RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Changes in spectra of cultivated and gathered plants in the Bronze Age: A study based on archaeobotanical data from the Czech Republic

Změny v sortimentu pěstovaných a sbíraných rostlin v době bronzové: Studie na základě archeobotanických dat z České republiky

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The Bronze Age (BA) in Central Europe witnessed significant transformations in various aspects of human activities. This study focuses on changes in subsistence strategies during the BA, represented by the assortment of edible plants. We examined charred macroremains from 39 archaeological sites in the Czech Republic. Our aims include providing an overview of crop records, determining the dating of new crop introductions, and identifying spatial patterns of the assortment changes. The results indicate a complex agricultural transformation. Emmer and einkorn dominated in the Early Bronze Age (EBA), while the broomcorn millet was widespread in the Middle Bronze Age (MBA). The Late Bronze Age (LBA) saw increased cereal and pulse diversity, whereas the Final Bronze Age (FBA), characterised by coexisting cereals, represented a terminal stage of the process of gradually evolving subsistence strategies. The study highlights the sudden introduction of broomcorn millet in the MBA and expanding the range of crops, which allowed more flexible responses to local conditions and a better distribution of field work throughout the year.

archaeobotany – Bronze Age – millet – Central Europe – agriculture

Doba bronzová byla obdobím velkých změn, které se projevily v různých aspektech lidské činnosti. Tato studie se zaměřuje na změny sortimentu jedlých rostlin v době bronzové. Zjištěné poznatky jsou postavené na analýzách zuhelnatělých rostlinných makrozbytků z 39 archeologických lokalit v České republice. Cílem bylo vytvořit přehled nálezů pěstovaných a sbíraných rostlin a určit, od kdy se na zkoumaném území objevují. Neméně důležité bylo rozpoznat případné prostorové rozdíly v nalezeném sortimentu. Výsledky naznačují, že v průběhu doby bronzové prošlo studované území složitou zemědělskou transformací. Zatímco ve starší době bronzové dominovaly pluchaté pšenice (dvouzrnka a jednozrnka), od střední doby bronzové se po celém území rozšířilo proso. Od mladší doby bronzové zaznamenáváme zvýšenou diverzitu obilovin a luštěnin. Terminální fázi zkoumaného procesu představuje pozdní doba bronzová, charakteristická vzájemně koexistujícími obilninami. Studie vyzdvihuje význam náhlého rozšíření prosa ve střední době bronzové, a také poukazuje na postupné obohacování sortimentu pěstovaných plodin, které umožnilo pružněji reagovat na místní podmínky a pravděpodobně také lépe rozložit polní práce v průběhu roku.

archeobotanika – doba bronzová – proso – střední Evropa – zemědělství

Introduction

In Central Europe, the Bronze Age was a dynamic period associated with the rise of European civilization, the development of crafts and agriculture, as well as intensive contacts among human communities. The communities across Eurasia were connected via long-distance trade and migration routes (see e.g., *Anthony 2010*; *Harvig et al. 2014*; *Allentoft*

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et al. 2015; *Frei et al. 2015*; *Haak et al. 2015*; *Long et al. 2017*; *Wang et al. 2019*). Raw materials (e.g. copper, tin, silex, amber, salt) and products were the objects of trade (*Goldenberg 2004*; *Grabner et al. 2007*; *Ernée 2012*; *Tisucká – Ohlídalová 2013*; *Zápotocký 2013*; *Přichystal – Šebela 2015*; *Chvojka et al. 2017*; *Powel et al. 2018*), and all sorts of innovations (especially bronze technology), ideas, cult and religion also spread along the trade routes (*Jockenhövel 2012*). From the economic point of view, the period can be divided into two phases (*Primas 1997*): 1) the phase when raw materials, i.e., copper and bronze were used as a medium of exchange (the Early and the Middle Bronze Ages); and 2) the phase when the cultural networks have changed and the circulation of bronze ingots and scrap metal was typical (the Late and the Final Bronze Ages; *Primas 1997*).

It has been hypothesized that innovations in agricultural practices may also have been stimulated by using bronze tools (*Jiráň et al. 2013*). However, among the most striking changes taking place in the Bronze Age was increasing the number of cultivated crops. This trend has been documented in plant macroremains in different regions of Central Europe (*Gyulai 1993*; *Rösch 1998*; *2013*; *Jones et al. 2011*; *2016*; *Hajnalová 2012*; *Dreslerová – Kočár 2013*; *Stika – Heiss 2013*; *Šálková et al. 2019*). The reasons that led to the diversification of the crop assortment have not yet been fully understood. An increase in extensive landscape exploitation (*Tserendorj et al. 2021*; *Šálková et al. 2022*) and colonisation of higher altitudes and less fertile soils (*Šálková et al. 2019*; *Kolář et al. 2022*) was observed during the Bronze Age. In addition to environmental factors, it has recently been shown that cultural factors, specifically socio-economic contacts with neighbouring regions, have also influenced decisions on which crops to grow (*Šálková et al. 2019*). A study focusing on the southern part of the Czech Republic (South Bohemia) has shown that the cultural relationship between South Bohemia and the Danube region was reflected in the selection of crops especially in the Early Bronze Age (EBA) and to a lesser extent also in the Middle Bronze Age (MBA). Later, during the Late Bronze Age (LBA) and the Final Bronze Age (FBA), an autonomous agricultural area developed in the South Bohemian region, with a crop composition more related to the central part of the Czech Republic (i.e., Central Bohemia; *Šálková et al. 2019*).

We selected the Czech Republic area as a good model territory to study in detail the assortment changes during the Bronze Age. The transformation of agriculture in the Bronze Age in this area was quite complex (*Dreslerová – Kočár 2013*; *Dreslerová et al. 2013*; *Šálková et al. 2019*; *2022*). Emmer (*Triticum dicoccon*) and einkorn (*T. monococcum*) with pea (*Pisum sativum*), lentil (*Lens culinaris*), flax (*Linum usitatissimum*) and poppy (*Papaver somniferum*) were grown there since the Neolithic (5600–4200 BC), whereas barley (*Hordeum vulgare*), mainly the hulled variety, became widespread in the Eneolithic (4500/4400–2300 BC). Glume wheats (*Triticum dicoccon* and *T. monococcum*) with an admixture of barley remained the staples in the EBA. Then, from the MBA onwards, the range of cereals increased to include broomcorn millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), spelt (*T. spelta*) and free-threshing wheats (*T. aestivum/turgidum*). Besides, enrichment of the range of legumes with faba bean, common vetch, bitter vetch and grass pea (*Vicia faba*, *V. sativa*, *V. ervilia* and *Lathyrus sativus*, respectively) was observed in this period. Also, the diversity of wild-growing plants (e.g. weeds, ruderal plants and grassland species) increased markedly during the Bronze Age (*Pokorná et al. 2018*; *Pyšek et al. 2022*).

The arrival of the C4 cereals, i.e., the broomcorn and foxtail millets were among the most prominent assortment changes in the Bronze Age. Multiple studies confirmed that broomcorn millet started to spread in the Czech Republic since the MBA (*Kočár – Dreslerová 2010*; *Dreslerová – Kočár 2013*; *Dreslerová et al. 2017*; *Pokorná et al. 2018*; *Šálková et al. 2019*). The oldest evidence of broomcorn millet in the country comes from a bog core in Zahájí in northwest Bohemia (*Bernardová 2009*; *Pokorný et al. 2015*). The waterlogged spikelets of *P. miliaceum* were ^{14}C dated to the Tumulus culture (1461–1383 BC) of the MBA. This date is in accordance with other ^{14}C dates based on charred millet grains from various sites of this country (*Filipović et al. 2020*). The pattern described above, evidenced by the analysis of plant macroremains, is consistent with the results of stable isotope analyses of animal and human bones (*Kaupová et al. 2018*), suggesting a striking change in diet between the early and late 2nd millennium BC, with C4 cereals contributing significantly to the LBA diet.

Our aims were to:
(i) bring an overview of macroremain records of cereals, pulses, oil plants and gathered fruits and nuts from various sites in the Czech Republic area dated to the Bronze Age;
(ii) determine the exact timing of the beginning of broomcorn millet and other new crops cultivation in the area;
(iii) identify changes of the spatial patterns of the assortment of crops over time;
(iv) examine relationships of the assortment changes with sites' locations, altitudes, and archaeological cultures.

Materials and methods

The original intention was to include in the study all available Bronze Age data that are included in the Archaeobotanical Database of the Czech Republic (Institute of Archaeology CAS 2017, referred to as CZAD; *Dreslerová – Pokorná 2015*). Instead, we decided to work exclusively with the data analysed by the authors of this study. In this way we wanted to overcome the problems associated with the unbalanced quality of data analysed by different authors over a longer period, especially before vs. after the 1990s. Until the mid-1990s, the samples for macroremain analyses were mostly taken non-systematically and processed without flotation (*Dreslerová – Kočár 2013*; *Beneš et al. 2022*). Consequently, the broomcorn millet grains were often absent in data being analysed before 1990. In addition, there are also finds of broomcorn millet grains older than the Tumulus culture, which were mostly negligible numbers of grains, now considered as contamination. Radiocarbon dating of individual grains is necessary in these controversial cases, especially if we want to draw conclusions from these findings. Unfortunately, the material from older analyses is often no longer available, so it is not possible to verify the findings.

Only precisely dated samples were included, which means that a reliable classification of archaeological cultures or at least main phases of the Bronze Age was available (for absolute dating of phases and cultures of the Bronze Age in the Czech Republic, see *Tab. 1*). The classification of the Věteřov culture was somewhat problematic, because there is no clear consensus among Czech archaeologists as to which phase of the Bronze Age it should belong. Some authors consider the Věteřov culture to be part of the EBA, while

Abbr.	Period	Dating
EBA	**Early Bronze Age**	**2300/2200–1600/1550 BC**
br.une	Únětice culture	2300/2200–1600 BC
br.vet	Věteřov culture	1700–1500 BC
MBA	**Middle Bronze Age**	**1700/1600–1250 BC**
br.tum	Tumulus culture	1700/1600–1300/1250 BC
br.mdt	Middle Danube Tumulus culture	1650/1600–1250 BC
br.c	Bronze Age C	1500–1250 BC
LBA	**Late Bronze Age**	**1300–1000/950 BC**
br.lus	Lusatian culture	1300–1025 BC
br.vel	Velatice culture	1300/1250–1000 BC
br.kno	Knovíz culture	1250–1025/950 BC
br.mil	Milaveč culture	1250–1025/975 BC
FBA	**Final Bronze Age**	**1025/950–800/750 BC**
br.l-f	Late to Final Bronze Age	1300–800/750 BC
br.slp	Silesian-Platěnice culture HaB	1100–800/750 BC
br.sti	Štítary culture	1025/950–800/750 BC

Tab. 1. List of Bronze Age archaeological cultures mentioned in the text. Abbr. – abbreviations of archaeological periods; Dating – absolute dating of the archaeological periods in the Czech Republic (based on *Jiráň et al. 2013*).

others place it in the MBA (for archaeobotanical context see *Hlásek et al. 2023*). We do not intend to solve this dilemma, however, we decided to include, in our study, the Věteřov culture into the EBA. We mainly followed the consistency of macroremain data, especially absence of broomcorn millet from most assemblages in our dataset dated to the Věteřov culture.

Data for our study were collected from 39 Bronze Age archaeological sites analysed by the authors of this study (PK and TS) between 2000 and 2021. Because several of the selected sites were multicultural, we obtained 51 assemblages (if a site contained data from multiple cultural phases, each phase was counted separately), which were later reduced to 46 to meet our criteria of each assemblage containing at least 15 cereal caryopses. The numbers of assemblages for individual phases of the Bronze Age were as follows: 12 phases (from 7 sites) for EBA, 7 sites for MBA, 19 sites for LBA, and 13 sites for FBA (list of all sites and phases used in our study is given in *Tab. 2*). In all sites, the macroremains were extracted from deposits using tank flotation and sieves with the minimum mesh size of 0.25 mm or smaller. All data were inserted into CZAD.

The spectrum of plants considered in the study includes cultivated crops (cereals, legumes/pulses, and oilseeds) and gathered (wild growing) fruits and nuts. All plant material was carbonized. To ensure homogeneity and comparability of the data between sites, we included only the findings of cereal caryopses, but not the findings of chaff and other threshing remains. The ‘storage’ finds i.e. higher concentrations of given crops were not excluded from the calculations. The data were expressed as absolute values of NISP (number of individual specimens) by site and phase (*Tab. 2*). The grain numbers of the indeterminate cereals (*Cerealia* and *Triticum* sp. in the original dataset) were not included in the calculations but were recorded (see *Tab. 2*). In some cases, the taxa were merged into clearly defined broader categories. For example, all records of cultivated barley were attributed as *Hordeum vulgare*. Most of the barley caryopses were hulled barley, while naked barley was represented only in a small admixture. Free threshing wheat (tetraploid and hexaploid varieties) was also merged into one category: *Triticum aestivum/compactum/durum/turgidum*. The combined taxon emmer/spelt was maintained separately because these records were relatively common in our data. For pulses, the category *Lens/Pisum/Vicia* includes all finds of cultivated legumes with uncertain identification. For gathered plants, we considered only taxa with edible fruits and nuts that can be interpreted with certainty as gathered plants. However, we did not consider taxa that are only suspected to have possibly been gathered for edible seeds, such as *Fallopia* and *Chenopodium*, which are also field weeds and their deliberate collection for food is a matter of debate (*Behre 2008*).

The ubiquity of individual taxa was calculated as percentage of sites/phases with the occurrence of the taxon in each Bronze Age phase. The Representativeness Index (RI) was calculated using the approach of *Stika – Heiss* (*2013*). The pie charts on the map (*Fig. 1*: a–d) show the representation of cereals in each Bronze Age phase at the spatial scale (the numbering of sites in *Fig. 1* corresponds to the numbers in *Tab. 2*). For sites with multiple phases, the data were summed for the pie chart within a single Bronze Age period. However, in some cases, when sites were too close to each other, we have not shown all sites on the maps for clarity (the sites with missing numbers in *Tab. 2*).

Results

The Early Bronze Age

Emmer was the most important cereal in the EBA, with quantitative dominance in all studied sites (*Fig. 1*: a; *Tab. 2*). Einkorn and hulled barley were also important. The difference in barley abundance between the western and eastern parts of the studied area is striking, with barley being more common in the west part of the area (see *Fig. 1*: a). Spelt and free threshing wheats (*T. aestivum/compactum/durum/turgidum*) were also documented but only in a low extent. Legumes were present only in a form of individual fragments which were not possible to identify precisely (*Lens/Pisum/Vicia*), with the exception of one bulk find of faba bean (*Vicia faba*) in Vrchoslavice – Na dílech site. No oilseeds were encountered in the dataset from this period. Gathered plants were documented at most sites, particularly hazelnut (*Corylus avellana*). Cornelian cherry (*Cornus mas*), blackthorn (*Prunus spinosa*) and elderberry (*Sambucus nigra*) were also present in several sites. The Vrcovice site (Věteřov culture) contained an exceptionally wide range of gathered fruits and nuts, in addition to the above-mentioned also wild strawberry (*Fragaria vesca/viridis*) and blackberry (*Rubus* sp.) (see *Tab. 2*).

The Middle Bronze Age

A significant change in the composition of cereals was observed in the MBA (*Fig. 1*: b; *Tab. 2*). It was identified as the first period with widespread cultivation of broomcorn millet. While the proportion of emmer decreased, broomcorn millet became dominant, or at least subdominant in many sites. Frequency and concentration of barley remained similar as in the EBA, whereas individual sites, mainly those in the southern part of the country, contained a high proportion of spelt. Finds of free threshing wheats were still only rare in this period, documented only from one site (Řepčín – Horní nivy). Rare finds of lentil (*Lens culinaris*), faba bean and unidentified legumes were also documented. Gathered plants were represented by several finds of elderberry and a single find of hazelnut.

Num	Site Name	Period	Alt.	Samp.	Cereals								Non-cereals						Gathered						
					Hor_vul	Pan_mil	Tri_dic	Tri_mon	Tri_spe	Tri_free	Tri_di/sp	Indet	Len_cul	Pis_sat	Vic_fab	Le/Pi/Vi	Lin_usi	Pap_som	Cor_mas	Cor_ave	Fra_ve/vi	Pru_spi	Rosa	Rubus	Sam_nig
EBA																									
1	Praha-Miškovice	EBA	240	7	2		7					95								1					
2	Vrchoslavice – Na dílech	EBA	210	2								3			261										
2	Vrchoslavice – Na dílech	br.une	210	2			129	27		2		153								1					
2	Vrchoslavice – Na dílech	br.vet	210	41	4		14	3	3	4		158				1			1						
3	Vrchoslavice-Vitčice	EBA	215	17	1		353	5			1	221													
3	Vrchoslavice-Vitčice	br.vet	215	92	27		422	4			3	297				1									
4	Hulín	EBA	195	168	68	2	1298	30		10	59	904				2				6					
4	Hulín	br.une	195	61	230		147	9	2	1	14	210								1					7
4	Hulín	br.vet	195	147	25	5	6756	107	5	4	25	840				3						1			
5	Pravčice	br.vet	196	14	1	1	251	10	5	9	1	117							9			7			1
6	Vrcovice	br.vet	420	36	11		6					228				4				20	13	5		82	15
7	Kučeř	EBA	458	15	3	1	5	5				5													1
MBA																									
8	Horní Počaply	MBA	150	4		22	1	1			3	28													
9	Brandýs	br.tum	230	2	16	5	16	1	1			38													
10	Medlov – Za školou	br.mdt	264	1		26	3					2													1
11	Slavonín – Horní lán	MBA	240	12	1	16	3				2	22	1			1				1					111
12	Řepčín – Horní nivy	MBA	230	39	1660	9	611	23	356	6		45													
13	Planá	MBA	400	16	1660	99	5		4381			3758	3		3	9									1
14	Dobřany	br.c	340	1	377	468		1	37			0				1									
LBA																									
	Brandýs	br.kno	230	49	589	649	120	18	155	4		720	41	20		8									
15	Drahelčice	br.kno	370	73	327	432	124	15	97	9		550	14			8					13	1	1	1	
16	Kněževes	br.kno	344	6	53	159	1746	55				440			1										
17	Tuchoměřice	br.kno	325	23	49	32	144	2	7	5		268	25	1	1	1				5					
18	Tuchoměřice-Kněžívka	br.kno	302	80	37	1029	85	4	19	4		201	22	4		13									2
19	Praha-Smíchov	br.kno	197	12	12	105	9	2	3			176	8			3									
	Praha-Bubeneč	br.kno	215	32	8	83	25	3	7			152	1	7		1									

Num	Site Name	Period	Alt.	Samp.	Cereals								Non-cereals						Gathered						
					Hor_vul	Pan_mil	Tri_dic	Tri_mon	Tri_spe	Tri_free	Tri_di/sp	Indet	Len_cul	Pis_sat	Vic_fab	Le/Pi/Vi	Lin_usi	Pap_som	Cor_mas	Cor_ave	Fra_ve/vi	Pru_spi	Rosa	Rubus	Sam_nig
21	Nebovidy	LBA	220	2	1	2	1		3			10				2									
22	Medlov – Za školou	br.luz	264	10	8	231	8		14			30	2			1									
	Vrchoslavice – Na dílech	LBA	210	2			1		1			35													
23	Vrchoslavice – Za Hróbňó	LBA	210	6	3	3	4		2	1		14													
24	Blučina-Cezavy	br.vel	236	39	1823	4118	2785	580	1073			1130	1	2		1									
25	Obory	LBA	370	3	11	341	2					72	1	1		5								1	
26	Zhoř	LBA	428	5		1	2					25	420	1		12				2					
27	Černýšovice	LBA	420	4	2	23	2	1	2		1	32	7	1		18									
28	Hvožďany	LBA	451	103	50	277	11	1	3	3	2	98	26	2		6		1		1				2	
29	Přeštice	br.mil	349	21	5	7	1					3													2
30	Zdice	br.kno	270	39	42	353	109	2		3	42	405	24	1	2	6				1					
FBA																									
31	Brandýs	br.sti	230	55	137	334	43	10	65	3		534	10			16									
32	Dřevčice – Na výsluní	br.l-f	229	9	1	2	18	2				24													
33	Praha – Dolní Chabry	br.sti	295	25	438	323	1433	404	168	5		1171	34	2		4									
34	Nebovidy	br.sti	220	5	4	241	292	4	7			276	21												
35	Medlov – Za školou	br.slp	264	4	15	11	18		7			30	1	2		1							1		
36	Hulín	FBA	195	94	514	529	1219	34	14	1	152	1163	35	4		26		57		1			1		2
37	Březnice – U Františka	FBA	445	6	41	7	4		1		12	52	18	1	2	7									
38	Bošovice u Čížové	FBA	440	20	16	11						56	5	1	1	6		1						12	
39	Písek-nemocnice	FBA	399	7	13	2	3		4	7	5	73	2	1											4
40	Rataje	FBA	400	14	47	13	5			2		38	3					2							
41	Klatovy – Pod borem	br.l-f	420	5	1	1	3					12												1	1
42	Ostrov u Stříbra	FBA	482	1	51	6						44	10												2
43	Bavoryně	br.l-f	300	183	2965	3846	1048	63	1048	90		1871	478	24		92	1						6		1

Tab. 2. List of sites and macroremains of edible plants. Num – numbering of the sites in maps shown in *Fig. 1*; Site Name – usually cadastre; Period – for abbreviations of archaeological periods and cultural phases, see *Tab. 1*; Alt. – altitude (metres above the sea level); Samp. – number of samples analysed and included in the study; Cereals – sums of charred caryopses of cereals; Non-cereals – sums of charred seeds of pulses and oilseeds; Gathered – sums of charred macroremains of gathered fruits/nuts (NISP in all cases; abbreviations of the plant names in *Tab. 3*). Indet – sums of charred caryopses which were not possible to identify (not included in the study).

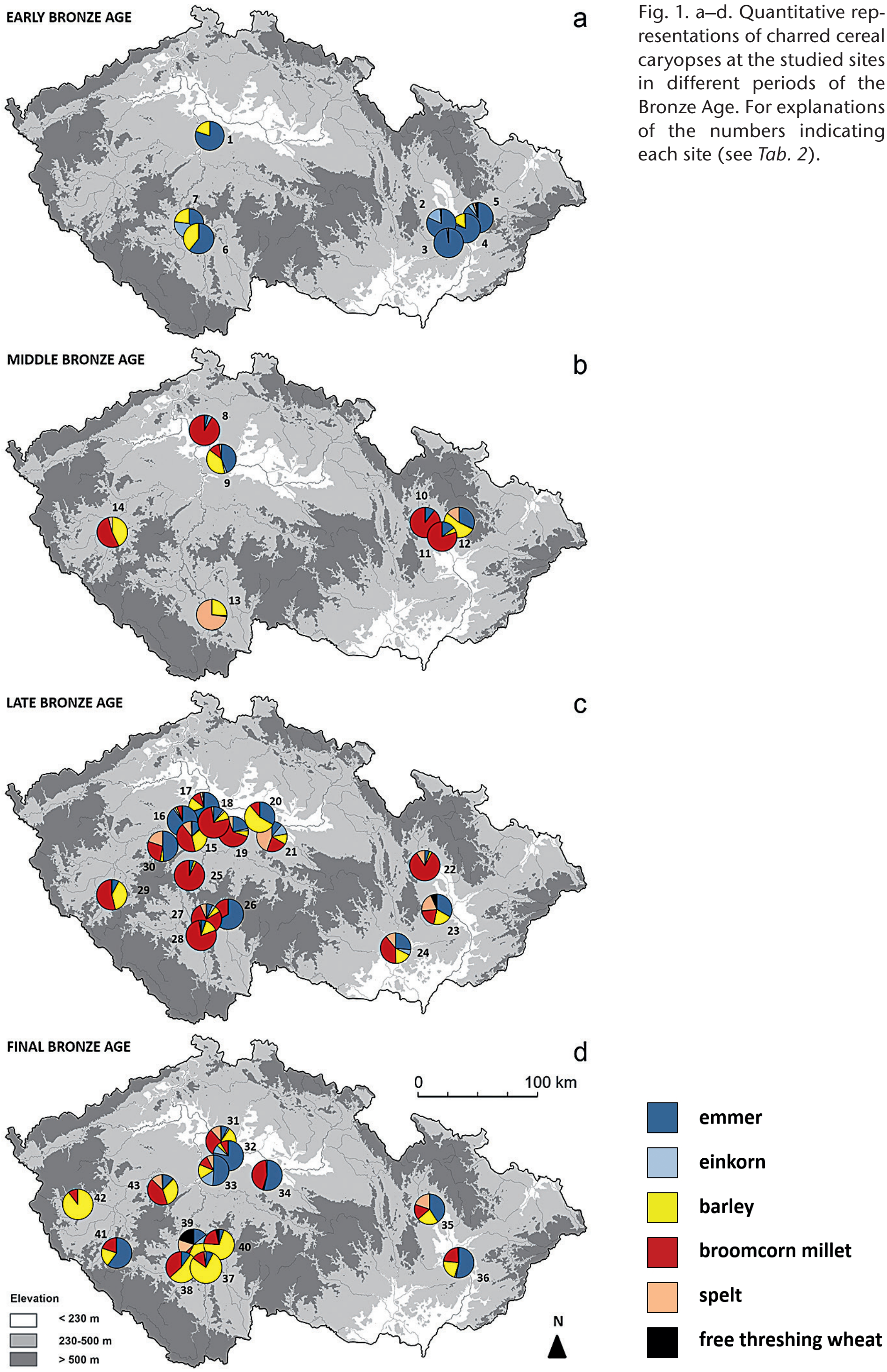

Fig. 1. a–d. Quantitative representations of charred cereal caryopses at the studied sites in different periods of the Bronze Age. For explanations of the numbers indicating each site (see *Tab. 2*).

The Late Bronze Age

The broomcorn millet culminated in the studied area in the LBA (*Fig. 1*: c; *Tab. 2*). Not only was the taxon documented in 95% of the investigated sites, but its RI (Representativeness Index) reached the maximum value (93) of all studied crops and periods (*Tab. 3*). RI of barley and emmer were also high (61 and 59 respectively). Also spelt became widespread (ubiquity 68; *Tab. 3*). Finds of pulses became widespread, lentil and pea (*Pisum sativum*) were documented in more than half of the sites (ubiquity 68 and 53 respectively), while faba bean was rare. One poppy seed (*Papaver somniferum*) was found at Hvožďany site. Wild growing edible plants, i.e., hazelnut, wild strawberry, blackthorn, rose (*Rosa* sp.), blackberry, and elderberry were present in many sites, but only in small quantities (*Tab. 2*).

The Final Bronze Age

All the cereals encountered in previous phases (emmer, einkorn, barley, spelt, free threshing wheat and broomcorn millet) were present in FBA, many of them co-occurring (*Fig. 1*: d; *Tab. 2*). Free threshing wheats were still rare. The sites were highly diversified, so that it seems as if the crops were selected deliberately to fit the local conditions. The most prominent pattern was a prevalence of emmer in fertile lowlands and of barley in higher elevations of the SW parts of the studied area (*Fig. 1*: d; *Tab. 2*). Lentil became more widespread, along with pea and faba bean, also poppy seeds were documented more frequently (*Tab. 2*). Gathered plants, mainly rose, blackberry and elderberry, represented only a small admixture.

Discussion

Representativeness of data

Although we evaluated data from 39 sites with more than 56,000 macroremains, our results are far from being representative enough. The sites differed greatly in the quantity of identified macroremains, from a few individual grains to more than ten thousand at the LBA Blučina-Cezavy site (*Tab. 2*). Unfortunately, the MBA, although the most important for understanding the BA transformation, was the least represented of all the periods studied. The maps in *Fig. 1* should only be viewed as indicative, since the pie charts do not take into account the amount of data. Nevertheless, we consider them useful to visualise the results and to recognize spatial trends.

In addition to the quantitative proportions of macroremains, we also expressed the results using ubiquity (*Tab. 3*). Ubiquity (frequency of occurrences within a period) can be, in some aspects, a better measure than quantitative proportion of macroremains, although it does not take into account the dominance of individual species, and it can also be biased in phases that contain very little data. Therefore, we also expressed the results using RI (*Tab. 3*), which takes into account both the quantity and dominance of individual species, as well as the total amount of macroremains and the number of examined samples at the site. Note the generally low RI values and concurrently high ubiquity values in MBA with the lowest number of sites (*Tab. 3*). On the contrary in LBA, the RI values of nearly all taxa are generally higher than in other periods, because of the highest number of sites.

Taxa	Scientific names	Category	Quantity of macroremains				Ubiquity				Representativeness Index (RI)			
		Period	EBA	MBA	LBA	FBA	EBA	MBA	LBA	FBA	EBA	MBA	LBA	FBA
Cereals														
Hor_vul	*Hordeum vulgare*	barley	372	3714	3025	4243	83	71	89	100	32	18	61	50
Pan_mil	*Panicum miliaceum*	broomcorn millet	9	645	7846	5326	33	100	95	100	12	9	93	51
Tri_dic	*Triticum dicoccon*	emmer	9388	639	5182	4086	92	86	100	85	80	9	59	55
Tri_mon	*Triticum monococcum*	einkorn	200	26	683	517	75	57	58	46	31	5	31	22
Tri_spe	*Triticum spelta*	spelt	15	4775	1386	1314	33	57	68	62	14	11	37	28
Tri_di/sp	*Triticum dicoccon/spelta*	emmer/spelt	103	5	45	169	50	29	16	23	22	2	8	10
Tri_free	*Triticum aestivum/compactum/ durum/turgidum*	free threshing wheat	30	6	29	108	50	14	37	46	25	2	22	17
Non-cereals														
Len_cul	*Lens culinaris*	lentil		4	592	617		29	68	85		2	31	28
Pis_sat	*Pisum sativum*	pea			40	35			53	54			24	16
Vic_fab	*Vicia faba*	faba bean	261	3	4	3	8	14	16	15	2	1	5	3
Le/Pi/Vi	*Lens/Pisum/Vicia*	lentil/pea/vetch	11	11	85	152	42	43	74	54	20	3	31	19
Lin_usi	*Linum usitatissimum*	flax				1				8				5
Pap_som	*Papaver somniferum*	poppy			1	60			5	23			5	7
Gathered														
Cor_mas	*Cornus mas*	cornelian cherry	10				17				5			
Cor_ave	*Corylus avellana*	hazelnut	29	1	9	1	42	14	21	8	13	1	10	4
Fra_ve/vi	*Fragaria vesca/viridis*	wild strawberry	13		14		8		11		2		5	
Pru_spi	*Prunus spinosa*	blackthorn	13		1		25		5		8		4	
Rosa	*Rosa* sp.	wild rose			1	8			5	23			4	10
Rubus	*Rubus* sp.	blackberry	82		4	13	8		16	15	2		10	3
Sam_nig	*Sambucus nigra*	elderberry	24	113	4	10	33	43	11	38	8	4	6	12

Tab. 3. Importance of individual taxa of edible plants according to the main Bronze Age phases. Taxa – abbreviations of taxa (used also in *Tab. 2*); Quantity of macroremains – totals of all charred macroremains (NISP) for each period; Ubiquity – percentages of sites, within a period, containing a given taxon; Representativeness Index – relative numbers (calculated according to *Stika – Heiss 2013*).

Therefore, to evaluate the changing importance of individual species, we recommend using as many different approaches as possible (in our case combining *Fig. 1*, *Tab. 2*, and *Tab. 3*).

Cereals

Emmer was the most important crop in EBA (RI 80; *Tab. 3*), dominating almost all sites (*Fig. 1*). However, it lost its dominant position in MBA and was replaced by other crops (mainly broomcorn millet). It became important again in LBA (RI 59), but only in some sites. Finally, in FBA, emmer was dominant or subdominant mainly in lowland sites on fertile soils, while in higher elevations it mostly formed only a limited proportion of cereal grains (*Fig. 1*: d). Einkorn always represented only an admixture, without any clear spatial pattern (*Fig. 1*) and with gradually decreasing values of ubiquity (from 75 to 46; *Tab. 3*). Free threshing wheat was present in all BA phases, but only as an insignificant admixture.

Spelt has been documented in the studied area since the Eneolithic (*Dreslerová – Kočár 2013*), similarly as in Austria, southern Germany and Switzerland (*Akeret 2005*; *Kohler-Schneider – Caneppele 2009*). In our data, spelt was initially documented with uncertainty (mostly as emmer/spelt in EBA; *Tab. 2*; *Tab. 3*). The reliably identified spelt became more frequent in MBA, while in Planá site, it was exceptionally dominant with more than four thousand grains and more than 70% of identified cereal grains (*Fig. 1*: b; *Tab. 2*). This exceptional site is in a good accordance with previously demonstrated cultural relationship of South Bohemia with the Danube region in EBA and MBA (*Šálková et al. 2019*). In younger periods of the Bronze Age (LBA and FBA) the importance of spelt was higher than in EBA, with ubiquity values above 60 and RI values around 30 (*Tab. 3*).

Barley was a subdominant cereal in some sites, whereas in other sites it formed only a limited share. In the EBA, it seems to be more important in the western part of the studied area compared to the easternmost sites (*Fig. 1*: a). However, this pattern may be the result of a bias caused by generally low amounts of identified grains in the westernmost sites (Praha-Miškovice, Vrcovice and Kučeř). The ubiquity of barley gradually increased in BA from 83 in EBA to 100 in FBA. In the FBA, barley became dominant (or subdominant) in nearly all sites in the south and west of the country, which is a territory with generally higher elevation and lower quality soils compared to the fertile lowlands in the north and east (*Fig. 1*: d).

The arrival of broomcorn millet in the study area is expected in the MBA (*Filipović et al. 2020*). However, broomcorn millet grains were already documented in some EBA sites in our dataset. These finds are assumed to represent a younger intrusion, as they are mostly linked to polycultural sites with well-developed younger phases, for example, Hulín (14 pcs.) and Pravčice (1 pc.); or these were single grains with an uncertain identification as in Kučeř (*Tab. 2*). On the other hand, it was our decision to include the Věteřov culture into EBA (see above). The dating of the Věteřov culture (1700–1500 BC) partly overlaps with the older phase of the Tumulus culture (1700/1600–1300/1250 BC), so we cannot rule out that these findings are correct, however, only a direct ^{14}C dating of the grains can answer this question reliably.

Only in the MBA, the evidence of broomcorn millet cultivation is considered reliable. The grains of *Panicum miliaceum* represented a dominant portion of cereal grains in many sites (*Fig. 1*: b) and also its ubiquity reached 100. This is in a good agreement with other finds from the country, like the earliest ^{14}C dated evidence from the waterlogged site Zahájí (1461–1383 BC; not included in this study; *Bernardová 2009*; *Pokorný et al. 2015*) and with other mass finds from the Tumulus culture (*Kočár – Dreslerová 2010*; *Dreslerová – Kočár 2013*; *Dreslerová et al. 2017*; *Šálková et al. 2019*). It is evident that the beginning of broomcorn millet cultivation in MBA was sudden and intense. In LBA, it reached the maximum RI (93), whereas its importance slightly decreased in FBA (RI 51).

Non-Cereals

Legumes were rarely documented in EBA and MBA, except for the single mass finding of faba bean in EBA (Vrchoslavice – Na dílech site). However, in younger periods faba bean was represented only by single seeds and its RI never exceeded 5 (*Tab. 3*). Although pea and lentil have been known in the Czech Republic already since the Neolithic (*Kočár – Dreslerová 2010*), their finds have expanded in our data only since LBA, with lentils being generally more dominant. The ubiquity of lentil gradually increased from 29 in MBA to 85 in FBA, while its RI reached around 30 in LBA–FBA (*Tab. 3*). Other less important legumes known in the Czech Republic since LBA–FBA (*Kočár – Dreslerová 2010*), such as common vetch (*Vicia sativa*) and bitter vetch (*Vicia ervilia*), were not represented in our data.

No oilseeds were encountered in our data until the end of MBA, while in LBA–FBA, poppy (*Papaver somniferum*) and linseed (*Linum usitatissimum*) were only sporadically recorded. Although flax has been documented in the study area since the Neolithic (*Kočár – Dreslerová 2010*), we have only one linseed from FBA Bavoryně site on our dataset. Also, poppy cultivation in the area is probably even older than BA, however, we recorded only one seed at the LBA Hvožďany site and three other records in FBA, the most remarkable of which are 57 seeds from the Hulín site (*Tab. 2*).

Finds of gathered fruits and nuts were relatively rare in the dataset, however, it is evident that they still played a certain role in the Bronze Age economy. Hazelnut and elderberry were among the most frequent finds. Cornelian cherry was found only in EBA, while wild strawberry and blackthorn were documented in both EBA and LBA. Blackberry was found in all periods except for MBA, and wild rose in LBA and FBA. The importance of individual taxa seems to have declined slightly over time, which is best seen in the example of hazelnut (*Tab. 3*). The wild rose, on the contrary, increased its importance towards the end of the BA. An unusually rich collection of gathered fruits and nuts was found in the EBA Vrcovice site, containing hazelnut, wild strawberry, blackthorn, blackberry and elderberry (*Tab. 2*). With a total of 135 seeds from five species of gathered plants, it is the richest site in the entire collection. This is the highest point of the Věteřov culture (420 m above sea level). Perhaps it may be a case where the insufficient harvest was compensated by gathering wild fruits, but the uniqueness of the case does not allow us to draw general conclusions.

Crops selection

The shift to millet and spelt cultivation together with an increase in pulses towards the younger phases of the BA reflects a change in subsistence strategies. However, the low number of sites from the crucial period (mainly from the MBA) makes precise understanding of the process particularly difficult. Based on the changing composition of cultivated plants, it is generally expected that the importance of spring-sown crops increased in the study area in the LBA (*Šálková et al. 2019*). Barley, as well as emmer and einkorn, can be grown either as spring-sown crops or as winter crops, while broomcorn millet and pulses are always sown in spring and spelt is often a winter cereal (*Hajnalová 2012*; *Šálková et al. 2019*). In order to specify the time of sowing, it would be possible to carry out a taphonomic and subsequently an ecological analysis of weed seeds at the studied locations (*Bogaard et al. 2001*), but this approach is beyond the scope of our study.

FBA appears to represent a final stage of agricultural transformation. While the RI of barley and broomcorn millet gradually increased from EBA towards FBA (from 32 to 50 and from 12 to 51), the RI of emmer decreased (from 80 to 55). As a result, the RIs of the three most important cereals were rather evenly distributed in the FBA (*Tab. 3*). The increased diversity of cultivated plants might have enabled deliberate selection of a suitable crop to achieve an optimum yield with respect to local conditions. The most important environmental factors which were previously proven to be governing crop choice were soil quality and length of growing season (*Dreslerová et al. 2017*). In the referred study, the hulled wheats correlated positively with chernozems and negatively with a mean annual precipitation, whereas barely positively correlated with altitude. Our data confirms this trend, mainly in the FBA. Broomcorn millet, on the contrary, dominated in our data from the MBA onwards in many sites regardless of elevation and the soil quality. This is somewhat inconsistent with previously published data (*Dreslerová et al. 2017*) which demonstrated dominance of broomcorn millet in the lowlands. It can be explained by the fact that we used a different dataset. We did not include some earlier analysed data, but we expanded the dataset with new data, especially from South Bohemia, which contained a high proportion of broomcorn millet, especially in LBA, in higher elevations.

Conclusions

We examined charred macroremains from 39 archaeological sites in the Czech Republic dated to the Bronze Age (BA) which provided data on proportional changes of cereals, pulses, oil plants and gathered plants. The most significant changes include the introduction of broomcorn millet in the Middle Bronze Age (MBA) and increased importance of pulses since the Late Bronze Age (LBA). Besides, we documented a shift in the importance from archaic diploid and tetraploid hulled types of wheat (einkorn and emmer) to hexaploid types (spelt) and perhaps even the free threshing wheats.

Emmer, initially the main crop in the EBA, lost its prominence in the MBA, however, it regained dominance in certain lowland sites again by the FBA. Barley, although present in all periods of the BA, was apparently more important in the south and south-west of the territory, especially in EBA and FBA. This trend could be related to possible preference for barley on poor soils and at higher elevations. Spelt showed an exceptional dominance in the southern part of the studied territory in the MBA; however, later it formed a common part of the assortment in different parts of the area, without any clear spatial pattern.

The study highlights a sudden introduction of broomcorn millet during the MBA. However, the limited number of sites, particularly from the MBA, complicates a precise understanding of all aspects of this transformative process. The dominance of broomcorn millet in the dataset from the MBA onwards, regardless of elevation and soil quality, challenges some earlier findings and underscores the importance of using diverse datasets for a comprehensive understanding of agricultural practices in the Bronze Age.

The changes observed in crop cultivation patterns indicate evolving subsistence strategies. The increased diversity of cultivated plants and the increase in the importance of legumes may have allowed a better distribution of field work throughout the year, as well as a deliberate crop selection, resulting in optimised yields based on local conditions.

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