Vegetation History and Archaeobotany (2018) 27:65–74
https://doi.org/10.1007/s00334-017-0621-3

ORIGINAL ARTICLE

# The plant economy of the Northern European Bronze Age—more diversity through increased trade with southern regions

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Received: 31 October 2016 / Accepted: 2 June 2017 / Published online: 28 June 2017
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## Abstract

Until recently the plant economy of the Northern European Bronze Age was only investigated locally or within modern boundaries. New results from the project "Settlements of the Bronze Age" by the Academy of Science and Literature Mainz allow us to now fill part of the remaining gaps in research. Summarizing all available data concerning the plant economy of the Northern European Bronze Age has shown that it constitutes a time of innovation and continuous change. In addition to the omnipresent *Triticum dicoccum* (emmer) and *Hordeum vulgare* (barley), this period is marked by the emergence of various new cultivars like *T. spelta* (spelt) or *Camelina sativa* (gold-of-pleasure). A comparison between the cereal spectra from several regions in Northern Germany and Scandinavia revealed differences and similarities which allowed for the reconstruction of multiple possible contact zones and various influences from adjacent cultures. Northern Germany and especially Schleswig–Holstein served as an important link for trading over land and by water between the southern areas and Scandinavia. The rising diversity of crop plants in the Late Bronze Age, which is for the first time comparable to the southern regions, reflects the increased trade and therefore stronger influence from beyond the Northern European Bronze Age, which resulted in an accelerated assimilation of innovations and new technologies.


**Keywords** Northern European Bronze Age · Plant economy · Representativeness index (RI) · Trade · Contact zones

## Introduction

The Bronze Age in Northern Europe starts around 1800 BC and proceeds until about 600 BC. The Northern European Bronze Age (NEBA) is as much a cultural term as a period. It is divided into the Earliest/Early Bronze Age (EBA, 1800–1100 BC) and the Late Bronze Age (LBA, 1100–600 BC) (Keiling 1999). At its maximum in the LBA the area of the NEBA stretched across Southern Sweden, Denmark and Northern Germany. The sphere of influence of the NEBA can be registered as far south as to the forelands of the Harz Mountains (Willroth 2002; Heske 2006).

As there are no natural deposits of raw material for bronze production in Northern Europe, the trade with adjacent cultures had to be intensified (Keiling 1999) in order to obtain the metal. Trade routes overland, so-called ox trails, whose course can be retraced during the Bronze Age (BA) through chains of burial mounds, were fixed ways of contact and communication (Zich 2002). However, there is evidence that primarily rivers and streams were used as more effective ways of transport (Willroth 1996). Whilst trade in the Late Neolithic and Earliest BA took place from the Aunjetitzer Culture by the way of the river Elbe, it shifted to a more eastern route by the Oder approximately 1550 BC along with the transition from the Aunjetitzer to the Lausitzer Culture (Hesse 2013). It can be assumed that agricultural innovations were transferred along the way and led to an increasing influence of southern/south-eastern groups on the development of the NEBA.

Communicated by F. Toulemonde.

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s00334-017-0621-3) contains supplementary material, which is available to authorized users.

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Until recently the few, more local investigations concerning the plant economy of the BA in Northern Germany constituted an insufficient data basis for representative evaluations and comparisons within and beyond the NEBA. Also results from the other regions of the NEBA were only evaluated within modern country boundaries. New results from analysis of several sites allow us to fill parts of the remaining gaps in research. Furthermore, they enable us, by comparison with other regions of the NEBA and Southern/South-eastern European groups, to provide a first comprehensive analysis of the development of the plant economy of the whole NEBA and the impact of other cultures.

## Materials and methods

Since 2007 research on macro remains from BA settlement sites of the NEBA and the northern region of the Lausitzer Culture was conducted by the botanical section of the project "Settlements of the Bronze Age" by the Academy of Science and Literature, Mainz. In the course of the project material from nine settlement sites in Northern Germany, especially Schleswig–Holstein, and 11 settlement and three ritual sites of the Lausitzer Culture in Brandenburg was analysed (for information concerning the individual sites see Effenberger in press). In order to compare the new data with other sites from the NEBA, published and unpublished macro remain analyses from the BA in Northern Germany, Denmark and Sweden were compiled. Furthermore, contemporaneous data from the adjacent regions of the Netherlands and the northern area of the Aunjetitzer/Lausitzer Culture was included.

For better comparability and in order to outline regional differences and similarities, the different sites from the EBA and LBA in Northern Germany, Denmark and Sweden were divided into 11 micro regions, in accordance with their location within Northern Europe or the local geology (Fig. 1). Schleswig–Holstein was separated into northern and southern regions according to their location north or south of the Schlei–Treene isthmus, which formed a natural boundary. The sites in the Netherlands were included by considering their absolute dating as criteria for an isochronic comparison, as there are differences in the relative periodic classification to the NEBA (Brinkkemper 2013). Iron Age (IA) sites dating to 800–500 BC were not considered.

In total 159 sites were included (ESM). While conducting a supra-regional comparison of different archaeological sites it remains difficult to ensure the comparability of the data. Differences in deposition processes, sampling strategies and sample processing at the sites make a distinction in the weighting necessary in order to minimize an overstated distortion of the overall picture through outstanding single finds. The most effective method at present for distinctive weighting of sites in a comparison is the semi-quantitative approach of Stika and Heiss (2013). This method on one hand provides a measurement for

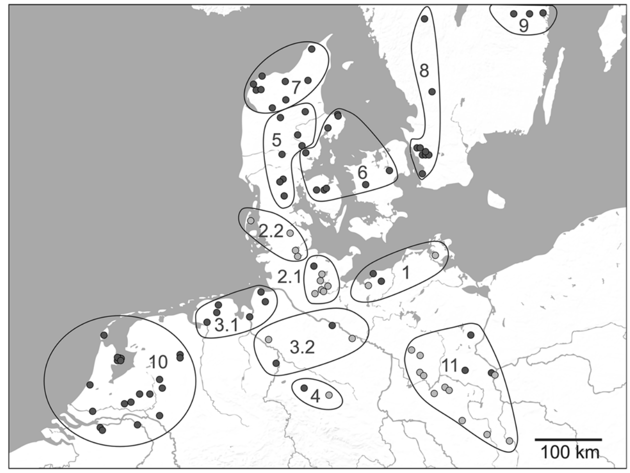


**Fig. 1** Settlements of the Bronze Age and applied subdivision into micro regions *1* Mecklenburg-Western Pomerania; *2.1* Southern Schleswig–Holstein; *2.2* Northern Schleswig–Holstein; *3.1* Northern Lower Saxony; *3.2* Middle Lower Saxony; *4* Southern Lower Saxony; *5* Middle Jutland; *6* Baltic Sea coast of Denmark; *7* Thy-region; *8* Southwestern Sweden; *9* Southeastern Sweden; *10* Netherlands; *11* Northern Lausitzer Culture (Brandenburg)

the importance of the individual crop plants, and on the other hand depicts the representativeness of the data and thus the significance of the conclusions drawn. Through this method a Representativeness Index (RI) is created based on the presence and quantity of a taxon per site as well as the total quantity of analysed plant material and the quantity of analysed samples. First scores corresponding to the number of finds of the individual crop taxa are assigned (Table 1). Afterwards these scores are multiplied by factors as established by Stika and Heiss (2013) that depend on the number of samples taken on the site and the overall quantity of macro remains including crop remains and weed seeds (Table 1). Through these correction factors it is ensured that sites with good sampling strategies and proficient sample processing (e.g. using sieves with fine mesh sizes) have a higher impact within the comparison. The subtotal of the scores for the different taxa multiplied by the corresponding factors is then summed up per site and per region to the RI (Table 2), which consequently constitutes a measurement for the quantity and quality of the available data for this region (the higher the RI value, the better the database per region). This semi-quantitative approach, which was developed for a comprehensive comparison of European material, proved to be too coarse for the NEBA with its usually smaller amounts of macro remains per site. It resulted in an overrepresentation of rare or unimportant species and could not be applied in its original form. Because of this, it became necessary to modify the system accordingly, which was achieved through a refinement of the scores scaling (Table 1).

The individual macro remain analyses of the NEBA showed many differences concerning the working methods.

**Table 1** Scoring system and correctional factors of the semi-quantitative approach after Stika and Heiss (2013) with modified system

| Σ macro remains per site | <1,000 s/f | >1,000 s/f | <1,000 s/f | >1,000 s/f |
|---|---|---|---|---|
| Scores | Amount per taxon, approach Stika and Heiss (2013) | | Amount per taxon, modified approach (Effenberger in press) | |
| 1 | <100 s/f | <100 s/f | <10 s/f | <10 s/f |
| 2 | >100 s/f | >100 s/f | 10–49 s/f | 10–49 s/f |
| 3 | – | – | 50–99 s/f | 50–99 s/f |
| 4 | – | Primary cultivar (25–49%) | >100 s/f | 100–499 s/f |
| 5 | – | Taxon dominant (>50%) | – | >500 s/f |
| 6 | – | – | – | Primary cultivar (25–49%) |
| 7 | – | – | – | Taxon dominant (>50%) |

| Factors | Requirements per site |
|---|---|
| ×2 | >20 samples or >1,000 l volume of samples |
| ×4 | >40 samples or >5,000 l volume of samples |
| ×5 | >100 samples |
| ×2 | No requirement of above applies, but samples contain >10,000 finds |

*s/f* seeds/fruits

To ensure comparability, the following standards were used for unification [for further details see Effenberger (in press)]:

- If undifferentiated *Hordeum vulgare* (barley) as well as both varieties (hulled and naked) were counted, all three categories were included in order to avoid under-representation in comparison to *Triticum*. The undifferentiated *Hordeum* was later separated into hulled and naked barley in accordance to their ratio on that site. For sites without further determination of *Hordeum*, the ratio of the individual region and period was used as reference for the separation into hulled and naked *Hordeum*.
- For the mostly not further differentiated naked wheat only a summarizing category (*Triticum aestivum/durum/turgidum*) was used.
- Only cereal caryopses and no threshing remains were included in the comparison to avoid an over-representation of speltoid cereals. If only threshing remains of a taxon were present, a value of 1 was taken for caryopses.
- *Triticum spelta* (spelt) caryopses cannot easily be separated from other wheat species with certainty, so they are missing entirely in the counts of some work groups. If spelt glume basis were present, the total amount was converted into a value for caryopses proportionally according to the ratio of *T. dicoccum* (emmer) caryopses to glume basis.
- Determinations of taxa as cf. were counted as certain determinations.
- Determinations as mixed categories (e.g. *T. dicoccum/spelta*) were separated according to the ratio of their glume bases on that site.
- Ceramic imprints of cereals were not included.
- For macro remain analysis with mass finds where only percentages were given (e.g. Hopf 1973) a total amount (1,000 caryopses) was assumed and individual portions per taxa calculated. For mass finds where only weight values were given a total amount was estimated.

This semi-quantitative method was applied only for the evaluation of cereal caryopses. Because of the predominantly charred preservation of macro remains from the NEBA and the low probability of charring or preservation of legumes and oil plants, only the frequency of their appearance on the sites was considered.

In order to put the results from the NEBA and their immediate adjacent regions in perspective, a broader comparison with contemporaneous cereal spectra of Europe was pursued. For this purpose, the results of the European Bronze Age overview of Stika and Heiss (2013) were used, together with investigations from Bruszczewo, Poland (Kroll, personal communication).

## Results

### The Bronze Age in Northern Europe: a period of innovation and continuous change in crop production

The supra-regional comparison of cereal spectra from the NEBA and the adjacent regions illustrates similarities as well as differences. For the EBA in some areas insufficient data were available (Table 2), so no entirely comprehensive overview was possible. For the LBA the dataset allowed

**Table 2** Number of sites and Representativeness Indices (RI) from the cereal spectra of the Northern European Bronze Age and adjacent regions in the Early Bronze Age (EBA) and Late Bronze Age (LBA)

| Region | Period | Number of sites | Σ RI/Region | RI *Hordeum vulgare vulgare* | RI *Hordeum vulgare nudum* | RI *Triticum dicoccum* | RI *Triticum monococcum* | RI *Triticum spelta* | RI *Triticum aestivum* | RI *Panicum miliaceum* | RI *Setaria italica* | RI *Avena* sp. | RI *Avena fatua* | RI *Avena sativa* | RI *Secale cereale* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mecklenburg-Western Pomerania | EBA | 1 | 95 | 25 | | 35 | 5 | 20 | 5 | | | 5 | | | |
| | LBA | 4 | 146 | 31 | 23 | 15 | | 14 | 16 | 23 | 4 | 12 | 2 | 2 | 4 |
| Southern Schleswig-Holstein | EBA | 6 | 190 | 40 | 10 | 66 | 24 | 32 | 12 | | | 6 | | | |
| | LBA | 4 | 152 | 39 | 14 | 33 | 5 | 15 | 13 | 21 | | 7 | | | 5 |
| Northern Schleswig-Holstein | EBA | 2 | 89 | 30 | 17 | 32 | | 5 | | | | 5 | | | |
| | LBA | 2 | 43 | 13 | 13 | 4 | | 4 | 2 | 2 | | 5 | | | |
| Northern Lower Saxony | LBA | 5 | 183 | 58 | 37 | 31 | 12 | | 11 | 15 | | 14 | | 5 | |
| Middle Lower Saxony | LBA | 4 | 192 | 31 | 37 | 51 | 4 | 14 | 11 | 26 | 5 | 11 | | | 2 |
| Southern Lower Saxony | LBA | 2 | 62 | 12 | 1 | 15 | 5 | 4 | 4 | 15 | 2 | 4 | | | |
| Brandenburg | EBA | 1 | 0 | | | | | | | | | | | | |
| | LBA | 10 | 253 | 33 | 30 | 47 | 8 | 15 | 17 | 58 | 4 | 24 | 8 | 5 | 4 |
| Middle Jutland | EBA | 9 | 367 | 62 | 123 | 63 | 6 | 49 | 21 | | | 33 | | 10 | |
| | LBA | 2 | 13 | | 7 | 3 | | 1 | 1 | | | 1 | | | |
| Baltic Sea coast Denmark | EBA | 12 | 212 | 11 | 96 | 45 | 6 | 24 | 13 | 1 | | 16 | | | |
| | LBA | 4 | 96 | 6 | 44 | 11 | 7 | 14 | 7 | 1 | | 6 | | | |
| Thy region | EBA | 10 | 270 | 21 | 87 | 68 | 18 | 37 | 28 | | | 11 | | | |
| | LBA | 7 | 181 | 16 | 45 | 33 | 5 | 31 | 33 | 1 | | 11 | 4 | | 2 |
| Southwestern Sweden | EBA | 8 | 54 | 11 | 15 | 9 | 2 | 2 | 12 | | | | | 1 | 2 |
| | LBA | 20 | 54 | 15 | 15 | 8 | 1 | | 10 | 2 | | | | 1 | 2 |
| Southeastern Sweden | EBA | 5 | 21 | 3 | 5 | 7 | | | 5 | | | 1 | | | |
| | LBA | 5 | 22 | 6 | 6 | 6 | | | 2 | | | 2 | | | |
| Netherlands | EBA | 17 | 169 | 55 | 47 | 54 | | | 11 | 2 | | | | | |
| | LBA | 12 | 196 | 37 | 57 | 54 | 6 | 1 | 1 | 10 | | 17 | 12 | | 1 |

for an approximately complete compilation of the plant economy, especially for the different regions of Northern Germany and Denmark (Table 2).

Despite the insufficient dataset it can be observed that the cereal spectra of the EBA in the areas already investigated are quite homogenous (Fig. 2). *Hordeum vulgare* and *Triticum dicoccum* were primary cereals everywhere, which remained constant all through the NEBA. Differences in the cereal spectra of this period exist in the ratio of *Hordeum vulgare nudum*/*vulgare*. In Denmark naked barley constitutes by far the most important cereal, while hulled barley plays only a minor role. In contrast, naked barley lost its importance in many areas of Northern Germany with the beginning of the BA in favour of hulled barley. The barley ratio of Northern Schleswig–Holstein seems to constitute a transition between the northern and southern percentages.

In the LBA the cereal spectra of the micro regions of Northern Germany become more heterogeneous, whereas in Denmark the homogeneity stays similar to the EBA (Fig. 2). *Triticum dicoccum* lost part of its importance together with the other speltoid wheats, *T. spelta* and *T. monococcum* (einkorn), in the course of the LBA in Northern Germany and Denmark. The differentiation in the hulled and naked barley ratio between Denmark, Northern Schleswig–Holstein and the southern regions of Northern Germany from the EBA is also visible in the LBA.

In comparison to the Neolithic an increasing diversification of cultivars can be noted for the NEBA. Indicator species for innovations in the cereal spectra of the BA are *T. spelta, Panicum miliaceum* (broomcorn millet) and *Avena* sp./*A. sativa* (oat, Fig. 2). Less pronounced alterations are the first appearance of *Secale cereale* (rye), probably in this period as a weed in cereal fields, and *Setaria italica* (foxtail millet) in some areas.

The cultivation of *T. spelta* can be traced as far back as to the transition of the Late Neolithic to the Earliest BA (2000–1800 BC) through radiocarbon dates from different sites (Fig. 3). It remains unclear from where and when exactly the cultivation of *T. spelta* spread into the north, as further investigations for the periods following the Middle Neolithic in Northern Germany and Denmark are necessary. In contrast to prior investigations (Stika and Heiss 2013) the new results suggest that *T. spelta* was an already well established cultivar in the EBA in all areas of Northern Germany and Denmark yet investigated (Fig. 2). In Northern Germany, in contrast to Denmark, only an indication of farming a mixture (intentional or unintentional) of *T. spelta* together with *T. dicoccum* with differing main cereals could be observed. *T. spelta* seems to play a more important role in Denmark. Considering that *T. spelta* poses an attractive alternative to *T. dicoccum* for Northern European cultivation conditions because of its stronger resilience to poor soils, wetness and frost (van der Veen and Palmer 1997), this would explain why it was preferably cultivated in the region of Thy/Denmark, where the soils, in contrast to Northern Germany, are already rated as heavily depleted in the BA (Kristiansen 1998; Bech and Mikkelsen 1999; Kneisel et al. 2012).

Due to new results, *P. miliaceum*, which according to prior investigations seemed to be of no importance for the plant economy of the NEBA (Behre 1998; Kučan 2007; Stika and Heiss 2013), is suggested to have been present from about 1400 BC in various areas of Northern Germany (Figs. 2, 3). The percentages of *P. miliaceum* within the cereal spectra of the NEBA decrease from the south-eastern to the northern and north-western areas. In the south-eastern areas of the NEBA and the northern regions of the Lausitzer Culture *P. miliaceum* can be said to become a main cereal at the transition to the LBA (Fig. 2), whereas the quantities of *P. miliaceum* from the North Sea coast of Lower Saxony and Sweden are rather low. The lowest amounts of *P. miliaceum* are documented for Denmark.

New insight can also be gained concerning the onset of *Avena* cultivation. Oat belongs to the late arrivals of cereal species in Middle Europe. The earliest evidence from the southern regions of Europe originates from the local BA (Körber-Grohne et al. 1988). In the course of the NEBA *Avena* sp. is present in the cereal spectra in increasing amounts, especially in Northern Germany and Denmark. Although the finds of *Avena* must mostly be interpreted as weed rather than cultivar, it is probable that it was frequently harvested together with the main cereal and maybe even eaten, albeit unintentionally. The frequency and amounts of *Avena* occurrences in several cereal spectra suggests that it gained in importance as a cultivated food plant in

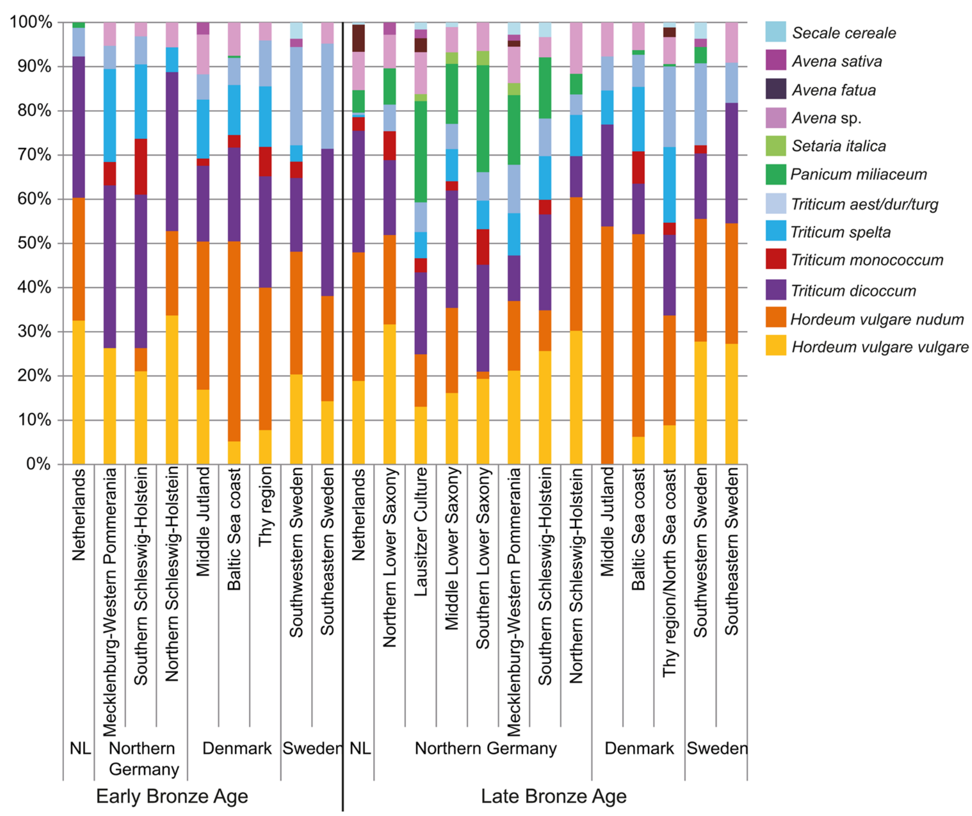


**Fig. 2** Cereal spectra of the different regions in Northern Europe during the Early (1800–1100 BC) and Late (1100–600 BC) Northern European Bronze Age; percentages are based upon the Representativeness Index (RI) per region and standardized at 100%

the LBA. Since then, first evidence of larger amounts of *A. sativa*, which may have spread from Middle Europe into the north (Behre 2001), can be observed in the coastal areas of Northern Germany. As *Avena* needs moist, cool weather conditions and a regular water supply for its growth, but is undemanding in relation to soil conditions (Zohary and Hopf 1988; Lieberei et al. 2007), the greater amounts of *Avena* in the coastal areas could indicate an early gradual shift to an intentional cultivation of the robust and productive cereal in these areas with an oceanic climate, leading to its importance as a main cereal in the following IA.

*Secale* is also present more frequently in different cereal spectra of the LBA. Although the caryopses must most likely be interpreted as its presence as a weed, it could reflect the enrichment of *Secale* in the cereal spectra, followed by the development from weed into cultivar in later periods. First isolated evidence for the emergence of *Setaria italica* in the southern-most regions of the NEBA (Fig. 2) cannot yet be interpreted as regular local cultivation, but shows the beginning of its spread from the south to the north through trade.

## Pulses and oil plants

Not only cereals, but also pulses and oil plants gain in diversity and importance with the beginning of the BA. In Northern Germany and the northern area of the Lausitzer Culture three different taxa of pulses were more or less frequently present on the BA sites (Fig. 4). From Denmark there is no evidence for the cultivation of pulses from the entire period. It remains unclear whether actually no cultivation took place or this depicts the state of research.

In the EBA and LBA of the different areas of Northern Germany *Pisum sativum* (pea) constitutes the most important pulse. Also there are first isolated indications of a possible cultivation of *Vicia faba* (horse bean), which increase in number during the BA. *Lens culinaris* (lentil) is only present on one site from the LBA in Mecklenburg-Western Pomerania (Kroll and Wiethold 2000). The increasing frequency and diversity of pulses in Northern Germany show that these cultivars gain in importance significantly during the BA.

In the northern area of the Lausitzer Culture in Germany, in contrast to the NEBA, *Lens* seems to be of great importance (Fig. 4). There is one find of *Lens* from the Aunjetitzer Culture already in this area, which could show an early cultivation of this species. From the Lausitzer Culture in the LBA the importance of *Lens* is underlined by the mass find of Lebehn (Neef 1997; Benecke et al. 2002). Furthermore the frequent appearance of larger amounts of *P. sativum* and *V. faba* illustrates the importance of pulse cultivation in general.

Oil plants, presumably also due to the low probability of their preservation in a charred condition, are only rarely found on sites from the NEBA in Northern Germany and Denmark. From the EBA from both areas there are only hints of the utilization of *Linum usitatissimum* (flax). With the transition to the LBA an increase in diversity can be noted. *Camelina sativa* (gold-of-pleasure) is present on more and more sites and reaches equal to or higher frequencies than *Linum* (Fig. 4), which depicts the shift in utilization from weed to cultivar. In addition in the southeastern part of the NEBA and from the Lausitzer Culture there is isolated evidence of *Papaver somniferum* (opium poppy) (Kroll and Wiethold 2000; Stika 2014). The rising importance of oil plants in the course of the BA is also highlighted by an increase in mass finds (*Camelina sativa*: Jürgenshagen, Kroll and Wiethold 2000; Rodenkirchen, Kučan 2007; Bjerre Enge 7, Henriksen et al. in press; *Linum*: Rodenkirchen, Kučan 2007) on sites from the LBA.

It can be concluded that the spectra of cultivars—cereals, pulses and oil plants—show a significant increase in diversity in the different areas of Northern Europe, especially in Northern Germany, in the course of the BA. A gradual introduction of new cultivars with *T. spelta* not later than at the transition to the EBA, *P. miliaceum* and *Camelina sativa* at the transition to the LBA, and *Avena* during the course of the LBA, can be noted (Fig. 3).

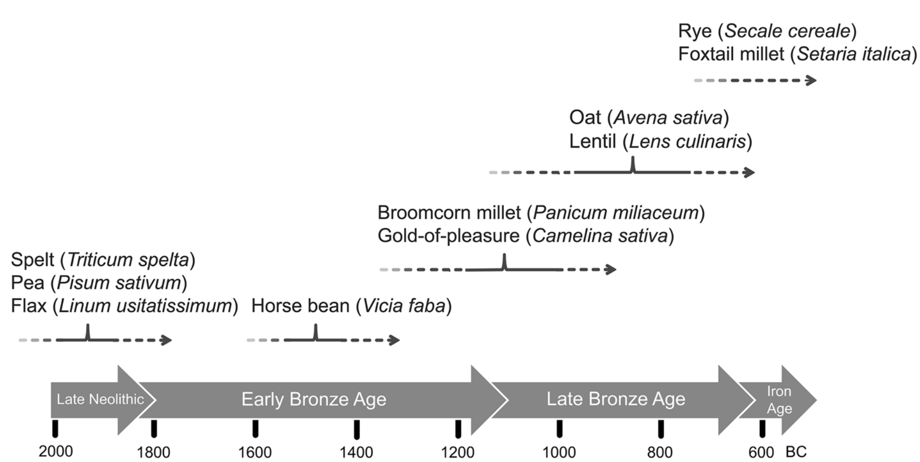


**Fig. 3** Timeline with appearances of new cultivars during the Northern European Bronze Age

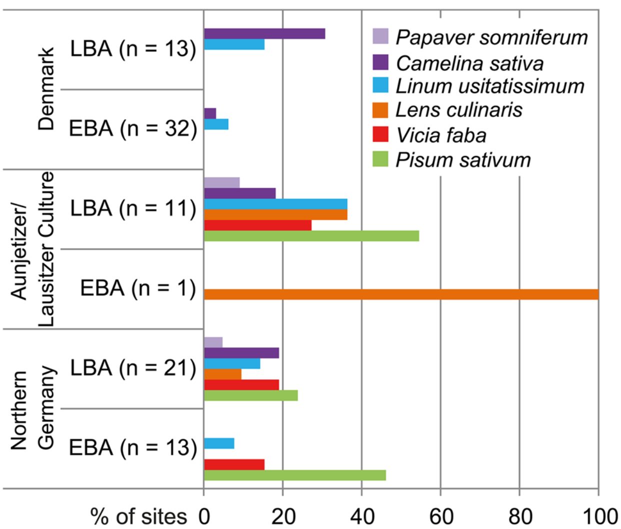


**Fig. 4** Frequency (% of sites) of pulses and oil plants in the Early and Late Bronze Age of Denmark, the Aunjetitzer/Lausitzer Culture and Northern Germany

## Discussion

### Contact zones within the NEBA and across Europe

Within the area of the NEBA and linking to the adjacent cultures, a multitude of possible contact zones and trade routes exist. The different water routes along the coastal areas of the North and Baltic Sea and following the different rivers (primarily the Elbe, Oder and Weser) constitute a quick and simple way of transporting trade goods or people and transferring knowledge. In addition, trade was pursued over land. Northern Germany geographically acts as connection between Scandinavia and Middle Europe. Schleswig–Holstein especially forms a transit route for trade and exchange over land and overseas. The question remains if and how this bridge function is reflected in the BA cereal spectra of this area.

By means of the patterns in the similarities and differences of the NEBA cereal spectra, various zones of influence and contact could be reconstructed (Fig. 5c). Exchange of goods and knowledge did not proceed within modern borders, but was orientated on ecological and economic factors.

It remained to be questioned whether the cereal spectra display a selection of cereals and thus possible influence from other groups, or just illustrate different ecological factors for differences in cereal cultivation. If the latter were to be correct, similar spectra could be expected for comparable growing conditions. That this is not the case can be seen especially in the different coastal areas, for example the North Sea and the Baltic Sea coast, where similar climatic conditions but nonetheless significantly different cereal compositions exist. In addition soil conditions cannot be a criterion for the selection of cereals, as the sites of Schleswig–Holstein, Mecklenburg-Western Pomerania, Middle and Southern Lower Saxony and Brandenburg are situated on various soils, but show rather homologous cereal spectra. Therefore it can be concluded that the differences and similarities of cereal spectra from the NEBA can be used for the definition of contact zones.

The cereal spectra of the three regions in Denmark are largely homogenous, equally in the EBA and the LBA. New cultivars like *P. miliaceum* are missing or do not reach as significant proportions as in the southern parts of the NEBA. This rather hints at isolation to an extent of this area from the other regions of the NEBA. On the other hand, the homogeneity of the cereal spectra within the Danish regions suggests dense contact and communication there through time.

Apart from this the insufficient dataset for the Early NEBA allows only for the observance of a north–south divide between Denmark and Northern Germany in relation to the importance of naked barley. The ratio of naked to hulled *Hordeum* of Northern Schleswig–Holstein suggests this region to be a transition area between Denmark and the southern areas of the NEBA (Fig. 5c).

For the LBA there are several indicators for the definition of possible contact zones. The north–south divide of naked *Hordeum* and the transitional position of Northern Schleswig–Holstein, which can be suspected for the EBA, can also be found in the LBA. This confirms contact along the coastal areas of the North and Baltic Seas and overland by way of Schleswig–Holstein.

Similarities in cereal cultivation can be identified along the southern North Sea coast of the Netherlands and Northern Lower Saxony in the LBA. These regions are marked by a dominance of *Hordeum*, absent or little evidence for the cultivation of *T. spelta*, comparatively small amounts of *P. miliaceum* and higher percentages of *Avena* (evidence for *A. sativa* from Northern Lower Saxony). The seeming lack of "absorption" of new cultivars could reflect missing or reduced contact with the south-eastern groups, as seems to be the case in Demark. Furthermore, the similarities in cereal cultivation could indicate a more intensified and closed-off contact within the area of the southern North Sea coast. It remains to be seen, whether this contact zone continues towards the north, because there are no macro remain analysis from the immediately adjacent area of Dithmarschen, which is supposed to be a centre for wealth and trade in this period (Kneisel 2013).

*Panicum miliaceum* appears as another important factor in the reconstruction of contact zones between the NEBA and the adjacent regions between 1100 and 600 BC. The gradual decrease of importance of *P. miliaceum* from southeast to northwest (Fig. 5c) indicates contact with and particularly strong influence from the south-eastern regions.

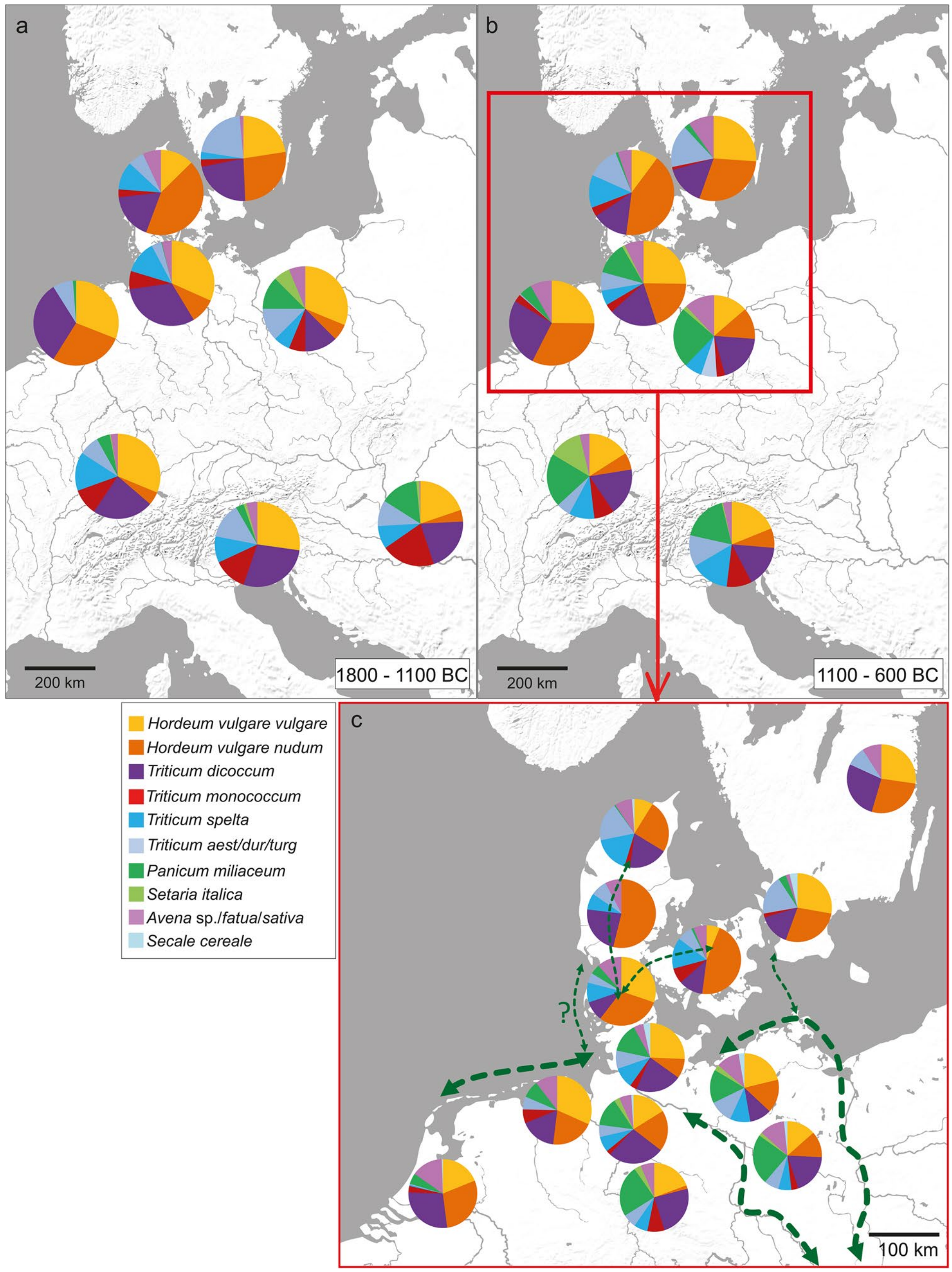


**Fig. 5** Cereal spectra of Northern Europe (percentages per region are based upon the Representativeness Index (RI) in Table 2) and Southern and Middle Europe (percentages are based upon the RI according to Stika and Heiss 2013) between 1800 and 1100 BC (**a**) and 1100–600 BC (**b, c**); *green arrows* (**c**) mark possible contact zones within and to the Northern European Bronze Age

This could reflect the impact of a trade route along the river Oder towards the coastal areas and following the coast, along which the new cultivar could have spread into the north. It seems to have been established with reduced intensity from southeast northward. Southern Schleswig–Holstein seems to be influenced more strongly by the south-eastern cultures than Northern Schleswig–Holstein, similar to Southern and Middle Lower Saxony in comparison with the North Sea coast of Lower Saxony. The Swedish cereal spectrum resembles more the spectra of the south-eastern regions of the NEBA and less the Danish ones. Therefore direct contact with the southern Baltic Sea coast by sea is more likely than with the nearby Danish Isles.

In summary the different cereal spectra of the NEBA and the immediate adjacent regions show gradual variations from south to north and from west to east, which indicate increased influence and trade along the rivers and coastal areas, especially in the southern North Sea area and along the Oder. Agricultural innovations like the cultivation of *P. miliaceum* could have, at least in part, spread this way into the NEBA.

The question remained, whether the south-eastern contact zone, which was visible within the NEBA, could be verified in a broader European context. For this purpose, a comparison with the results of the compendium of the European cereal economy of Stika and Heiss (2013) was conducted. The EBA in Northern Europe (the period from 1800 to 1100 BC) is contemporaneous with the Middle BA to LBA in the area of Greece, Bulgaria and Pannonia as well as the EBA to MBA in Central Europe, the Alpine region and Italy (von Schnurbein 2009) (Fig. 5a). For the LBA (1100–600 BC) only the RIs from Central Europe, the Alpine regions and Italy were used (Fig. 5b), as in the other regions the transition to the IA had already taken place. For this general comparison with the NEBA the RIs of Italy and the Eastern Alpine region were combined as well as the RIs of Central Europe and the Western Alpine region.

In all of Europe the BA, especially the LBA, is a time of diversification in crop production. The spread of the cultivation of *P. miliaceum* is visible in all areas (Stika and Heiss 2013; Kneisel et al. 2015), which emphasizes its status as indicator for innovations in the BA. By 1800–1100 BC *P. miliaceum* was well established as a cultivar in Greece/Bulgaria/Pannonia and possibly Poland (Fig. 5a). In the Alpine region, Middle Europe and the Netherlands it had already been introduced, but did not reach significant amounts. Around 1100–600 BC a further spread and establishment of *P. miliaceum* to the north-western areas of Europe can be observed (Fig. 5b). In Central Europe, the Alpine area, Northern Italy, the Lausitzer culture in the Brandenburg region and the southern/south-eastern parts of the NEBA *P. miliaceum* is now present as another primary cereal. Scandinavia, especially Denmark, exhibits the lowest amounts of *P. miliaceum* in all of Europe.

*Setaria italica* as a cultivar is certified in the southern and south-eastern regions of Europe in the timeframe of 1800–1100 BC, especially in Italy and Central Europe (Stika and Heiss 2013) (Fig. 5a). In the LBA *S. italica* occurs in increasing amounts in the northern and north-western regions of Europe, as can be seen in the southern parts of the NEBA especially (Fig. 5b, c). Accordingly, the spread of *S. italica* took the same route from the south/southeast to the north as did *P. miliaceum*.

It can be concluded that the southeast-northwest divide of the arrival of new cultivars, which is also reproduced in the European context in the course of the BA, certifies the spread of agricultural innovations from the southeast of Europe into the north.

## Conclusions

The consideration of pan-European cereal spectra from the BA underlined the bridging function of Northern Germany, especially Schleswig–Holstein, in respect of the spread of innovations in the plant economy within the NEBA over land and along the coasts. The differences visible in the cereal spectra seem to be caused by the specific contact zones and direct local influence from the adjacent regions (Fig. 5c). Innovations in the NEBA seem to arrive primarily from the South-eastern European groups. While in the first stages of the EBA a big distinction between the cereal cultivation of the NEBA and the southern groups of Europe is still apparent, the rate of establishment of new cultivars accelerates with the intensified trade in the course of the BA. This leads, for the first time in the history of Northern European agriculture, to an alignment of the spectra of cultivars between the southern regions of the NEBA and the advanced southern groups during the LBA.

The term "third food revolution", which was coined for the changes in the plant economy of the LBA in Europe (Kneisel et al. 2015) cannot be applied to the NEBA. The establishment of new cultivars proceeds gradually, although at an accelerated rate, during the whole BA (Fig. 4) and continues in the IA with the final establishment of *Avena* as the main cereal and the possible beginning of *Secale* cultivation. In conclusion, the NEBA represents a time of change and innovation in the plant economy, which also creates a basis for later developments in crop cultivation.

**Acknowledgements** This study is part of the project "Settlements of the Bronze Age" from the Academy of Science and Literature, Mainz. I want to thank Almuth Alsleben, Hans-Peter Stika, Julian Wiethold, Helmut Kroll, Stefanie Klooß, Wiebke Kirleis and Karl-Heinz Willroth, who provided unpublished data and/or advice, Ingo Lütjens, Benjamin Irkens, Susanne Jahns, Immo Heske and Dorothea Feiner, who provided additional material for macro remain analysis, and Timo Effenberger, Hans-Peter Stika and Otto Brinkkemper, who helped to improve this paper.

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