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ORIGINAL ARTICLE

Inventions, innovations and the origins of spelt wheat

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Abstract

What turns an invention into an innovation? How, if at all, might we observe this process archaeologically? Loosely put, new varieties of plants or animals might be considered as inventions (whether from deliberate breeding or by chance), but ones that are only taken up by humans more systematically as innovations when certain social, demographic, economic and environmental factors encourage such take-up. The archaebotanically-observed history of spelt wheat (*Triticum spelta*) is an interesting case in this respect. Prior to 3000 BCE, spelt is occasionally found in very small amounts at sites in eastern Europe and south-west Asia, but is usually considered to be a crop weed in such contexts, rather than a cultivar. However, rather suddenly across Central Europe ~ 3000−2500 BCE spelt appears more consistently at multiple Chalcolithic and especially Bell Beaker sites, in quantities which suggest a shift to its use as a deliberate crop. By the full-scale Bronze Age in this region, spelt becomes one of the major crops. This paper discusses this Central European process in greater detail via macro-botanical evidence. It argues that demographic factors during the Neolithic may have inhibited the spread of Asian spelt into central Europe, and that while small amounts of local European spelt were probably present earlier on, it was only at the very end of the Neolithic, in tandem with human population increases and major technological changes such as the introduction of the plough that spelt was taken up as a cultivar. In particular, a shift by some communities in the region ~ 3000−2500 BCE to more extensive (and sometimes plough-enabled) agricultural strategies may have favoured deliberate cultivation of spelt on less productive soils, given this variety's relative robustness to harsher conditions. In other words, a combination of conditions was necessary for this innovation to really take hold.

Keywords Triticum spelta · Innovation process · Neolithic · Demography · Evolutionary archaeology

Introduction

In the following, we make use of innovation theory to conceptualize the significance of spelt within the economic and social realm. The origin of spelt is an evolutionary biological process; its integration into agricultural practices and systems turns genetics into economics.

The emergence of new varieties of plants and animals, under breeding conditions or by chance, can be considered from an economic point of view as an invention in the sense that those varieties are new, and their purpose or usefulness is unknown. The success of such an invention is called innovation, which depends on many factors, societal as well as environmental. In this paper we would like to show which archaeologically comprehensible factors turn such an invention into an innovation; we use the origin, early spreading and final establishment of spelt as an example. Gabriel Tarde (1843–1904) and Joseph Alois Schumpeter (1883–1950) have each put forward the basics of a theory of innovation although neither of them uses the word itself. There is one feature that connects both the social and economic science concepts of innovation and that is the separation of invention from innovation. While the sociologist Tarde (1890) is interested in any novelty or improvement in any kind of social phenomenon, Schumpeter (1952) defines innovation neither psychologically nor sociologically but strictly economic. Schumpeter speaks of "Durchsetzung neuer Kombinationen" (*enforcement of new combinations*) of the means of production.

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According to the widely accepted definition by Everett Rogers (1931–2004), innovation diffusion is "…the process by which (1) an innovation (2) is communicated through certain channels (3) over time (4) among the members of a social system" (Rogers 2003).

Schumpeter (1934) defines innovations in the economic sphere as fresh combinations of new or existing knowledge, resources, equipment or other factors and he makes a distinction between, on the one hand, an invention, which might happen everywhere without any intent and, on the other hand, innovation as a process with an economic purpose. In fact, innovation is the process that carries inventions into society. Though invention and innovation are closely connected, both can stand alone: "Innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation" (Schumpeter 1939). If we see the invention as the origin of something new and the innovation as the disseminating process this concept can be successfully applied in archaeological contexts.

The word "innovation" is often used in archaeological research (e.g. Müller 2013; O'Brien et al. 2014, for innovation theory in archaeology: Kerig 2016) but rarely clearly defined, with archaeologists tending to see it simply as the arrival of something new (e.g. Frieman 2021) and often used in connection with the notion of technological progress. In contrast, Shennan (2001) incorporated demography and cultural innovation where cultural innovations operate similar to genetic mutations, though unlike mutations, cultural traits can be transmitted by non-parents and horizontally by peers. In our understanding of innovation, the mutation would be analogous to the invention in the sense that some inventions might be attractive to imitate, others less so and some would not make any difference at all. The innovation process would then be the passing and spreading of the invention in the transmission process. Shennan's model (2001) shows that larger populations where cultural traits are passed on by a combination of vertical and oblique (horizontal) transmission have a very major advantage to smaller ones. Important for the understanding are the two principal ways of increasing the population for transmission, one is demographic growth and the other the contact with another, formerly equally isolated population. Shennan uses the model to explain the emergence of novel traits in human culture. Though his model is able to show that transmission can only take place in phases of population growth it does not explain the unconnected occurrence of novel traits at certain times and places. The analogue of mutation and invention however is likewise not wholly convincing – that is because in small populations genetic mechanisms often prevent the phenotypic emergence of deleterious mutations (e.g. Robinson et al. 2018). It goes without saying that deleterious inventions have succeeded and continue to do so.

Inventions can come out of thin air or "from god", which means they occur arbitrary and might or might not be of future use. Also, to continue the mutation analogue, they might be "pre-adaptations" and prove to be useful ex post. It seems likely that with the number of people also the number of ideas and the intellectual exchange increase and thus more inventions occur in larger populations.

Population density and cultural transmission are two factors that seem closely connected. "Cultural transmission is the process through which cultural elements, in the form of attitudes, values, beliefs, and behavioural scripts, are passed onto and taught to individuals and groups" (Taylor and Thoth 2011). From an archaeological perspective, one might add that also the knowledge about the sources of raw materials and foreign goods, the mastering of technologies by crafts are passed through cultural transmission - cultural transmission is the inheritance of practices and knowledge. Necessary conditions for cultural transmission are contact and communication: Nothing can be passed on without people actually meeting each other. Population density becomes the crucial factor as innovations are easier passed on under a high encounter rate. Grove (2016) however proposes that individual encounter rates depend not only on population density but on the product of density and mobility: highly mobile but low-density populations might have the same encounter rates as low mobility, high density populations. Walker et al. (2021) carried this assumption to inter-community encounters but found only weak supporting evidence. Both these models are dealing with hunter-gatherers, which are thought to be per se more mobile than Neolithic farmers are. Thus, in farming communities, population density might play a more important role in cultural transmission processes than mobility.

The invention of spelt - where and when

In Central Europe *Triticum spelta* L. (spelt) occurs as a new cultivar rather suddenly in disparate locations at the very end of the Neolithic, in Bell Beaker and contemporary contexts. In Switzerland (Akeret 2005; Jacomet 2008) and South–West Germany (Lechterbeck et al. 2014a), it is found in Bell-Beaker contexts, in Lauda-Königshofen (E. Fischer pers. comm.) in a corded ware context, but contemporary to the sites in South-West Germany and Switzerland and it was also found at Vojens, Brødrene Gram (Robinson 2003) in Denmark in Bell-Beaker contemporary contexts. The origins of *T. spelta* are somewhat mysterious. Two hypotheses as to its origin are discussed: in Southwest Asia, but then it is not known by which route it came to Central Europe, or spontaneously on site from local wheat species, which would explain its sparse occurrence at disparate locations. Newer analyses prove that *T. spelta* is polyphyletic (Dvorak et al. 2012), therefore both hypotheses might be true.

In the beginning perhaps being a crop weed, *T. spelta* becomes later one of the main crops in the Early and Middle Bronze Age (EBA, MBA) in western Central Europe, the Alps and their foreland. From there it apparently spread to Scandinavia, to Southern France, to the Pannonian basin, and Greece (Stika and Heiss 2013). Though, according to Stika and Heiss (2013) it was not introduced to the Iberian Peninsula or to Italy south of the Po valley. But *T. spelta* has been cultivated later at least on the Northern Iberian peninsula in the Iron Age (Tereso et al. 2013; Seabra et al. 2018; Peña-Chocarro et al. 2019).

T. spelta is a hexaploid hulled wheat. It is widely accepted that Asian spelt originated via hybridization of hulled emmer and goat grass (*Aegilops tauschii* Coss.). Newer genetic analyses prove however, that European *T. spelta* originated by hybridisation of a free threshing hexaploid wheat and hulled emmer (Dvorak et al. 2012) thus Asian and European spelt have different origins.

However, it is not possible to prove genetically whether Asian spelt migrated to Europe during the Neolithic or whether European spelt originated on site. Up to now, aDNA analyses on prehistoric *T. spelta* are missing due to the lack of suitable material, therefore it is worthwhile to have a closer look at its early distribution and history.

Triticum turgidum ssp. *dicoccon* (Schrank ex. Schübl) Thell., cultivated emmer, one of the parents of *T. spelta*, is one of the founder crops brought to Northwestern Europe with the first farmers (Bakels 2014). *Triticum turgidum* ssp. *dicoccoides* (Asch. & Graebn.) Thell., wild emmer, is distributed all over the fertile crescent (Fig. 1) but with a focus in the western part and it is thus not surprising that cultivated emmer occurs there very early, already around 10,500 BP (Zohary et al. 2012). *Aegilops tauschii*, the other parental species of Asian spelt, is almost exclusively distributed east of the 40° longitude (Fig. 1) and has its centre of distribution along the southern shores of the Caspian Sea and in Azerbaijan (Kole 2011). The area where both species occur is restricted to north-eastern Syria, South–Eastern Turkey and northern Iraq which is the area where *T. spelta* could have possibly originated. Asian spelt cannot occur spontaneously on location because *A. tauschii* is not present everywhere. It can only arise under cultivation of emmer wheat in the designated area of origin and then spread as a crop weed.

The parent species for European spelt are a free threshing hexaploid wheat and cultivated emmer. Cultivated emmer occurs all over Central Europe since the beginning of the Neolithic. Confirming free threshing, hexaploid wheat in the archaeobotanical record however is problematic: the grains look similar to grains of tetraploid naked wheat; therefore, these are reasonably summarised as *T. aestivum/durum/turgidum* in archaeobotanical reports. A safe differentiation is only possible if chaff is present (Jacomet 2006). Grains of free threshing wheat are reported all over Europe (Colledge 2016) during the Neolithic but sites with chaff from hexaploid free threshing wheat are quite rare (Fig. 2). Colledge's dataset covers only Central- and Northwest-Europe, but evidence from other areas, especially the Near East, is likewise sparse: while tetraploid free threshing wheat derives directly from cultivated emmer, has hexaploid free threshing wheat the same ancestry as Asian spelt. It might have originated in the same area, but all of the classic sites only report tetraploid wheat (Maier 1996) in the Neolithic. More recently, hexaploid wheat, both naked and hulled, could be proven genetically in Çatalhöyük in Turkey

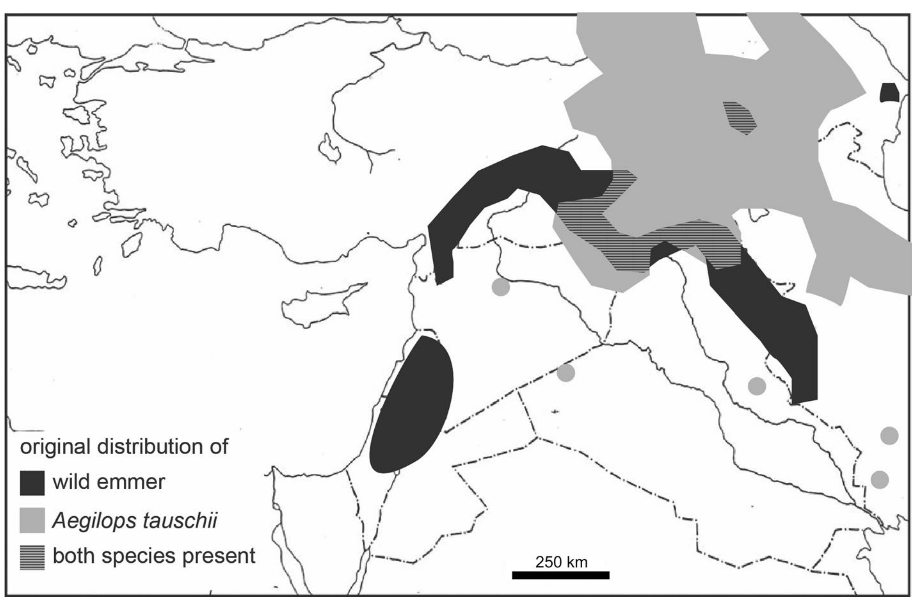

Fig. 1 Distribution areas of *Triticum turgidum* ssp. *diccocoides* (wild emmer) and *Aegilops tauschii* (goat grass) redrawn from Zohary et al. 2012 and Kole 2011. Cultivated emmer occurs first in areas where wild emmer is present and hybridization of goat grass and cultivated emmer can occur in these areas

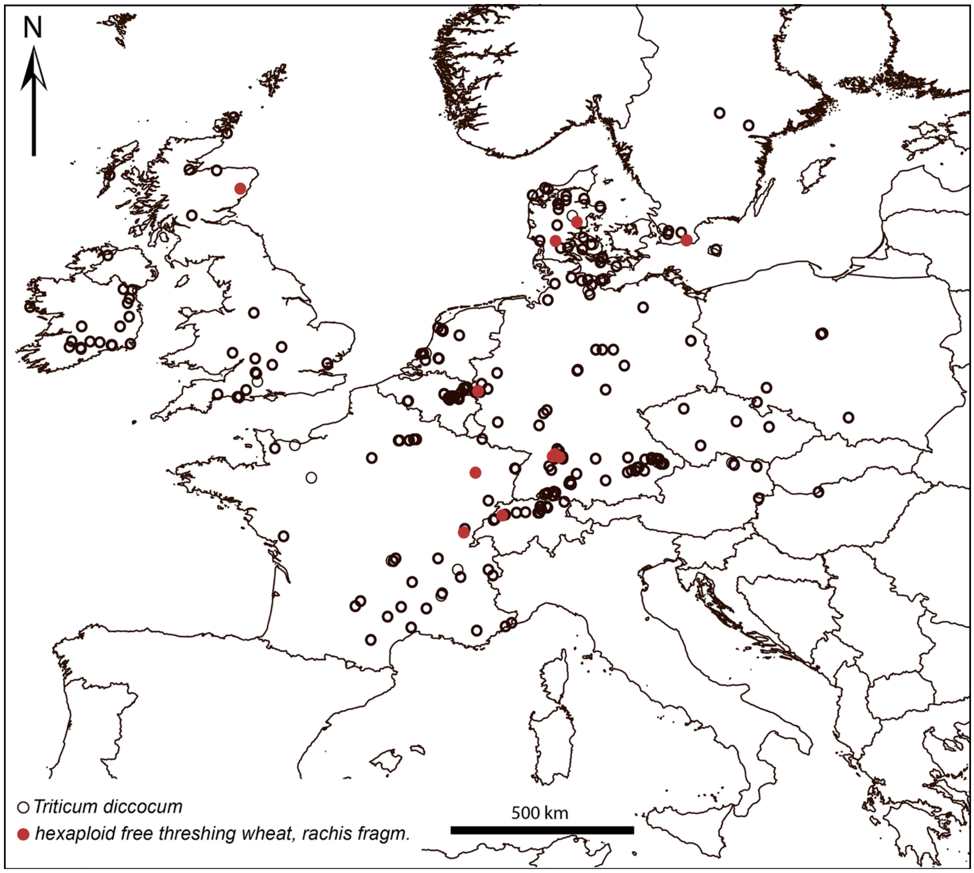

Fig. 2 *Triticum turgidum* ssp. *diccocon* (cultivated emmer, grains and chaff) and finds of free threshing hexaploid wheat rachis fragments (taxon code TRIFTHR) in the Middle and Late Neolithic of Central Europe (data from Colledge 2016; for details of the sites see ESM)

around 8,400 BP (Bilgic et al. 2016). Unlike *T. spelta*, chaff of naked hexaploid wheat is found in Neolithic contexts of different ages in Central Europe. Important in this context is Erkelenz-Kückhoven (Knörzer 1995, 1998), where botanical remains from an linear pottery culture well contained rachis fragments of hexaploid naked wheat (Maier 1996). This find shows that naked hexaploid wheat was present in European cereal spectra from the beginning of the Neolithic if only very sparse. Not morphologically but genetically detected was naked hexaploid wheat at the lake site Zürich/Mozartstrasse for around 3900 BC (Schlumbaum et al. 1998). Both Maier (1996) and Schlumbaum et al. (1998) refer to other sites in Southern Germany and in the Netherlands where Neolithic hexaploid naked wheat was found. It is however not present in Neolithic Eastern European contexts, though both *T. spelta* and *T. aestivum* grains are reported from Poland (Lityńska-Zając 2016) but due to the problem with the identification of grains that might be misidentifications. European spelt, unlike Asian spelt, can occur spontaneously through hybridisation on spot, as both parent species have been present throughout the Neolithic in Central Europe.

T. spelta macroremains are difficult to identify in the archaeological record, the grains look very much like emmer grains, especially when charred in the spikelets (Jacomet 2006) and chaff can be confused with certain barrel-shaped *Aegilops* species esp. *A. cylindrica* Host (Nesbitt and Samuel 1996). Reliable identification of *T. spelta* is only possible when spikelet forks and/or glume bases are present. For this paper, only sites with reliable *T. spelta* finds were taken into consideration. Sites where only grains are reported, are not discussed here.

Early finds of *T. spelta* (Fig. 3), i.e. finds before the Bell Beaker period, are reported from the identified possible area of origin for the 7th-8th millennium BP (Zohary et al. 2012 and references therein). It has been questioned whether *T. spelta* spread from there to Central Europe and if so, by which route. The most obvious route would have been over Turkey and the Balkans, but there are no reliable finds of *T. spelta* from Turkey except from Erbaba (van Zeist and Buitenhuis 1983). Nesbitt (2001) doubts the presence of *T. spelta* in near eastern archaeobotanical assemblages at all and ascribes isolated occurrences to misidentifications. In the light of early *T. spelta* finds from Transcaucasia it was suggested that it originated in Transcaucasia or Iran and then spread to Europe to arrive several millennia after the introduction of agriculture (Andrews 1964; van Zeist 1976). However, *T. spelta* is also sparse, if not absent as Nesbitt (2001) states, in Transcaucasian Neolithic assemblages.

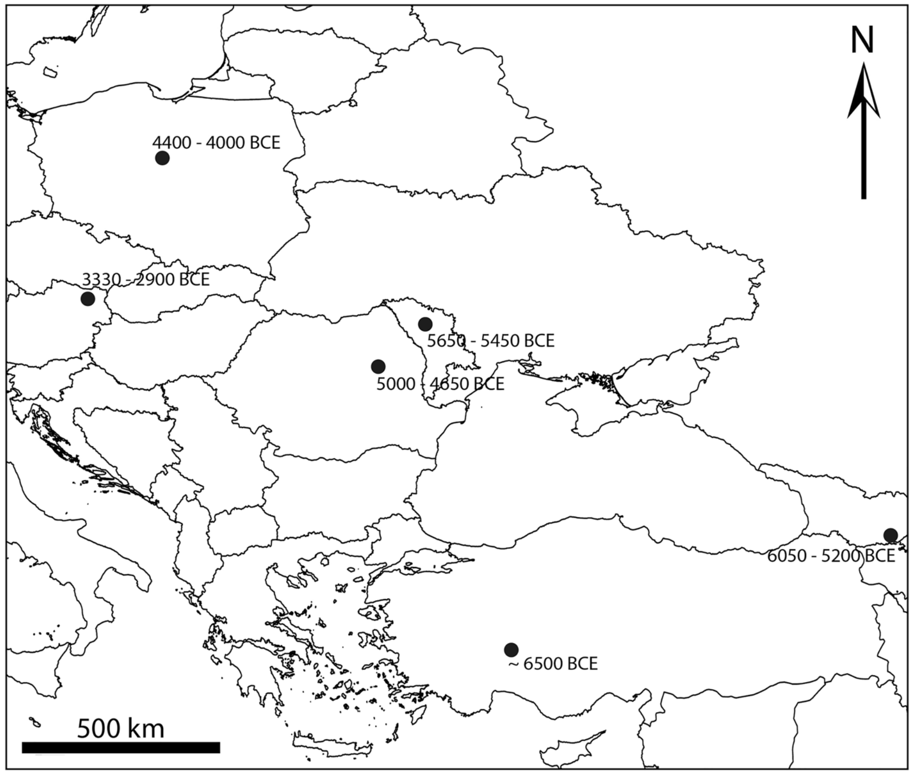

Fig. 3 *Triticum spelta* (spelt) finds before the End Neolithic (data from Zohary et al. 2012 and Kohler-Schneider and Caneppele 2009)

Those occurrences which are reported in Zohary et al. (2012) and in Kohler-Schneider and Caneppele (2009) suggest that *T. spelta* finds before 3000 BCE are recorded no more westerly than eastern Austria (Fig. 3). It is very difficult to draw conclusions as to its origin and spread from sparse and probably doubtful occurrences. The dates do not show a clear tendency for the spreading of *T. spelta* from the area of origin via either the Balkan or the Transcaucasian route. It has apparently never been a crop in the Neolithic therefore its occurrence is purely accidental. Radiocarbon dates for botanical macro remains from Hundsteig, Eastern Austria (Kohler-Schneider and Caneppele 2009) where *T. spelta* occurs in quite high quantities, date approximately between 3330 and 2900 BCE. The wide range of the date is due to a plateau in the calibration curve. The site of Hundsteig (Pieler 2001) belongs to the Jevišovice culture. In contrast to the roughly contemporaneous Baden culture, the Jevišovice culture features strikingly small settlements situated mainly on hilltops and above steep river valleys (Kohler-Schneider and Caneppele 2009). They were possibly part of a copper trading network. More westward finds of *T. spelta* are not known before the End-Neolithic, namely Bell-Beaker and contemporary contexts. In contrast to more easterly finds are those from Hundsteig quite substantial indicating that here *T. spelta* might have been a crop.

The *T. spelta* finds from Bell Beaker and contemporary contexts (Fig. 4) come from disparate locations, though one might define two main regions, (i) lowland Switzerland and southwestern Germany and (ii) Denmark. The Bell Beaker *T. spelta* finds occur in regions where both parent species of European spelt are present in the Late Neolithic (Fig. 2) therefore it is highly probable that *T. spelta* originated onsite. In Eastern Austria however, no secure hexaploid free threshing wheat (i.e. rachis fragments) is recorded for the Neolithic – one of the parent species of European spelt seems to be missing from the area. It is therefore probable that the find from eastern Austria represents the westernmost find of Asian spelt in Europe so far and that the finds from the End-Neolithic are the first records of European spelt.

Innovation processes behind spelt

The appearance of *T. spelta* involves genetic mutation that can be seen as an invention occurring relatively suddenly. In contrast, its spread and establishment within the wider crop mix can be seen as an innovation process. The choice of which plant to cultivate is a cultural one, and the establishment of a crop as widely available, reified as a separate category in people's taxonomies and routinely used depends on many factors, cultural as well as environmental. In non-literate communities only such innovations can survive that are actually in use and/or passed on (Kerig 2016).

In the last couple of decades, demographic reconstruction has returned to being a key agenda in archaeological

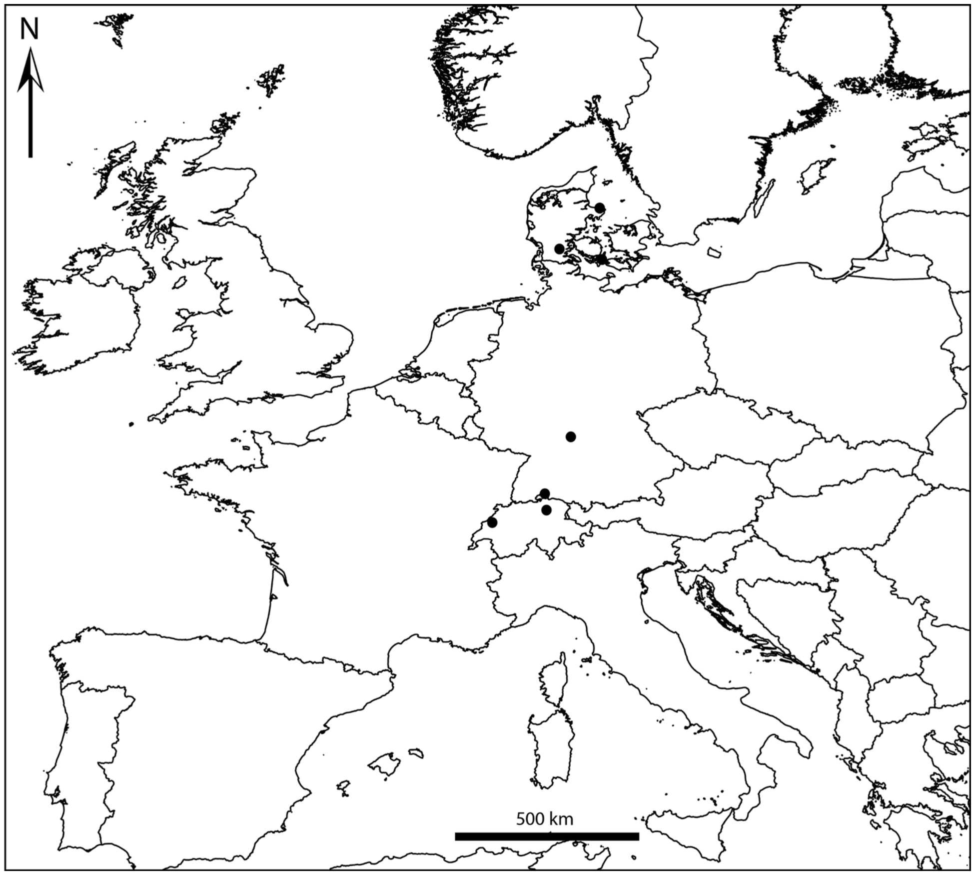

Fig. 4 Secure *T. spelta* finds from Bell Beaker and contemporary contexts (data from Akeret 2005; Lechterbeck et al. 2014a; Colledge 2016)

research (e.g. Hassan 1981; Chamberlain 2006; Renfrew 2009; Zimmermann et al. 2009; Shennan 2013) and major efforts to assess population densities and demographic developments in the European Neolithic have been made.

In the course of the EUROEVOL project, T. Kerig and A. Bevan took digitised versions of the Buchvaldek et al. (2007) culture area atlas as a rough proxy for settlement density (Fig. 5). These reflect which areas in Europe archaeologists assign to cultures. Figure 5a shows the situation for the time window 3400−3200 BCE. For this time window, 54.5% of the area have been assigned to a culture. Central Europe seems to have been quite densely populated, but there is almost a "culture free corridor" which separates Western and Eastern Europe. This might be due to research- or actual settlement gaps. Many of the empty spaces are at least mountainous regions or otherwise unfavourable areas like marshland, which were most probably not settled throughout the whole of the Neolithic (Fig. 6). Eastern Austria, where Neolithic *T. spelta* was found, is well connected to the east but there are unassigned regions to the west and north. That leads to the assumption that cultural contacts would have been preferably to the east. It does not mean, however, that there has not been any cultural exchange whatsoever to the west. Elements of the Baden culture for example are found in Horgen contexts at Lake Constance (Köninger et al. 2001; de Capitani 2002) thus evidencing cultural contact but they remain exceptions. *T. spelta* however was not one of those elements. There are several well-analysed Horgen pile dwelling sites with excellent preservation conditions for botanical macro remains but *T. spelta* was never found in them.

Figure 5b shows the situation in the time window 2700 −2450 BCE. Even fewer areas are attributed to archaeological cultures and many of them are isolated, indicating fewer cultural contacts between settled areas. Shortly after that period, *T. spelta* finds occur in disparate locations, and we would argue that the "invention" part of the *T. spelta* story took place at this time of assumed low population density.

Two regional studies comparing the vegetational record of pollen analysis and demographic data derived from radiocarbon dates from the Neolithic to the BA were carried out in the areas where *T. spelta* occurs first in Bell Beaker and contemporary contexts (Lechterbeck et al. 2014b; Feeser et al. 2019). Lechterbeck et al. 2014b investigated the correlation of land use and demographic development in the Western Lake Constance area. Since 2014, the methodology for the reconstruction of population fluctuations was improved (Timpson et al. 2014; Crema 2022), therefore, the analysis was updated for the current paper. No additional radiocarbon dates were added. The radiocarbon density

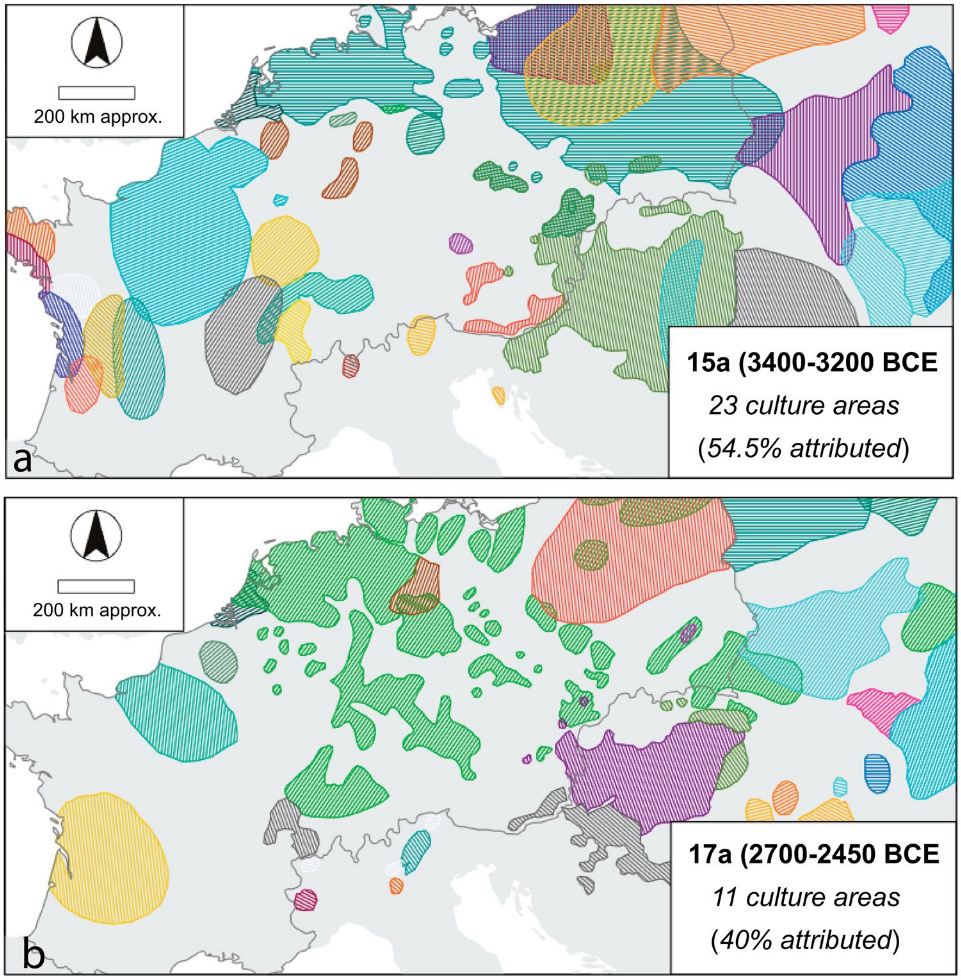

Fig. 5 Maps of Central Europe, digitized from Buchvaldek et al. 2007. They depict the areas assigned to a culture in two different Neolithic time windows. The colours correspond to different Neolithic cultures in the area. Here only the assignment of a culture to a region is of interest not the culture as such

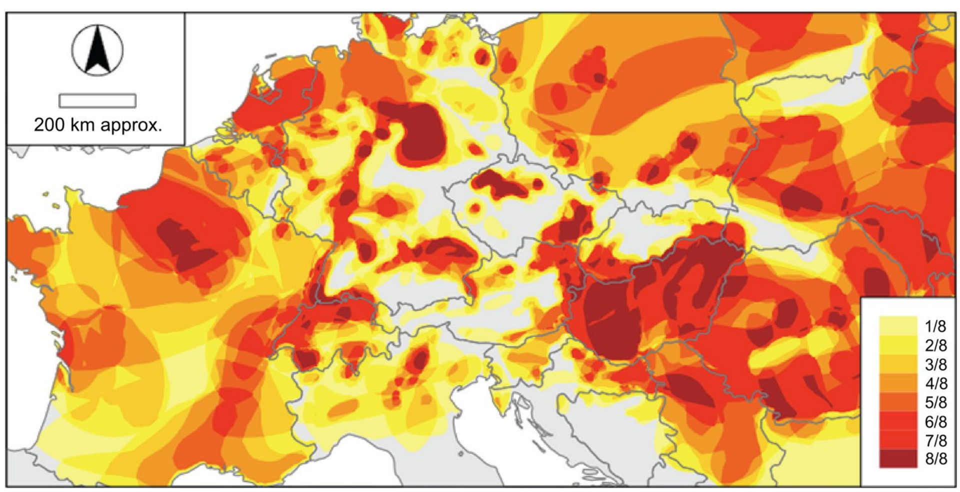

Fig. 6 Overlay of all areas persistently attributed to Neolithic cultures. The colours display the number of times a region falls within a culture area, out of eight Neolithic phases

curve (SPD: sum probability distribution of ^{14}C dates) for the region (Fig. 7) shows a rapid decline from the late Neolithic towards a minimum in the first part of the EBA and then a steep rise in the second part. This correlates with phases of abandonment and increased land use, respectively. Here indeed the "invention" of *T. spelta* happened in a phase of major demographic decline whereas its "innovation", i.e. the spreading and establishment happened in a phase of demographic growth.

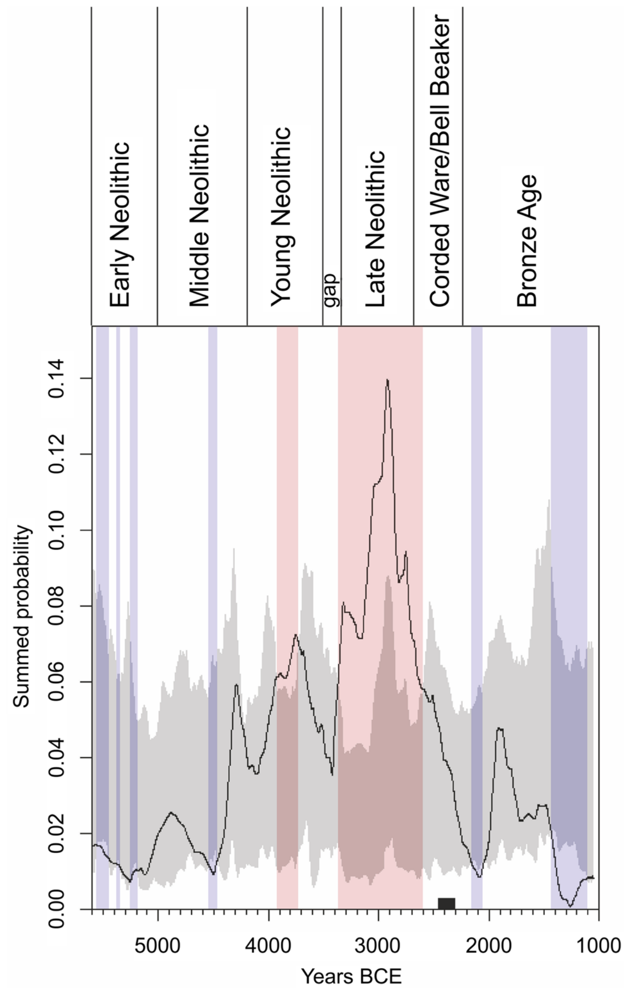

Fig. 7 Radiocarbon density curves from the Western Lake Constance area. The black bar represents the radiocarbon dates for the Bell Beaker site Welschingen-Guuhaslen where *T. spelta* was found

Feeser et al. 2019 made a comparison of pollen data and radiocarbon derived demographic data for Northern Germany and Southern Jutland. Though the picture is not as clear as in the Lake Constance area, also they record a demographic decline between 2400 and 2300 BCE. This coincides with the dating of house V on the site of Brødrene Gram, Vojens, Danmark to 2460 – 2200 BCE where secure finds of *T. spelta* where made (Robinson 2003). Apparently, also in this area the first occurrence of *T. spelta* coincides with a demographic bust. The EBA is connected to a demographic boom in both regions. So far, the establishment of *T. spelta* fits Shennan's model of transmission. Whether the "invention" of *T. spelta* also took place in a period of demographic bust in Cortaillod sur Les Rochettes cannot be decided as no analyses of SPD and pollen data for the region exist, but it is definitely an isolated occurrence.

We cannot answer the question why *T. spelta* did not succeed earlier in the Neolithic, but some assumptions can be made. In a case study, Lechterbeck et al. (2014a) stated a discontinuity between corded ware and Bell Beaker lifestyles – in the Western Lake Constance area corded ware and bell beaker do not occur in the same regions nor at the same time. Here, corded ware land use is forest based with a higher amount of wild food resources, evidence for open land is missing, it resembles the farming technique of the younger Neolithic. But there is a continuity between Bell Beaker and EBA lifestyles: the Bell Beaker phase resembles BA land use with indicators for open fields, grasslands and the cultivation of *T. spelta*. Lechterbeck et al. 2014a concluded that the Bell Beaker economy is the first stage of production typical for the EBA in the regions north of the Alps. It seems that *T. spelta* is only part of a whole package of inventions that became intrinsic in the BA.

Conclusions

The evidence so far allows to assume that *T. spelta* originated in the Near-East sometime in the early Neolithic but did not migrate further west into Central Europe than Eastern Austria in the course of the Neolithic and it had never been a main crop. Only at the very end of the Neolithic at the transition to the BA it becomes a major crop in some disparate locations. In the EBA, secure *T. spelta* finds occur in sites close to those sites where it was first cultivated in the Neolithic (Fig. 8).

T. spelta is a polyphyletic cereal and genetic analyses revealed that it originated twice in the course of prehistory, once in the Middle East as Asian spelt from cultivated emmer and *Aegilops tauschii* and a second time as European spelt from hexaploid free threshing wheat and emmer. Asian spelt cannot occur spontaneously, as one of the parent species is not present in European Neolithic contexts. Its sparse occurrence in Transcaucasia and the Balkan seems to indicate that it was a crop weed under emmer wheat cultivation and was not recognised as a cultivar. Early finds of *T. spelta* remain doubtful but it could be made probable that Asian spelt reached eastern Austria by the young Neolithic. The exceptional Jevišovice site of Hundsteig has substantial amounts of *T. spelta* finds, so here it might already have been recognised as a crop. The pattern of settled areas at that time suggests cultural contacts and exchange rather to the east. Between the early finds and the occurrences of *T. spelta* in Central Europe there is a time lag and, probably even more important, a large geographical distance. Also, the occurrences in Central Europe are substantial and suggest that *T. spelta* has been a crop rather than a weed. European spelt can occur spontaneously by hybridisation and it could be shown that both parent species were present in the Late Neolithic in the areas where it is later found in the Bell Beaker period.

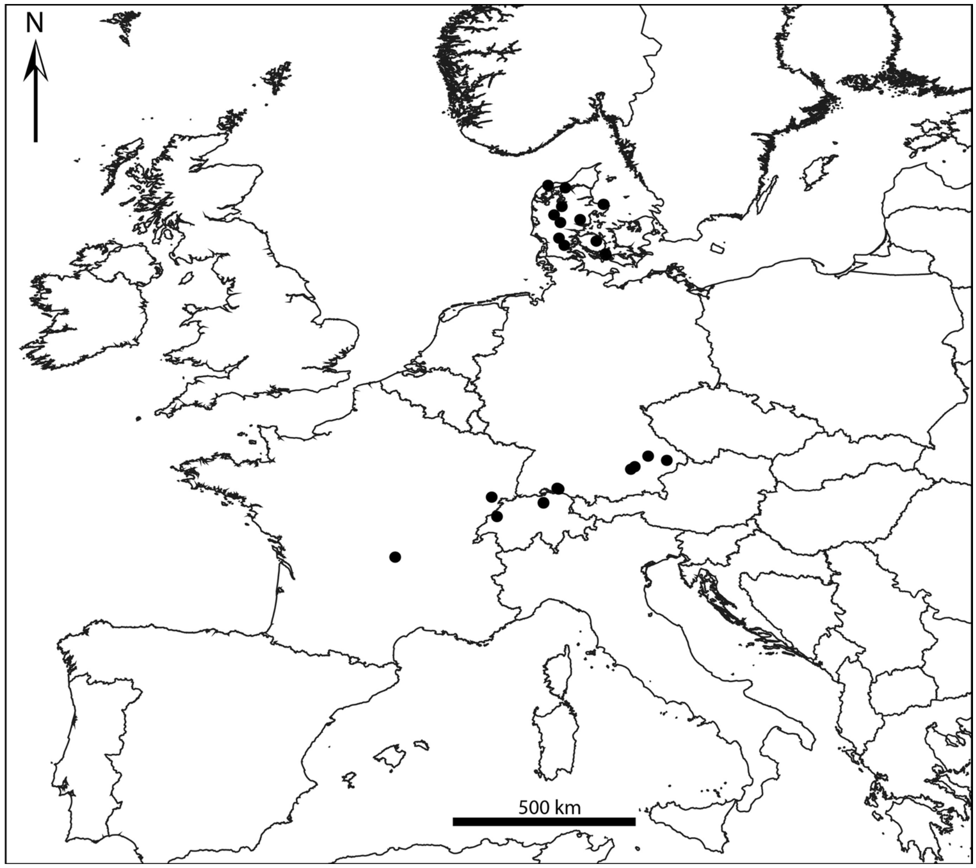

Fig. 8 Secure *T. spelta* occurrences in the Early Bronze Age (data from Colledge 2016; for details of the sites see ESM)

It is highly probable that *T. spelta* occurred during the whole of the Neolithic as a crop weed in Western and Central Europe but was not favoured as a cultivar. Under the small scaled, intensive agricultural practices of the Neolithic *T. spelta* was not attractive. Only the agricultural changes at the end of the Neolithic and the beginning of the BA leading to more extensive arable farming made *T. spelta* an attractive cultivar as it gives good yields on less fertile soils and under a broad range of climatic conditions. This might also have levelled out the disadvantages of dehusking.

It could be shown that the first cultivation of *T. spelta* in Central Europe occurred in a period of demographic bust. The occurrence of *T. spelta* can be seen as an "invention" (sensu Schumpeter) and the demographic boom at the beginning of the BA launched an innovation process that in the end established *T. spelta* as a crop.

The establishment of *T. spelta* in Central Europe during the course of the BA coincides with a change in subsistence strategies: for the first time, large fields were worked with ploughs, the first meadows occur, the shift from two aisled to three aisled houses in the North European plain and parts of Scandinavia (Harding 2000; Armstrong Oma 2016) hints to the stabling of animals which made dung for manuring available, to name only a few examples. *T. spelta* is a relatively undemanding plant with respect to soil quality and gives good yields even under harsher conditions. This might have been an advantage under a more extensive land use strategy on less productive soils.

Finally, it is worth briefly mentioning the later history of *T. spelta*, which continues to be innovative and impactful. A range of important changes occur to dominant mixes of cereal species present in Europe and the Mediterranean during the 1st millennium BCE which was at least in part due to the increasing scale of market economies, bulk grain shipment and growing taste in certain regions for breads over porridges (for a summary see Bevan 2019, pp 130–134). Amongst these changes, that occur several millennia after our period focus here, there is shift towards further increased use of *T. spelta* wheat in temperate Europe (from the Alps northwards and also the Atlantic fringe, but not further south, potentially linked to specific above-ground storage practices such as small poster granaries, see Sigaut 1989; Mills 2006). The twin attraction of *T. spelta* in this later phase is that its substantial glumes provide a certain hardiness in colder and wetter parts of Europe's mid-latitudes, but also that its grain is glutinous enough to produce a bread, whilst also being good for other traditional foods. *T. spelta* continued to be a very important component in diets after the end of the Roman Empire and into the Early Medieval period (Devroey and van Mol 1989).

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