Piličiauskas et al. 2017b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018). By comparison, the earliest remains of domestic plants in Estonia come from the Iru hilltop settlement (ca 2700 BC; chronology after Poska and Saarse 2006) where a corded pottery sherd was found with a charred *Hordeum vulgare* (barley) grain embedded in its surface, together with an imprint of another grain (Kriiska 2009). However, it must be noted that this is primarily a Bronze Age site. The grain itself was never AMS ^{14}C dated, and therefore the actual chronology of the find remains uncertain (Piličiauskas 2018). Besides these few instances no other domesticated plant remains were reported from Neolithic sites in the E-SE Baltic (Piličiauskas 2018).

The Early Bronze Age (1700–1100 BC)

Here we use the Bronze Age chronology of the SE Baltic (Čivilytė 2014), which closely follows the Nordic Bronze

Age chronological system (Hornstrup et al. 2012; Ling et al. 2014). The current state of research reports that the earliest direct, securely dated evidence on domesticated crops in the SE Baltic comes from the Kvietiniai settlement in north-west (NW) Lithuania. During the excavations in 2015 several soil samples were taken for floatation. Further analysis led to a discovery of few *Hordeum vulgare* grains and grain fragments. Plant remains were directly AMS ^{14}C dated and yielded dates between 1409 and 1123 cal BC (Grikpėdis and Motuzaitė-Matuzevičiūtė 2018; Piličiauskas 2018). Apart from this, only a single other instance of cultivated plants dating to the second millennium BC was recorded in the region. A small botanical assemblage was discovered in the Kreiči settlement (ca 2000–1700 BC), western Latvia. It contained single grains of *Hordeum vulgare* and cf. *Triticum monococcum* (einkorn) (Rasiņš and Tauriņa 1983). Unfortunately, none of the macrofossils were AMS ^{14}C dated and were eventually lost, making it impossible to apply direct dating methods (Grikpėdis and Motuzaitė-Matuzevičiūtė 2018; Piličiauskas et al. 2018). To this date, evidence on crop cultivation from the first half of the Bronze Age remains very scarce.

The Late Bronze Age (1100–500 BC)

In contrast to the EBA, archaeobotanical finds from the LBA are significantly more abundant. Assemblages from the Turlojiškė site in southern Lithuania contained charred caryopses of *Panicum miliaceum* (broomcorn millet) dated to 908–485 cal BC (Antanaitis-Jacobs et al. 2002). Pottery imprints of *Panicum* were also found in the Narkūnai hilltop settlement (800–550 cal BC), E Lithuania. A few other pottery imprints of cereal grains were also discovered alongside. They most likely belonged to either *Hordeum* or *Triticum* sp. (Podėnas et al. 2016). However, the richest archaeobotanical assemblage in Lithuania comes from the Luokesa 1 lakeshore settlement in eastern Lithuania (625–535 BC). Organic material on the site was extraordinarily well preserved due to waterlogged conditions. Botanical remains of crops covered a relatively wide range of plant species. These included *P. miliaceum*, *T. dicoccum*, *H. vulgare*, *Pisum sativum* (pea) and several species unreported from other sites in the SE Baltic—*Triticum spelta* (spelt) and *Camelina sativa* (gold of pleasure or false flax). Chaff fragments of *T.* cf. *monococcum* were also discovered (Pollmann 2014).

Cultivated plant macroremains were also found in first millennium hilltop settlements in Latvia. A few grains of *Vicia faba* (broad bean), *H. vulgare* and *T. aestivum* (bread-wheat) were discovered in Mūkakalns (Rasiņš and Tauriņa 1983). Samples from Kivutkalns (811–547 cal BC, chronology after Oinonen et al. 2013) contained a wide array of crops including *Camelina sativa*, *V. faba*, *H. vulgare*, *P. miliaceum*, *Pisum sativum* and *T. dicoccum*. Unfortunately, the chronology of the finds is still debatable, because the grains were not dated using AMS ^{14}C and the archaeological site itself contains several occupational layers, the latest dating to the Roman Iron Age (Graudonis 1989; Oinonen et al. 2013). LBA assemblages from Estonia are also limited to finds from enclosed hilltop settlements (primarily from Asva, eastern part of the Saaremaa Island, dated to ca 900–500 BC). On few separate occasions pottery sherds with grain impressions were discovered (Lang 2007). These include impressions of *H. vulgare* and *Triticum* sp. Imprints of *Avena* sp. were also reported, however the absence of floret bases rendered it impossible to determine whether these belonged to cultivated oat *A. sativa*.

New archaeobotanical evidence from Lithuania

Site description

Emergence of enclosed hilltop settlements is one of the characteristic traits of the LBA in the SE Baltic. One such site was discovered in 2016 in the vicinity of the town of Kukuliškiai, western Lithuania. The settlement was AMS ^{14}C dated to 887–406 cal BC. It sits on the edge of the Littorina sea upper terrace, just 300 m east of the Baltic Sea. The hilltop plateau is flat, 38 × 20 m in size. Erosion signs are visible along the NW edges of the plateau. The area is now covered by dense forest vegetation.

In summer 2017 the Institute of Baltic Region History and Archaeology conducted a field survey and field evaluation of the site. A total of 36 geological boreholes were drilled to determine the most suitable location for a small trial trench. Following that, a 10 m^2 trench was excavated at the SE end of the settlement. Borehole data and archaeological excavations revealed that the site features a single occupational layer. It was a neatly sealed time capsule, preserved under a layer (up to 0.5 m thickness) of aeolian sand. Beneath it lay a Bronze Age cultural layer, ranging between 0.25 and 0.80 m in thickness (Fig. 2). A total of 221 finds were collected. These included non-decorated Bronze Age striated, rusticated and smooth-surfaced pottery sherds, the base of a crucible, fragments of raw amber, and osteological remains of cattle and even-toed ungulates (Urbonaitė-Ubė and Ubis 2018). The crucible base belongs to an exceptional three footed crucible type. The closest analogies were previously found in the Ķivutkalns hilltop settlement, situated on the Dole Island in lower reaches of the Daugava River. The latter site was a part of a circum-Baltic communication network and was closely related to Nordic metallurgical traditions (Graudonis 1989). A section of a wooden enclosure was also uncovered alongside seven archaeological structures cut into the subsoil. The

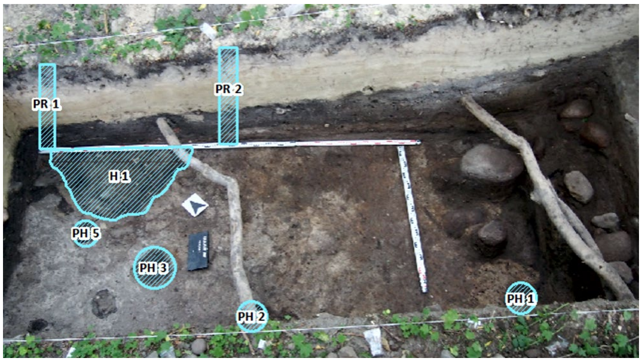

Fig. 2 Trial trench in Kukuliškiai. Sampled profiles and structures marked in light blue. *PH* posthole, *H* hearth, *PR* profile

structures consisted of six postholes and a hearth. Soil samples were taken from the trench for floatation and archaeobotanical analysis.

Materials and methods

During the excavations in 2017 a total of 27 soil samples were collected. Two profile columns, four postholes and one hearth were sampled. Sample collection relied on the strategy described by Jones (1991) as 'purposive and judgment sampling'. Soil for floatation was collected from the trench directly, primarily targeting undisturbed layers and structures.

Soil samples of known volume were mixed with water in the laboratory environment and the floating fraction was retrieved using sieves with a mesh size of 250 µm. Dried material was sorted and identified under a binocular microscope at a magnification of × 10–120. Plant remains were identified using seed reference collections of the Laboratory of Quaternary Research, Nature Research Centre (Vilnius) and the Institute of Archaeology, University College London. Scientific plant nomenclature follows Mirek et al. (2002). Identified taxa were arranged into broadly defined ecosociological groups (Behre and Jacomet 1991; Latałowa et al. 2003) whilst keeping in mind that some of the specified taxa could belong to different plant communities (Latałowa 1999). Recorded plant remains found in floatation samples are presented in the score list (Table 1). Eight plant macrofossil specimens were sent for AMS ^{14}C dating to Poznań Radiocarbon Laboratory (Poland) and the Centre for Physical Sciences and Technology (Lithuania). Radiocarbon ages were calibrated using the OxCal 4.3 software and InCal13 atmospheric curve (Bronk Ramsey 2009; Reimer et al. 2013). Calibrated dates are presented at 95.4% probability (Table 2).

Results

Archaeobotanical analysis revealed a range of plants grown and consumed by the LBA inhabitants of the Kukuliškiai hilltop settlement (Fig. 3). All 27 samples were fully analysed. A total of 751 carbonized macrofossils was recorded. Plant remains represented 27 taxa, most of them belonging to cultivated species (84.4%). Cereals constituted a larger portion of cultivated plants. The dominant crop (30.4% of total crop remains) was *Hordeum vulgare* (predominantly var. *vulgare,* hulled barley). It was followed by significantly smaller amounts of *Triticum* spp. (7.6%) and *P. miliaceum* (6.5%). Hulled wheats—*T. dicoccum* and *T.* cf. *spelta*—were more abundant than the free-threshing *T. aestivum/durum* (bread/hard wheat). However, it should be noted that no glume bases of spelt were found, thus it is possible that only emmer wheat was present on the site. Naked wheat finds were limited to just a few grains. Several *Avena* sp. (oat) grains were also found in the samples. So far these are the earliest AMS ^{14}C dated *Avena* sp. grains in the E Baltic. Among these finds only a single floret base was discovered. Unfortunately, the glume base was fragmented, and the proximal end was poorly preserved, therefore it was not possible to determine whether it belonged to the cultivated *A. sativa* or the wild *A. fatua*. This also being a single find, it does not yet allow us to draw any definite conclusions about the possibility of oat cultivation on the site.

Remains of pulses comprised a considerably smaller portion of cultivated plants (1.4%). Even so, findings of this study still revealed that the LBA community at Kukuliškiai cultivated a wider range of legumes than previously reported from other sites in the SE Baltic. Several grains of *Pisum sativum*, *Vicia faba* and *Lens culinaris* (lentil) were identified. One grain of each legume species was selected for AMS ^{14}C dating. The *Lens culinaris* grain yielded a date of 752–406 cal BC. So far, this is the earliest recorded find of lentil in the region. Dates of other legume grains also fall within the range of the Hallstatt radiocarbon plateau (ca. 800–400 cal BC) and therefore more precise chronology is currently not possible. Nevertheless, this is still the earliest directly dated *V. faba* grain in the SE Baltic.

Analysis also revealed that samples contained several wild taxa. Finds included a small number of charred fruits and seeds of wild plants which were likely used as a food source. Fragments of a hazelnut shell (*Corylus avellana*), and seeds of *Rubus idaeus* (raspberry) and *Malus sylvestris* (crab apple) were identified. Finally, a few species of weeds and ruderal plants were also recorded. While macrofossils of *Chenopodium album*, *Persicaria lapathifolia* and some smaller millets (mostly *Setaria* cf. *pumila*) were recorded in larger quantities, most of the other taxa were represented by just a few specimens.

Table 1 Charred plant remains from the Kukuliškiai hilltop settlement

Taxon	Type of remains	Structures					Profiles	
		PH 1	PH 2	PH 3	PH 3	H1	PR 1	PR 2
Volume floated (l)		3	1.1	0.3	0.35	3.5	12	16
Cultivated plants								
Avena sp.	c	–	–	–	–	–	–	1
Avena sp.	gb	–	–	–	–	–	–	1
cf. *Avena* sp.	c	–	–	–	–	–	–	2
Cerealia indet.	c	29	20	2	16	97	74	97
Hordeum vulgare	c	–	1	4	6	24	36	25
Hordeum vulgare, naked	c	–	–	–	–	–	1	1
Hordeum vulgare, hulled	c	5	–	–	2	18	56	9
cf. *Hordeum vulgare*	c	3	2	–	–	–	–	–
cf. *Hordeum vulgare*	chaff	1	–	–	–	–	–	–
Lens culinaris	c	–	–	–	2	1	–	–
Panicum miliaceum	c	–	–	–	–	2	14	2
cf. *Panicum miliaceum*	c	–	–	–	–	2	17	4
Pisum sativum	c	–	–	–	–	–	1	–
cf. *Pisum sativum*	c	–	1	–	–	–	–	–
Triticum aestivum/durum	c	–	–	–	–	–	2	4
Triticum dicoccum	gb	–	–	–	–	2	2	–
Triticum cf. *dicoccum*	c	–	–	–	2	1	2	10
Triticum cf. *spelta*	c	1	–	–	–	1	1	7
Triticum sp. glume wheat	c	–	–	–	–	–	–	13
Triticum sp.	c	–	–	–	–	–	2	1
Vicia faba	c	–	–	–	–	1	–	2
cf. *Vicia sativa*	c	–	–	–	–	–	1	–
Weeds and ruderal plants								
Chenopodium album	s	3	3	–	–	6	13	3
Fallopia convolulus	f	–	–	–	–	–	1	–
Galium spurium	f	–	–	–	–	–	1	–
cf. *Galium spurium*	f	1	–	–	–	–	–	–
Persicaria lapathifolia	f	3	17	–	7	4	3	1
Setaria cf. *pumila*	c	–	–	–	–	–	8	–
Setaria cf. *verticillata*	c	–	–	–	–	–	–	1
cf. *Setaria* sp.	c	1	–	–	–	1	1	–
Urtica dioica	s	–	–	–	–	–	–	1
Wetlands, wet meadows, riverside								
Carex flava	f	–	–	–	–	–	1	–
Carex hirta	f	–	–	–	–	–	–	1
Carex nigra	f	–	–	–	–	–	1	–
Carex vulpina	f	–	–	–	–	–	2	–
Forests, glades and clearings								
Corylus avellana	f	1	–	–	–	–	2	1
Malus sylvestris	s	–	–	–	–	2	–	–
Rubus idaeus	s	–	–	–	–	–	–	1
Solanum dulcamara	s	–	–	–	–	1	–	–
Others								
Euphorbiaceae		–	–	–	–	–	1	–
Indet.		3	2	–	–	3	3	13

c caryopses, *f* fruits, *gb* glume bases, *s* seeds

Table 2 Direct ^{14}C dates of carbonized domestic plant macrofossils from the Kukuliškiai hillfort

Site	Sample	Lab code	Radiocarbon age (BP)	Calibrated age (BCE)
Posthole no. 1	*Hordeum vulgare* (grain)	FTMC-24-4	2,603 ± 41	887–556
Posthole no. 1	*Hordeum vulgare* (grain)	FTMC-24-5	2,467 ± 50	767–416
Hearth no. 1	*Hordeum vulgare* (grain)	FTMC-24-6	2,483 ± 40	780–430
Hearth no. 1	*Hordeum vulgare* (grain)	FTMC-24-7	2,540 ± 41	803–540
Posthole no. 5	*Hordeum vulgare* (grain)	FTMC-24-8	2,496 ± 50	793–431
Hearth no. 1	*Vicia faba* (grain)	Poz-105385	2,480 ± 35	775–431
Posthole no. 5	*Lens culinaris* (grain)	Poz-105606	2,435 ± 35	752–406
Profile no. 1	*Pisum sativum* (grain)	Poz-105607	2,475 ± 30	771–431

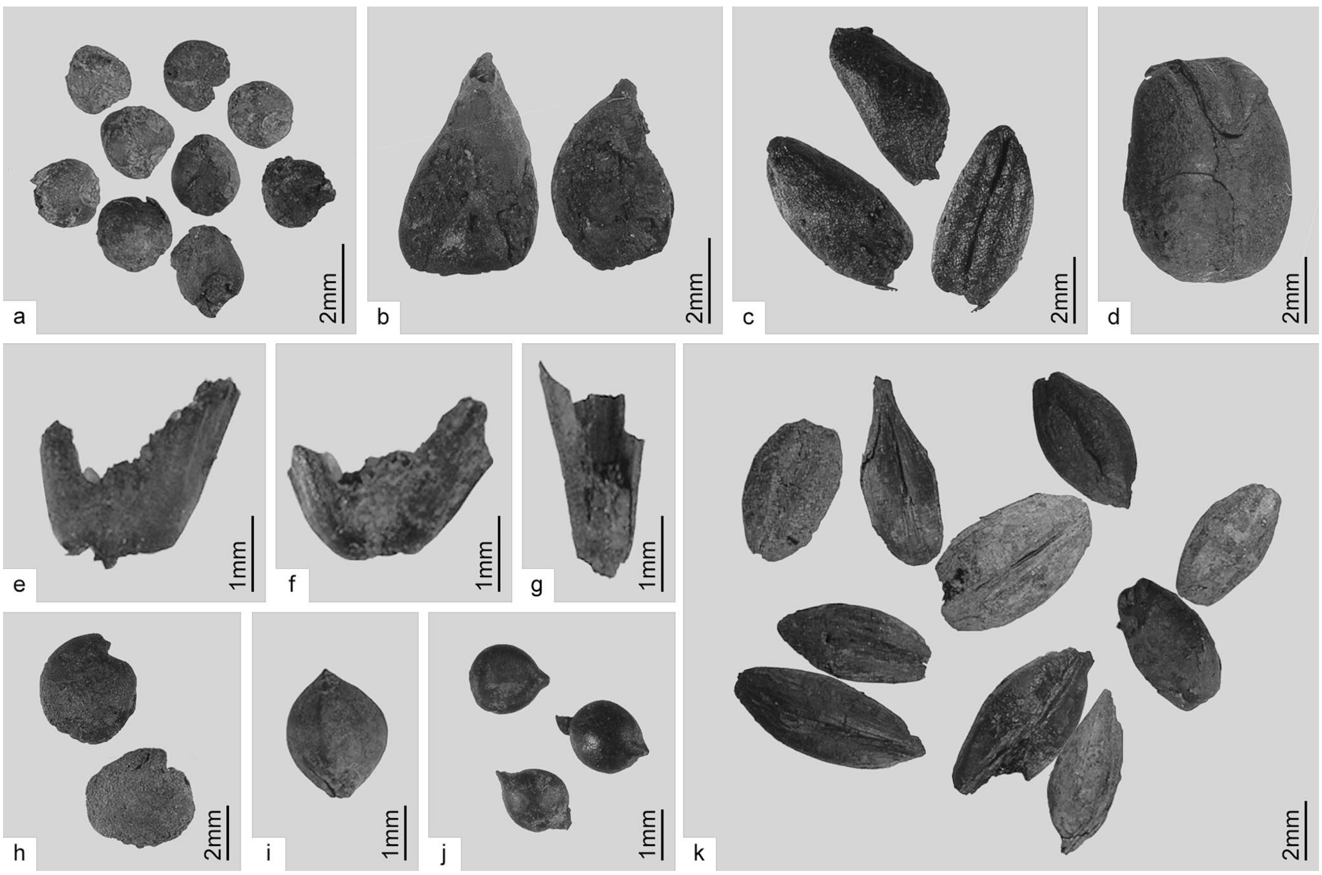

Fig. 3 Charred plant remains from the Kukuliškiai hilltop settlement. **a** Grains of *Panicum miliaceum*. **b** seeds of *Malus sylvestris*. **c** Grains of *Triticum* cf. *dicoccum*. **d** Grain of *Vicia faba*. **e–f** Spikelet bases of *Triticum dicoccum*. **g** Glume base of *Avena* sp. **h** Grains of *Lens culinaris*. **i** Nutlet of *Fallopia convolulus* (black-bindweed). **j** Nutlets of *Persicaria lapathifolia* (pale persicaria). **k** Grains of *Hordeum vulgare* var. *vulgare*

Discussion

The earliest crop package in the SE Baltic

Crop assemblages containing more than just a few grains are still rare in the SE Baltic. The Kukuliškiai and Luokesa 1 settlements are so far the only two sites with archaeobotanically rich, well documented and securely dated contexts. Such finds play a vital role in understanding the earliest stages of crop cultivation. They allow us to better explore composition of the initial crop package in the region. Samples from Kukuliškiai contained the previously unreported taxon *Lens culinaris*. While these crops are known to have been cultivated in neighbouring Poland since the Neolithic, it was previously only reported from sites in the SE Baltic dating from the Iron Age (IA) and onward. Dated samples also established a firm chronology for cultivation of *V. faba*. These plants were previously reported only from Kivutkalns, Latvia. Unfortunately, this hilltop settlement features several occupational layers and the grains were not directly dated, leaving their exact chronology open for debate. Doubts about the reported dates are based on the fact that charcoal samples do not follow the stratigraphic sequence (Oinonen et al. 2013; Mittnik et al. 2018) with samples predating the undisturbed cemetery layer situated beneath the settlement horizon (Vasks and Zariņa 2014). Kukuliškiai contexts with *Avena* sp. grains were also securely dated for the first time. However, the size of the grains (length: 3.3–3.8 mm; breadth: 1.3–1.4 mm; thickness: 1.1–1.2 mm) and the single fragmented floret base seem to point to these belonging to uncultivated species, probably *A. fatua*.

Changes visible in quantity and variety of plant macrofossils from this period are also visible in the palynological records. The data suggest a shift in the agriculture of the SE Baltic starting around the EBA to LBA transition. Pollen records from Duba lake in southern Lithuania indicate significant changes in land management related to farming activities beginning as early as 1300–1200 BC (Stančikaitė 2013). It has been suggested that these changes were probably caused by the adoption of farming and the beginning of agriculture-based economy (Stančikaitė 2013). While the phenomenon itself raises little discussion, the exact chronology is still heavily debated (e.g. Piličiauskas 2016; Piliciauskas et al. 2017b). Looking at existing archaeological and archaeobotanical evidence it is possible that these developments may, in fact, be taking place around 1100–1000 BC.

The composition of the earliest archaeobotanical assemblages also indicates significant changes in the economy and lifestyle of the LBA communities in the SE Baltic. Cultivation of hulled barley has often been interpreted as an indicator of permanent and well-maintained fields (Engelmark 1992; Gustafsson 1998; Robinson 2003). These plants require significantly more readily soluble nutrients, particularly nitrogen, than speltoid wheats or naked barley and in order to obtain reasonable yields the fields must be manured (Gustafsson 1998; Viklund 1998). The issue of using animal (stable) manure in the SE Baltic has been discussed in more detail by Pollmann (2014). In contrast to Luokesa 1, the Kukuliškiai settlement lies in a very different landscape setting. According to the pedological regionalization of Lithuania, the site is located in the Šventoji—Nida arenosols district (Volungevičius and Kavaliauskas 2009). Arenosols are typically extremely low in all essential nutrients, are highly acidic and have very low water-holding capacities (Volungevičius 2013; Volungevičius et al. 2016). They are always much less productive than other soils in the same region and require careful management and fertilization (Volungevičius 2013). Therefore, cultivation of peas, broad beans and lentils may also signal the existence of permanent fields and a continuing shift towards sedentarism. They are particularly attractive because contrary to most other flowering plants, legumes are able to fix atmospheric nitrogen through symbiosis with the root bacterium *Rhizobium* (Zohary et al. 2012). This replenishes nutrients in the soil and prolongs its fertility. This in turn allows fields to be used for a longer time span and encourages communities to lead a sedentary lifestyle. Finally, botanical assemblages from Kukuliškiai also contained some indications of nitrogen-rich soils in the form of weeds and ruderal plants. In general, finds of small weed seeds are very scarce in the Bronze Age contexts from the SE Baltic. This is a likely result of a combination of factors ranging from prehistoric crop harvesting techniques to soil sample retrieval biases (Engelmark 1992; Gustafsson 1998; Robinson 2003). Several plant remains from Kukuliškiai (e.g. *Chenopodium album, Persicaria lapathifolia*) belong to nitrophilous species, which, in turn, might support the hypothesis of the existence of manured fields. However, it is important to point out that these finds in Kukuliškiai come from a very limited number of features, which are more likely associated with routine household activities than, for example, crop storage. The formation process of these fills dictates that finds may not necessarily reflect a specific activity or a single depositional episode. Therefore, more data on well-preserved weed-rich assemblages from the SE Baltic, associated with more specific activity zones, are needed to elaborate on the subject of manuring practices and techniques of crop cultivation in the region.

Arrival of farming

The dating of the arrival of farming remains one of the most discussed questions in the prehistory of the SE Baltic. The current state of research reveals no firm evidence of crop cultivation in the region before the LBA (Piličiauskas et al. 2017b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018). Current archaeobotanical data firmly suggest the adoption of farming during the EBA to LBA transition. However, this does not mean that contradictory evidence will not appear in the future. By comparison, in other parts of N Europe subsistence economy of CWC groups was characterized by strong emphasis on animal husbandry, however crop cultivation was also used (Kirleis 2019; Vanhanen et al. 2019). CWC sites from the Netherlands, Denmark, Sweden and Germany reveal evidence of the cultivation of *H. vulgare* var. *nudum*, *T. dicoccum*, *Linum usitatissimum* (flax) (Oudemans and Kubiak-Martens 2014; Beckerman 2015; Kubiak-Martens et al. 2015). There are also some indications of possible cultivation of *Pisum sativum* (Kirleis 2019). This also contrasts greatly with the situation in neighbouring Poland where the central part of the country was already occupied by the early Danubian farmers from the beginning of the

Neolithic (from about 5650 to 5480 cal BC; Bieniek 2007). Assemblages from sites associated with the Linear Pottery culture reveal cultivation of a wide range of crops. Cultivation of *T. monococcum*, the 'new glume wheat' (presumably *T. timopheevi*), *T. dicoccum*, *H. vulgare*, *T. aestivum*, *P. miliaceum*, *L. usitatissimum*, *Papaver sominiferum* (opium poppy) and *Pisum sativum* started with the arrival of LBK people (Gluza 1984; Rook and Nowak 1993; Bieniek 2007; Lityńska-Zając 2007).

It is, therefore, striking that earliest evidence of farming in the SE Baltic only appears in the deposits dating over 4,000 years later. It has been suggested that the apparent absence of evidence may, in fact, be caused by the lack of routine sampling and insufficient documentation (Piličiauskas 2016; Piličiauskas et al. 2017b; Grikpėdis and Motuzaitė-Matuzevičiūtė 2018). However, this explanation was at least partially dismissed by the excavation of four different CWC sites in Lithuania in 2015 and 2016. These excavations employed systematic soil sampling and on-site floatation. Yet the results revealed that floatation of over 1,600 l of soil did not result in a single crop macrofossil being discovered (Piličiauskas 2018). A more probable explanation is that the economic development of the study region was distinctively different from the traditional European Neolithic transition. The earliest farmers of the Linear Pottery culture did not reach the Eastern European forest zone, and thus local communities continued to rely on the Mesolithic subsistence strategies even after they adopted malleable technologies such as pottery from possible eastern/south-eastern influences (Piličiauskas 2002; Jordan and Zvelebil 2009; Piličiauskas et al. 2017a). However, this alone does not explain the scarcity of farming evidence continuing until the very end of the EBA. In addition, it is known that the transition from foraging to more sustainable forms of economy had already started in the Neolithic. Local CWC communities relied on a mixed economy based on animal husbandry and gathering of wild resources for their subsistence (Piličiauskas et al. 2017a). The exclusion of crop husbandry from their subsistence strategies could have resulted from their social preferences. However, while other forms of subsistence were considered rather than farming, the existing evidence of the earliest domesticated plants shows that attempts at crop cultivation predate the LBA.

This scarcity of farming evidence is better understood by looking at the cases of Neolithic agricultural abandonment in N Norway and Britain (Sjögren and Arntzen 2013; Stevens and Fuller 2012, 2015). They show that changing environments and crossing biogeographic zones not only presented significant challenges for the spread of farming to the northern margins of temperate Europe, but also occasionally caused agricultural collapse. Avoiding failure was key to agriculture's successful dispersal and the resilience of agricultural packages was increased in a number of ways, including intensification of human labour, expansion and diversification of crop packages, and genetic changes to crops themselves (Fuller and Lucas 2017). The environmental conditions of the SE Baltic presented a significant barrier and numerous genetic adaptations were required before farming could successfully spread into the region (Motuzaitė-Matuzevičiūtė 2018). Adaptations through seasonality changes usually play a major role in adapting to new environments (Sherratt 1980). These include establishing genetic controls on seasonality, especially flowering times and length of growing season (Fuller and Lucas 2017). Therefore, it could be argued that farming was only firmly established in the region around the LBA after several crop species, primarily barley, became adapted to the local environment and the risk of crop failure was reduced (Motuzaitė-Matuzevičiūtė 2018). The transition to farming was further aided by the climate warming which started around 750 cal BC (Gaigalas 2004; Sillasoo et al. 2009). In such a case the fragmented evidence from earlier periods is a likely illustration of the early attempts that have failed.

Agrarian intensification in the Baltic Sea region

The LBA agrarian intensification of the SE Baltic was most likely not an isolated case but rather a part of broader social, economic and technological developments sweeping across northern Europe. Limiting our scope to SE Baltic material would severely hinder our understanding of the origins and spread of farming in the study area. Evidence from sites across the Baltic Sea shows that the end of the EBA (ca. 1200 BC onward, after Gustafsson 1998) was marked by intensification of agriculture and changes in landscape management. This coincides with the agricultural developments observed on the SE fringes of the Baltic Sea and provides a context for the eventual arrival of farming, followed shortly by the rapid agrarian intensification of the region.

Looking just south from the study region, we see that data from northern Poland reveal a sharp increase in both scale and intensity of agricultural activities during the EBA to LBA transition. Pollen records show significant environmental changes starting around 1400/1300 BC (Wacnik 2005, 2009; Wacnik et al. 2012). These were mostly a result of development of a production economy based on plant cultivation and animal raising. Even more significant changes during this period are visible in southern Scandinavia. Pollen records from S Sweden present evidence for an opening up of the forested landscape and the creation of extensive grasslands (Berglund 1991; Gustafsson 1998). Major changes are also apparent in archaeobotanical assemblages. The importance of speltoid wheats and *H. vulgare* var. *nudum* (naked barley) declined in favour of *H. vulgare* var. *vulgare*. Cultivation of hulled barley is generally recognized as an indicator of manured fields (Engelmark 1992). It has a greater requirement for easily soluble nutrients, especially nitrogen, in order to produce an acceptable yield. This suggests that some form of manuring was employed (Engelmark 1992; Grabowski 2014). Also, macrofossils of oil plants and arable weeds became much more common (Engelmark 1992; Gustafsson 1998). This has often been interpreted as a result of abandonment of an extensive agriculture in favour of an intensive one, with changes in the farming system with permanent, manured fields being established at this time (Engelmark 1992; Gustafsson 1998). Similar developments are seen in contemporaneous sites from Denmark. Data show opening up of the landscape over the course of the Bronze Age and the appearance in settlement layers of a well-developed arable weed flora including nitrophilous species. This could also be explained by the introduction of permanent fields and systematic improvement/maintenance of the soil fertility using animal manure (Robinson 2003).

In general, during the end of the EBA northern Europe underwent a massive transformation of the farming system moving towards a more intensified agriculture aimed at surplus production. However, this should not be regarded as an isolated occurrence, but rather as a radical change of the whole society which took place throughout Europe (Gustafsson 1998). Intensification of contacts across northern Europe have integrated previously isolated regions into a wider network (Kristiansen and Larsson 2005; Wehlin 2013; Earle et al. 2015). It is therefore likely that farming spread into the SE fringes of the Baltic Sea alongside other innovations including malleable technologies and developments of social structure.

The presence and scale of intensifying connections is well illustrated by SE Baltic archaeological material. Firstly, the appearance of stone ship graves has served as a basis for locating the Nordic communication zones. Construction of such graves was limited to the coastal regions of Kurzeme, Saaremaa Island and the Northern Estonian coast near Tallinn and Kaliningrad (Graudonis 1967; Okulicz 1976; Lang 2007) and is generally regarded as a foreign burial custom which was common in Gotland and along the Scandinavian coast. This is also supported by the Staldzene and Tehumardi hoards (Vasks and Vijups 2004; Sperling 2013), which contained artefacts typical of Nordic culture. Secondly, studies of early metallurgy and its products, both imported and created in the SE Baltic, have concluded that metal consumption in the LBA had more than doubled compared to the EBA (Sidrys and Luchtanas 1999). The SE Baltic region lacks any metal artefact types exclusive to the region and metal objects are dominated by artefact types originating from Nordic and Lusatian cultures (Sidrys and Luchtanas 1999; Lang 2007; Čivilytė 2014). This indicates that even after metal crafting reached the region, the technology remained exclusively of foreign origin. Rarely identifiable negatives of clay casting moulds were also made for artefacts of Nordic influence, such as Mälar type axes or Härnevi type pins (Čivilytė 2014; Sperling 2014). Lastly, emerging social diversification was accompanied by the establishment of the first identifiable settlement pattern. Settlement locations were strategically chosen alongside economically significant routes, primarily on the coast and near the Daugava River. Hilltop areas were prioritized over the lowlands, and excavations on these sites have often revealed several stages of enclosure construction (Graudonis 1989). This has also been explained as a reflection of intensifying communication networks between Nordic and Lusatian cultures, and the indigenous communities of the SE Baltic.

Conclusions

Current archaeobotanical evidence from the SE Baltic indicates that attempts at some form of crop cultivation could be traced back to the EBA. However, there is little debate that grain-rich assemblages in archaeological contexts only start appearing after the EBA. This advocates that farming on any significant scale did not exist before the EBA to LBA transition. New finds from the Kukuliškiai hilltop settlement expand our understanding of the early farming practices in the region. New radiocarbon dates also allow the earliest secure chronologies on *Vici faba*, *Lens culinaris* and *Avena* sp. finds. Data show that Bronze Age populations cultivated a wide range of cereals and pulses which included hulled and naked *Hordeum*, *Panicum*, *Triticum* spp. (free-threshing and glume wheats), *V. faba*, *Pisum* and *Lens*. Several crop species alongside limited finds of weeds and ruderal plants also indicate the possibility of permanent or semi-permanent cultivation with manuring and well-maintained fields. The agrarian intensification of the SE Baltic was not an isolated economic development, but rather a part of complex social transformation. Archaeological data show that starting around 1400/1300 BC rapid social, technological and agricultural developments across the Baltic Sea resulted in intensifying interactions among the different parts of the region. Communication routes originating primarily from Nordic and Lusatian cultures accelerated the spread of farming into the SE Baltic, which was previously prevented by a combination of social, economic and environmental factors. Adoption of farming followed by rapid agrarian intensification encouraged sedentarism, enabled surplus production and accelerated the growth of social diversification and complexity.

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