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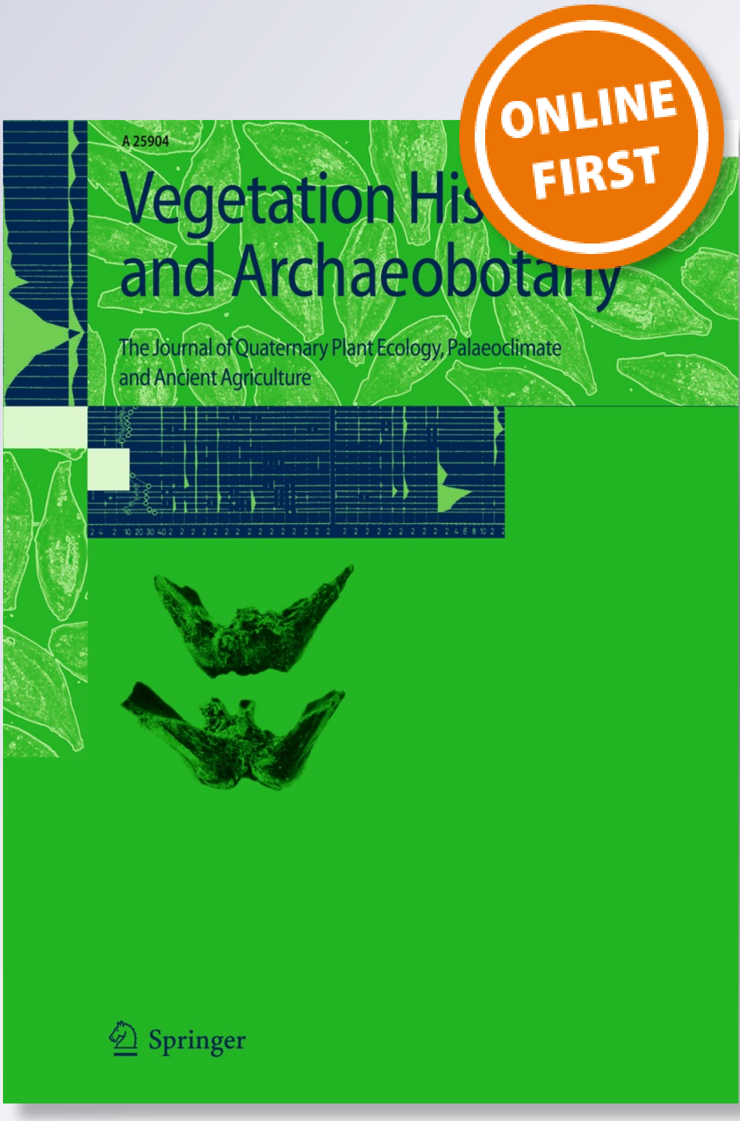
Vegetation History and Archaeobotany
The Journal of Quaternary Plant Ecology, Palaeoclimate and Ancient Agriculture - Official Organ of the International Work Group for Palaeoethnobotany

ISSN 0939-6314

Veget Hist Archaeobot
DOI 10.1007/s00334-012-0377-8



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ORIGINAL ARTICLE

Trends in cereal cultivation in the Czech Republic from the Neolithic to the Migration period (5500 B.C.–A.D. 580)

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Received: 25 November 2011 / Accepted: 21 September 2012

Abstract This study summarises the current state of research on cultivated cereals from archaeological sites in the Czech Republic. We discuss the first appearances of particular cereals, their first proven cultivation (which usually happens much later) and their part within cereal husbandry. The questions of possible contamination of archaeobotanical material and problems concerning the identification of some cereal taxa are related to this topic. Trends in the importance of the cultivation of individual cereals are shown with generalized linear models (GLMs), based on an assemblage of 81 newly sampled sites. The results of GLM enable the division of the cereals into four groups characterised by: (1) species showing a gradual decrease in importance—*Triticum monococcum* (einkorn) and *T. dicoccum* (emmer), (2) species with progressively accumulating representation on sites during prehistory—*Hordeum vulgare* (common barley) and *T. spelta* (spelt), (3) those with a marked increase by the end of prehistory—*T. aestivum/turgidum* (naked wheat), *Avena* sp. (oats) and *Secale cereale*, (rye) and (4) a specific group including only *Panicum miliaceum* (broomcorn millet). There is a gradual increase in the diversity of cultivated cereals through time, starting with *T. monococcum* and *T. dicoccum*, followed by *Hordeum*, *Panicum*, *T. spelta* and *T. aestivum/turgidum*, *Secale* and *Avena*. Comparison of the chronological development of cereal cultivation in the area of the Czech Republic and surrounding countries shows a general correspondence with the trends observed in other parts of eastern-central Europe, although with some local specific differences.

Keywords Archaeobotany · Eastern-central Europe · Charred cereal remains · First cultivation · Generalized linear models

Introduction

Cereals have accompanied societies as a main component of their subsistence since the beginning of arable agriculture. Cereals spread into central Europe with the early Neolithic Linearbandkeramik (LBK) Culture from ca. 5500 B.C. onwards. As Colledge et al. (2005) state, only the glume wheats *Triticum dicoccum* Schübl. (emmer) and *T. monococcum* L. (einkorn) were present in the majority (56%) of LBK sites in central Europe, occasionally accompanied by *Hordeum vulgare* L. (barley). The cultural uniformity (including cereal production) of the LBK complex disintegrated relatively rapidly and subsequent changes in the range of grown crops reflect later regional and temporal differences in the evolution of farming. In pre-industrial societies all other social and cultural processes are determined by the efficiency of subsistence (Steward 1955). For both social and historical interpretations, an understanding of crop cultivation through archaeobotanical research is necessary.

There is a long tradition of archaeobotanical research in the Czech Republic (hereafter referred to as "CR"). The first finds of macro remains of cultivated plants within archaeological contexts came from the archaeological excavations of R. Volný in Rajhrad in 1846 (Skutil 1940; cited by Tempír 1966). Since the 1930s a more systematic collaboration between archaeologists and archaeobotanists has been

Communicated by M. Latałowa.

Electronic supplementary material The online version of this article (doi:10.1007/s00334-012-0377-8) contains supplementary material, which is available to authorized users.

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established. Nevertheless, since the mid-1990s the majority of samples have come from incidental finds of noticeable amounts of charred grains (also called judgment samples, after Van der Veen 1987). Further samples were taken non-systematically and processed without flotation techniques.

The first overview of the Czech archaeobotanical macroremains was done by Z. Tempír in 1966. E. Hajnalová expanded these results and collected all prehistoric finds of cultivated crops from former Czechoslovakia (in Wasylikowa et al 1991). The latest summary of this research came out twenty years later, when Kočár and Dreslerová (2010) compiled the data from over 270 prehistoric archaeological contexts in the CR (Bohemia, Moravia and Silesia) analysed in the last 70 years (Fig. 1; for the chronology of Czech prehistory, see Table 1). That paper described the representation of cultivated crops and the changes through agricultural prehistory, but did not deal with the question of their first intentional cultivation or their importance in farming systems. In this respect the study presented here, dedicated exclusively to cereals, extends the previous one.

The main aims of the present study are therefore to discuss the beginning of intentional cultivation of a particular cereal species. In addition we intend to assess the importance of individual cereal taxa for agriculture in the different prehistoric periods within the area of the Czech Republic.

Materials and methods

For solving the question of the beginning of an intentional cultivation of particular cereal species, the complete set of 279 archaeobotanical finds from the territory of the CR up to 2010 was used (Kočár and Dreslerová 2010). The majority of these samples were collected before systematic sampling and flotation techniques became usual on archaeological sites, so therefore only 81 new archaeobotanical assemblages processed by standardized methods of sampling and flotation were taken into consideration for a reconstruction of the importance of particular taxa (Fig. 1, Table S1,Table 2). The selection of the data enabled their further statistical evaluation by the generalized linear models (GLM).

The 81 recently excavated sites sampled by P. Kočár are located in various parts of the country, from the lowlands in central Bohemia and southern Moravia to the hilly areas in western Bohemia. Since all samples come from rescue excavations they differ in numbers and volumes. The samples represent various archaeological contexts. Settlement features and settlement layers were sampled preferentially. In some periods, namely the Late Eneolithic Corded Ware and Bell Beaker Cultures and the Early Bronze Age Nitra Culture, there were few or no settlement remains, and there are only graves (for chronology see Table 1). For this reason samples were taken from grave infillings (not the grave inventory; for more details see Table S1). The traces of some cultures, such as Globular Amphora, occur within the framework of other Middle Eneolithic culture settlements as individual features; therefore an extensive sampling was not possible, for example the Vávrovice site produced only two samples. Because of their rarity, these data were included in this study.

All macroremains come from dry sites only and all analyzed materials were preserved in a charred state. The

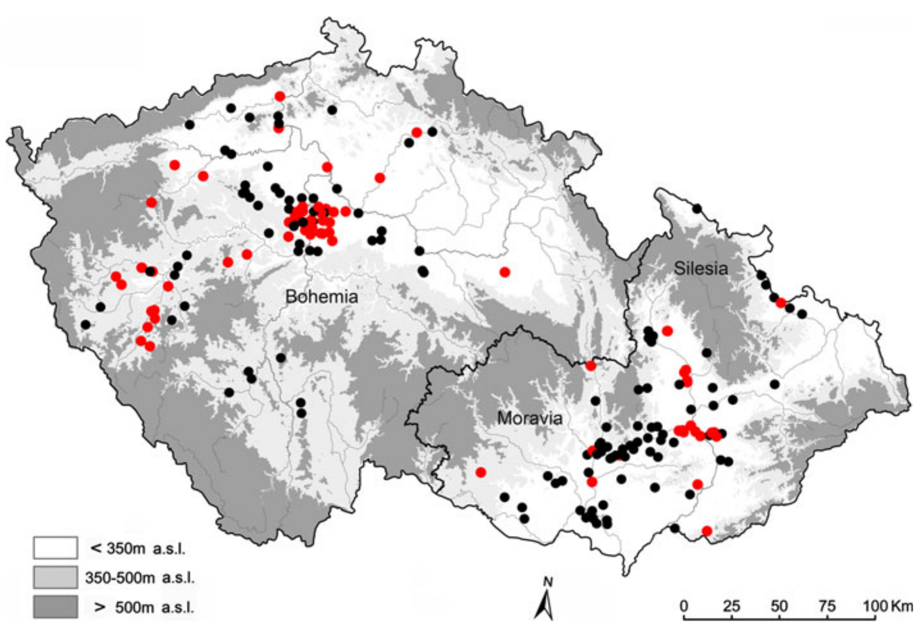

Fig. 1 Archaeological sites with archaeobotanical investigations of cereal macroremains in the Czech Republic; *red dots* sites analysed by P. Kočár and used in the statistical analysis, *black dots* botanical analyses by other authors

Table 1 Chronology of Czech prehistoric periods and selected archaeological cultures (after Jiráň and Venclová 2007–2008)

Prehistoric periods		B.C./A.D.	Selected archaeological cultures	B.C./A.D.
Neolithic	Early	5500 – 4900	Linearbandkeramik Culture (LBK)	5500 – 4900
5500 - 4400 B.C.	Late	4900 – 4500/4400	Stichband Pottery Culture (STK)	4900 – 4600
			Moravian Painted pottery Cult. I	4700 – 4300?
	Proto	4400 – 3800	Schussenried Culture	4200
			Moravian Painted pottery Cult. II	4300? – 4000?
Eneolithic	Early	3800 – 3400	Funnel Beaker Culture	3800 – 3400
4400 - 2300 B.C.			Řivnáč Culture	3100 – 2900
	Middle	3400 – 2900/2800	Globular Amphora Culture	3100 – 2900
			Cham Culture	3100 – 2800?
	Late	2800 – 2300/2200	Corded Ware Culture	2800 – 2500
			Bell Beaker Culture	2500 – 2300/2200
	Early	2300 – 1600	Unětice Culture	2300 – 1600
			Nitra Culture	2100 – 1900
			Věteřov Culture	1700 – 1600
Bronze Age	Middle	1600 – 1250	Tumulus culture	1600 – 1250
2300-750 B.C.			Knovíz Culture	1250 – 1025
	Late	1250 – 1000/950	Velatice Culture	1300 – 1025
			Milaveč Culture	1250 – 950
			Lusatian Culture	1300 – 1025
	Final	950 – 750	Nynice Culture	950 – 750
	Early	750 – 475/450	Hallstatt	
Iron Age			Bylany Culture	800 – 625
750 - 1 B.C.			Plátěnice Culture	700 – 450
			Hallstatt D/La Tène A	625 – 400
	Late	450 – 25	La Tène	
Roman Per.		A.D. 1 – 400		
Migration Per.		A.D. 400 – 580		

The Eneolithic period (ca. 4400/4200–2300 cal B.C.) is the equivalent of Late Neolithic in western, central and northwest Europe and Chalcolithic (or Copper Age) in southeast and eastern Europe; in accordance with the Czech prehistory chronological system both Roman and Migration periods belong to prehistory

numbers of the different remain types, such as grain/glume base/rachis internodes, are listed in Table 2. The statistical analysis includes exclusively caryopses, and no other parts of plants such as rachis internodes or glume bases were considered. The reason for this is that sites in the CR, as in other parts of Europe, tend to produce only chaff of glume wheats (*T. monococcum/dicoccum*), while chaff of other cereals like *Hordeum*, *T. aestivum/turgidum*, *Secale* and *Avena* are found very rarely, if at all. The different possibility of detection of the particular taxa would not allow for the comparison of their numbers—glume wheats would end up being overestimated.

The absence of rachis internodes on most sites did not permit precise identification of tetraploid and hexaploid naked wheats. There is only one exception: at the Early Iron Age site of Medlov eight rachis internodes of tetraploid naked wheat were found. In the following text, the term "naked wheat" therefore includes all naked tetra- and hexaploid species (*T. aestivum* L. */compactum* Host. */durum* Desf. */turgidum* L., which we combine as "*T. aestivum/turgidum*". For the same reason (the absence of rachis internodes) it was not possible to differentiate explicitly between multi-rowed *Hordeum* (4-rowed and 6-rowed forms, *Hordeum vulgare* L.) or to prove the presence of the two-rowed form of *Hordeum* (*H. distichum* L.); also in the case of *Hordeum* there is an exception: in the La Tène period site of Olomouc-Řepčín, 20 rachis internodes of 6-rowed hulled *Hordeum* (*H. vulgare* sp. *vulgare*) were found. Moreover, the existence of badly preserved *Hordeum* caryopses in some sites did not allow for the precise identification of hulled and naked forms. Owing to major differences between various sites, all data included in the statistical analysis were incorporated into a group "*H. vulgare*" (which means many-rowed *Hordeum* with no differentiation between naked and hulled forms). The nomenclature of scientific plant names follows Zohary and Hopf (2000).

Around 101,000 charred cereal grains from 81 sites were identified and included in the statistical analysis. These cereal remains were extracted by flotation using an Ankara type device (Pearsall 1989), with 0.25 mm mesh size, and examined with a stereomicroscope. They were identified by the use of the seed (plant diaspores) reference collection of the Department of Landscape Archaeology and Archaeobiology, Institute of Archaeology, Prague and with the help of various literature sources (Jacomet 1987, 2006). The

Site	Epoch/Culture	Chronology B.C./A.D.	No. of samples	*Avena* sp. (g)	*A. sativa* (ch)	*Hordeum vulgare* (g)	*H. v.* ssp. *vulgare* (ch)	*H. v.* var. *nudum* (g)	*Panicum milliaceum* (g)	*Secale cereale* (g)	*Setaria italica* (g)	*Triticum aestivum* Type	*T. aest./turgidum* (ch)	*T. dicoccon* (g)	*T. dicoccon* (ch)	*T. monococcum* (g)	*T. monococcum* (ch)	*T.* cf. *spelta* (g)	*T. spelta* (ch)
Bdeněves	PEN - Schussenried c.	4200	7			34								76		6			
Bdeneves I	EIA - HD-LTA	625-400	40	1		280			19	1		7		21		1		89	
Bdeneves III	EIA - HD-LTA	625-400	31			59			4					5				18	
Bezměrov	LEN - Corded Ware c.	2750-2500	11			16								2					
Blučina Cezavy	LBA - Velatice c.	1300-1000	16	1		1,806			2,802					2,357	743	369	976	137	1,570
Brno Přízová	EIA - HD-LTA	625-400	25	1		19			43	6		23		18		1		32	1
Chotěbudice	LBA	1250-1025	12											19	156	2	93		
Dolní Chabry	LBA - Knovíz c.	1250-950	27			209			331					1,440	28	408	2	169	20
Dřevčice	LIA - La Tène	450-25	9			1			2					18		2			
Holubice	Roman period	A.D. 1-400	5	5					6	20				12	5			5	2
Holubice	EIA - Bylany c.	750-625	6	211	5	1,467				4		4		11				2	
Hostivař	LBA - Knovíz c.	1250-1025	213	17		348			2,356	1		26		1,115	725	14	56	7	6
Hostivař	EIA	750-640	40			122		1	75			1		187		35		25	
Hrušov	ENE	4400-3750	2			21			8			1		5				1	
Hulín I	NE - Linear pottery c.	5500-4900	110	3		574		3	606			1		1,348	33	34	4	15	8
Hulín I	LEN - Corded Ware c.	2750-2500	31			1								15					
Hulín I	LNE - Moravian Painted pot. c.I	4600-4300	61	3		221		9		2				147	1	9		2	
Hulín I	EBA - Nitra c.	2100-1900	19									2		3		1		1	
Hulín I	LEN - Bell Beaker c.	2500-2300	51			9			36					196	1	3		2	
Hulín I	EBA - Unetice c.	2200-1600	9			1								5		2			
Hulín I	LIA - La Tène	450-25	64	1		34		3	18			1		17	1	1		10	1
Hulín I	LBA	1000-750	29			1			9					26					
Hulín I	MBA - Věteřov c.	1700-1600	10											13		2			
Hulín I	EBA - Nitra c.	2100-1900	181	5		32			6	1		4		7,744	328	149	53	42	62
Hulín III	Roman period	A.D. 1-400	18			94								6					
Hulín Pravčice II	MBA - Věteřov c.	1700-1600	170			5		56	10					11	2	1	1		
Hulín Pravčice II	EIA	750-625	44	19		40,664			69		217	2		1,223	25	35	45	20	5
Hulín Pravčice II	NE - Linear pottery c.	5600-4900	234	1		12			3					890	6	369	12		
Hulín Pravčice II	LEN - Bell Beaker c.	2500-2300	95			3								212	2	2,215	12		
Hulín Pravčice II	PEN -Moravian Painted pot. c.II	4400-4300	10	1		1			7			166		13				6	
Hulín Pravčice II	NE - Linear pottery c.	5500-4900	17			1			1			9		251		10	4	5	1
Klatovy Pod Borem	LBA - Milaveč c.	1250-950	6			1			1					3					
Kněževes	LBA - Knovíz c.	1250-1025	49	1		81			407			4		1,815	2,067	58			
Kněžívka	LBA - Knovíz c.	1250-1025	90			16		5	65			2		42		3		11	
Křimice	LBA - Lusatian c.	1300-1025	4											532	20	250	4		
Kroměříž I	PEN-EN	4300-3750	52			38		60	2,135			4		149	7	2		592	7
Kroměříž I	NE - Linear pottery c.	5500-4900	99	3		2		1						221	29	3		2	
Lažínky	EIA	750-625	91	1		208			43			2		35				9	
Litovice	ENE - Funnel Beaker c.	3800- 3400	5											3		2			
Medlov RD	FBA - Silesian c.	950-750	5	1		29			96			1		23	35	1		5	20
Medlov	LBA - Lusatian c.	1250-1025	10			8			20					10				16	
Medlov	EIA - Platenice c.	700-450	23	3		157			154			11	8	186				203	
Medlov	EIA	750-625	4	1		15			11					27				13	
Olomouc Řepčín	LIA - La Tène	450-25	3			1,997	20		2			5		696	385	378	3	21	181
Olomouc Řepčín	LEN - Corded Ware c.	2800-2500	34	1		19			7			1		12		2		28	
Olomouc Řepčín	MBA	1600-1250	19			6								6					
Olomouc Slavonín	MBA	1600-1250	13			1			16					5				2	
Ostrov u Stříbra	FBA - Nynice c.	950-750	3			149			9					10					
Praha Hloubětín	Roman period	A.D. 1-400	57	8		333			88	22		14		376	1	14		347	4
Praha Hloubětín	EIA	625-400	10	47		854			5	1		3		19				5	
Praha Hlubočepy	NE - Linear pottery c.	5500-4900	8			1								52	7	14	22		
Praha Jinonice	LIA - La Tène	450-25	37	11		218			20	3		81		254	2	20		489	40
Praha Liboc	EIA - Bylany c.	750-640	7			2,179			10			3		142	4	5	2	154	
Praha Miškovice	EIA - Bylany c.	750-640	68			1						1		282		5			
Praha Miškovice	MEN - Rivnac c.	3100-2900	3			6			1			1		12					
Praha Smíchov	LBA - Knovíz c.	1250-1025	17	1		9		2	100					9	4	2	1	3	
Praha Vysočany	LIA - La Tène	450-25	18	4		15			4	2		9		10		1		26	
Přemyšlení	PEN - Jordanov c.	4200	3			1						1		15		2			
Přeštice	LBA - Miilaveč c.	1250-1025	12			5			7					1					
Příšovice	NE - Stichband pottery c.	4900-4600	116	1		2		2						343	678	163	462		
Radkovice	MEN - Cham c.	2830-2626	19			10								6		1			
Stříbrnice	LEN - Bell Beaker c.	2500-2300	11											3					
Tachlovice	EIA - Bylany c.	750-640	15			52			63			2		41	17	5		2	
Tachlovice	NE - Linear pottery c.	5500-4900	30			2								139	56	16		3	
Těšetice	LNE - Moravian Painted pot. c.I	4600-4300	28											161		30	2		
Tuchoměřice	LBA - Knovíz c.	1250-1025	12	6		49			32			5		144	137	2		7	1
Vávrovice	MEN - Globular Amphora c.	3100-2900	2											865		6			
Velké Přílepy	LEN - Bell Beaker c.	2500-2300	2											27		3			
Vitčice	Roman period	A.D. 1-400	39											3				1	
Vitčice	LEN - Corded Ware c.	2850-2500	49			2								185		297			
Vitčice	LEN - Bell Beaker c.	2500-2300	53											4					
Vitčice	MBA - Věteřov c.	1700-1600	480			29		1				7		1,848	36	20		4	
Vlinčves	EBA - Unětice c.	2300-1600	60			398								193	40	17		1	1
Vokovice	NE - Linear pottery c.	5500-4900	9											5	2	2			
Vrchoslavice II	EBA - Unětice c.	2200-1600	18									1		11	2	1			
Vrchoslavice II	Migration period	A.D. 400-580	3	138		157			153			3		992	11	567		27	
Vrchoslavice II	Roman period	A.D. 1-400	27	5		5			1			1		2		2			
Vrchoslavice III	MBA - Věteřov c.	1700-1600	48	1		4						6		138	1	30		3	
Záběhlice	LBA - Knovíz c.	1250-1025	56	1		39			370			2		52	2	3		1	
Zdice	LBA - Knovíz c.	1250-1025	20			28		14	353			3		109	259	2	4	42	252
Želeč	Roman period	A.D. 1-400	1			2								16	1		2		
Zlechov	PEN - Schussenried c.	4200	3	2					27	4	113							1	
Sum grains				505		53,163		157	10,611	67	330	420		27,640		5,598		2,606	
Sum chaff					5		20						8		5,859		1,760		2,182

◂ **Table 2** Numbers of charred cereal remains from the 81 recently investigated sites considered in this article. *ch* chaff, *g* grain. For dating, see Table 1

obtained data were processed by GLM (McCullagh and Nelder 1989) implemented in S-plus version 4.5 (Statistical Sciences 1999). GLM are the generalization of ordinary least squares regression and are ideally suitable for data with non-normal distribution (Table 3; Fig. 2). GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function. GLM also relaxes the requirement of equality or constancy of variances that is required for hypothesis tests in traditional linear models (LM). The proportion of particular cereals in a sample has a binomial distribution. That is why we use GLM with a binomial distribution of response variables instead of LM, which assumes normal distribution of the response variables. The significance of particular models was tested using an F-test (Table S2).

In order not to completely ignore the older data, and also to trace the first signs of cultivation of a taxon, we also tried to compare the numbers of grains in all of the cereal assemblages from 279 sites. For such a comparison which also considers the formation of an assemblage, we divided the dataset into two groups which we call "individual finds" and "grain-rich finds". "Individual finds" are understood as an assemblage consisting of less than 50 caryopses of one taxon from the same site. Such finds may

Table 3 Number of sites with the occurrence of analysed cereals (based on all known data 279 sites); *dark grey*, first evidence of a cereal taxon; *light grey*, first evidence of intentional cultivation. For more explanations, see the text

Taxon	Number of sites including:	Neolithic	Eneolithic	Early Bronze Age	Middle Bronze Age	Late/Final Br.Age	Hallstatt	La Tène	Roman/Migration p.
Avena sp.	individual finds	3	0	4	1	18	17	16	14
	rich finds							1	3
Hordeum vulgare s.l.	individual finds	13	30	17	9	42	35	28	22
	rich finds		2	4	2	13	13	11	5
Panicum miliaceum	individual finds	5	5	3	6	40	27	21	15
	rich finds				1	14	8	3	3
Setaria italica	individual finds					1	2	1	1
	rich finds						1		1
Secale cereale	individual finds			6	1	3	9	17	5
	rich finds							1	
Triticum dicoccum	individual finds	47	53	19	9	42	29	23	17
	rich finds	14	9	12	1	14	10	7	3
T. monococum	individual finds	36	28	13	6	24	15	21	9
	rich finds	8	4	4	1	6	1	1	1
T. "new type"	individual finds							1	
	rich finds								
T. spelta	individual finds	2	9	7	2	21	19	13	9
	rich finds					6	6	5	
T. aestivum type	individual finds	5	12	8	3	22	27	24	19
	rich finds					2	1	9	2

represent "background noise" in the sense of Bakels (1991). In contrast, "rich-grain finds" are understood as: (a) finds identified by the authors of published analyses as storage contexts (older data with insufficient quantification of a sample, but with other evidence of the existence of a large amount of macroremains) (b) all 50+ finds of caryopses in one sample (c) finds of a given cereal in more than ten archaeological contexts from the same site. Partly, such assemblages can also contain storage finds. The reason for selecting this particular solution is that in the majority of older publications there is no information about the sample volumes. For the same reason larger amounts of finds could not be categorised as "storage finds" in the sense of Kreuz and Schäfer (2008, p. 160), where a concentration of at least 100 crop seeds per litre of sample is required.

In the list of sites, one site may show up several times because several settlement phases were found there. Information about the dating of the settlement features/layers was taken from the archaeological reports. There are no radiocarbon or dendrochronology dates for the evaluated samples (except one), therefore we use the dating of a particular archaeological period/culture according to Jiráň and Venclová (2007, 2008).

Results

The presence of "individual" and "rich" cereal finds based on all 279 sites is shown in Fig. 2 and listed in Table 3 (for archaeological periods see Table 1). The number of cereal taxa varies through the periods. Fewer taxa are present during the Neolithic and Eneolithic than in the later periods. Grain-rich samples occur usually much later than individual finds.

The earliest finds of cultivated cereals come from sites of the Early Neolithic LBK Culture. Only *Triticum monococcum* and *T. dicoccum* were found in grain-rich samples. *T. aestivum/turgidum* (naked wheat), *Panicum miliaceum* L. (broomcorn millet), *Hordeum vulgare* (barley), *T. spelta* L. (spelt) and *Avena* sp. (oat) are only present as individual grains (for an evaluation of the reliability of the identifications, see discussion). The first grain-rich find of *Hordeum* comes from the Early Eneolithic Funnel Beaker Culture (ca. 3800–3300 B.C., Makotřasy site, Tempír 1985), while *T. dicoccum* and *T. monococcum* remain staples. During the Late Eneolithic and the Early Bronze Age the situation remains similar. Only the earliest presence of single grains of *Secale cereale* L. (rye) in Early Bronze Age contexts is worth mentioning.

Greater changes become visible from the Middle Bronze Age onwards. For the first time grain-rich assemblages of *P. miliaceum* appear. During the Late and Final Bronze Ages *T. dicoccum* and *Hordeum* take the dominant position among the

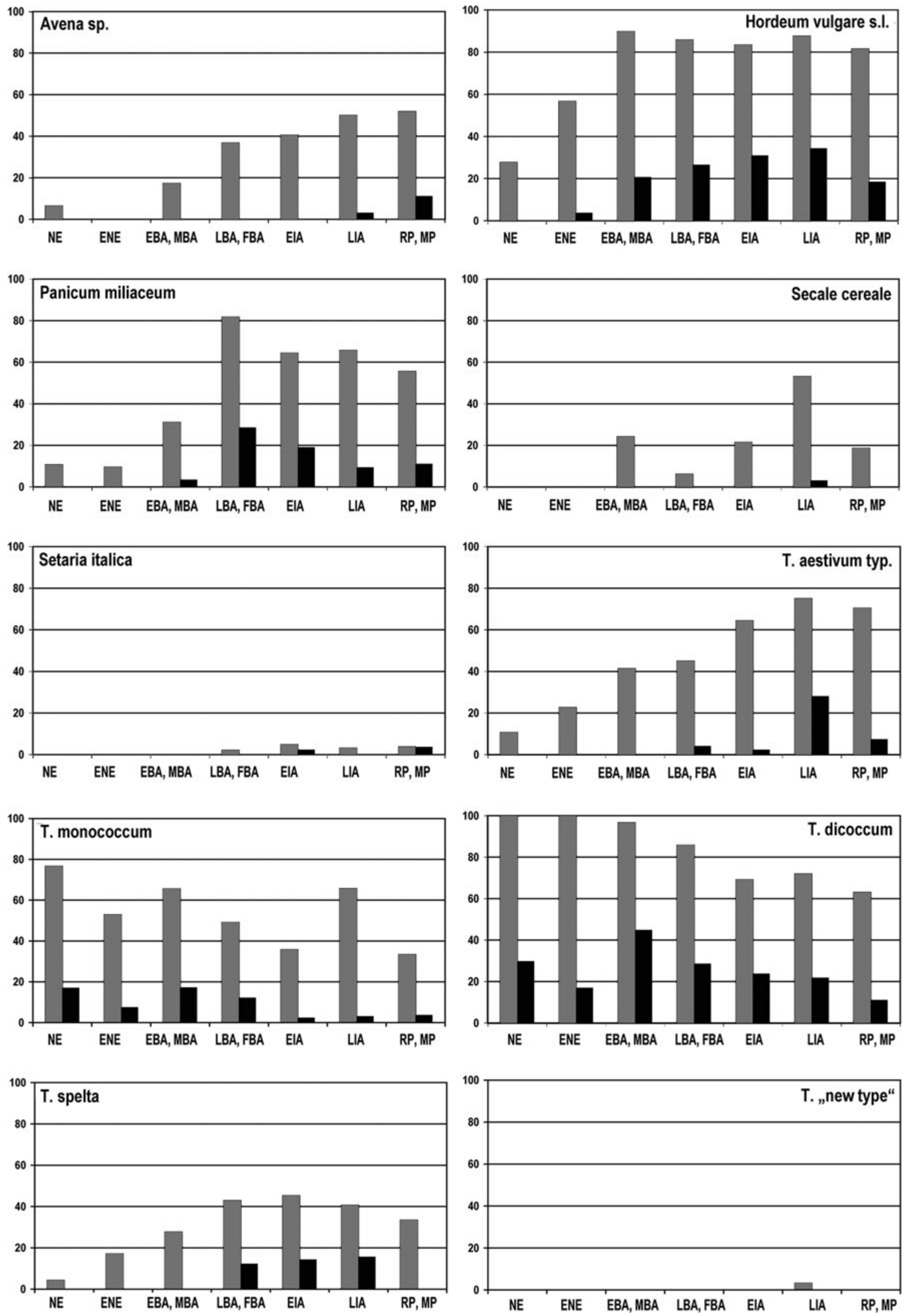

Fig. 2 Comparison of the presence of "individual" finds (*grey columns*) of cereal taxa and the presence of "grain-rich" finds (*black columns*) of a taxon on the basis of all known data (279 sites). Numbers = proportions based on the number of grains; for dating of the periods see Table 1

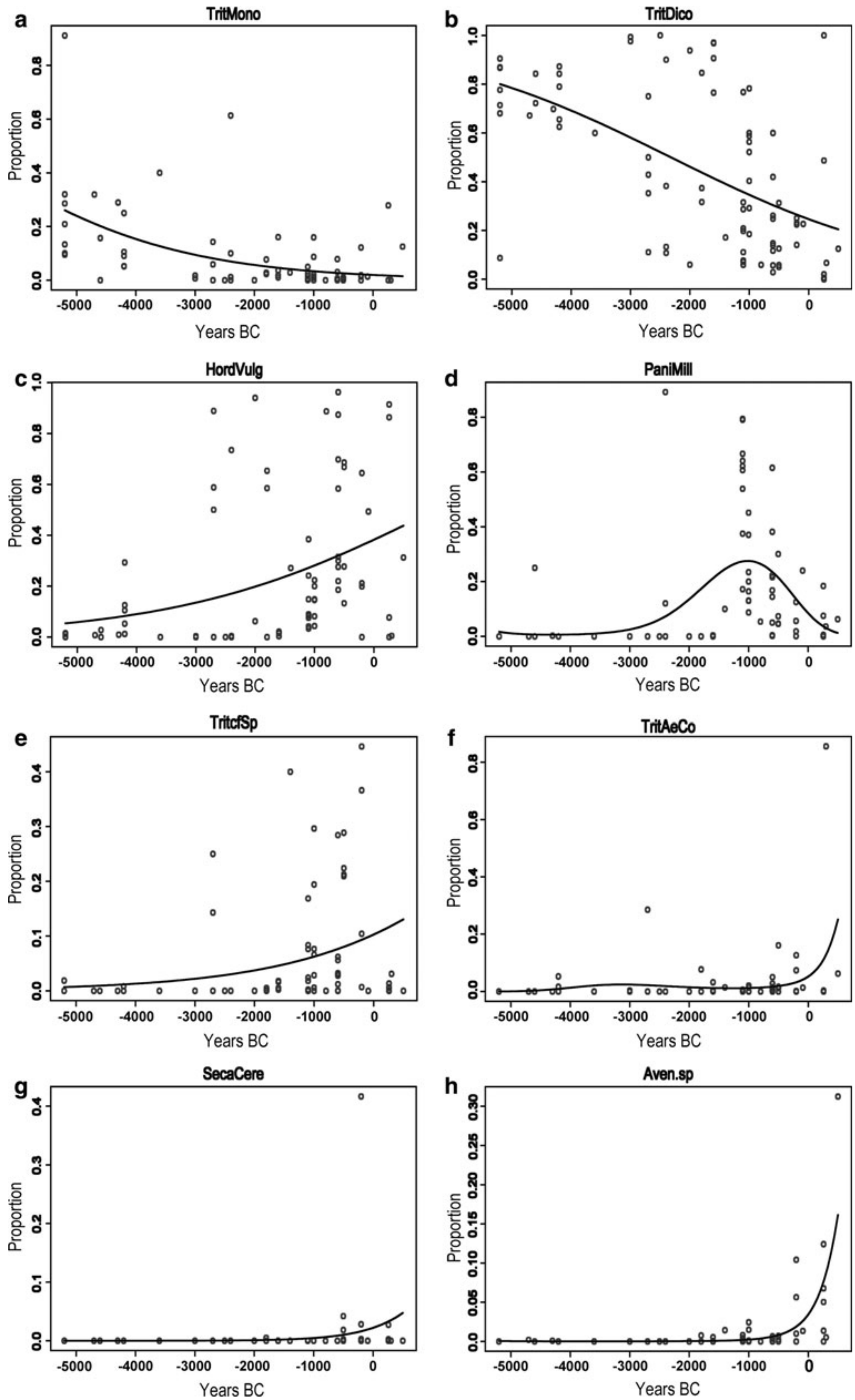

Fig. 3 Trends in the importance of individual cereals. Data were processed by generalized linear models (GLM) (McCullagh and Nelder 1989) implemented in S-plus version 4.5 (Statistical Sciences 1999). **a** *Triticum monococum*; **b** *T. dicoccum*; **c** *Hordeum vulgare* s.l.; **d** *Panicum miliaceum*; **e** *T. spelta*; **f** *T. aestivum/turgidum*; **g** *Secale cereale*; **h** *Avena* sp.

crops; also, *P. miliaceum* appears in considerable amounts. For the first time grain-rich finds of *T. spelta* and *T. aestivum/turgidum* appear. In the early Iron Age *T. dicoccum*, *Hordeum* and *P. miliaceum* prevail. A grain-rich sample of *Setaria italica* (L.) Beauv. (foxtail millet) was recorded for the first time. *T. aestivum/turgidum*, *Secale* and *Avena* occur as individual finds. In the Late Iron Age (La Tène period) the presence of *T. aestivum/turgidum* becomes more common. *Hordeum* is found in large amounts, and prevails together with *T. dicoccum* and *T. spelta*. Grain-rich finds of *Avena* (probably *A. sativa*) and *Secale* are also found. In the Roman period the dominant cereal is *Hordeum*, followed by *T. dicoccum* and *P. miliaceum*, *T. aestivum/turgidum*, *Secale* and *Avena*. There is a single find of *S. italica* from the Zlechov site. *T. aestivum/turgidum*, *Hordeum* and *T. dicoccum* are the most important cereals in the rare finds from the Migration Period.

The results of the statistical analysis by GLM (Fig. 3, Table S2) enable the division of the cereals into four groups according to their occurrence in time and help to clarify the relative importance of individual cereals through time:

The first group (I) includes taxa gradually decreasing in importance through time: archaic glume wheats—*Triticum monococcum* and *T. dicoccum* are assigned to this category (Fig. 3a, b). Both species vary in their proportions at prehistoric sites. In Fig. 3b it is clearly visible that *T. dicoccum* had absolute dominance among the cereals, especially in the earlier parts of prehistory. In contrast, *T. monococcum* never attained the same importance, with only a few exceptions.

The second group (II) is composed of taxa showing progressively increasing representation in the course of prehistory; these are *Hordeum* and *T. spelta* (Fig. 3c, e). Both taxa differ distinctively in their representation. In the earlier period until about 2000 B.C. *Hordeum* only appears in insignificant quantities; its importance increases considerably from the Early Bronze Age onwards. In contrast, *T. spelta* never attains any dominance among the cultivated cereals; it also increases in the later part of prehistory, above all, from the Late Bronze Age onwards, although not to the same extent as *Hordeum*.

The third group (III) includes taxa, the presence of which increases dramatically towards the end of prehistory (Late Iron Age, Roman and Migration periods): these are *T. aestivum/turgidum*, *Avena*, and *Secale*, and probably also *S. italica* (Fig. 3f, g, h). These taxa are present at the Czech prehistoric sites prior to the Late Iron Age only in very low numbers.

Finally, the last group (IV) covers *P. miliaceum* with a single distinct maximum occurrence in the Late Bronze and Early Iron Age (Fig. 3d). There is a noticeable chronological correlation between the "*P. miliaceum* period" and Urnfield cultures.

Discussion

Methodological problems associated with the first appearance of a cereal taxon

For most cereal taxa, the data show a significant discrepancy between the first appearance of individual finds of a taxon in the archaeobotanical assemblages and its first occurrence in grain-rich finds. It is not clear to what extent the rare presence of a cereal is the result of its role as a weedy admixture in prehistoric fields, as often mentioned in the literature (Behre 1992; Rösch 1997; Lityńska-Zając and Wasylikowa 2005; Kohler-Schneider and Caneppele 2009; Hajnalová 2012) or "accidental occurrence" (Bakels 2009). Alternatively, insignificant amounts of a crop in samples may be inferred as contamination during refuse disposal or a contamination after deposition (Jones and Halstead 1995). Movement and mixing of charred archaeobotanical material after its original deposition may be a result of various processes, such as mixing of contexts by ploughing and soil disturbance, and penetration by animals and root systems. A common way in which modern charred grains are introduced into the plough soil is seasonal stubble burning in the fields containing residues of dropped grains or unharvested spikes. Such a practice can still be found today (author′s personal experience from Slovakia). Besides, charred macroremains, usually kitchen waste, may be introduced into the field along with manure since at least the medieval period.

The observation made during the excavation of the Early Iron Age settlement site of Praha–Záběhlice can serve as a contribution to the general debate concerning such contaminations. All excavated settlement features were only of Hallstatt origin, based on the artefacts, and no traces of subsequent settlement or other activities, except for ploughing, were recorded. Archaeobotanical samples were taken from the features and cultural layers, but the plough soil above a certain pit was also deliberately sampled in order to determine a possible source of contamination. The feature fill contained only a range of cereals typical of the Early Iron Age: *P. miliaceum*, *Hordeum*, *T. dicoccum*, *T. monococcum* and *T. spelta*. Surprisingly, charred grains of the same taxa were also found in the plough soil accompanied by charred seeds typical of the medieval and post-medieval periods, such as *T. aestivum/turgidum*, *Secale* and *Avena* (Fig. 4). Ancient crop remains got into the plough soil presumably through ploughing of the Hallstatt cultural layers and the upper parts of the pit, which are archaeologically badly detected due to the mixing of dark plough soil and dark organic feature fill. Conversely, the infilling of the lower parts of the pit has not been affected by the rather shallow ploughing yet and therefore the charred remains of later cereal taxa such as *Secale*, *Avena* and *T. aestivum/turgidum* did not penetrate into the deeper layers of this feature. With the ongoing degradation of soil as well as the process of erosion within the site, such penetration would have been the case in the near future.

The question of the first appearance of selected cereal taxa and the start of their cultivation

Interpretation of the first appearance of particular cereal types is rather problematic. The re-examination of older

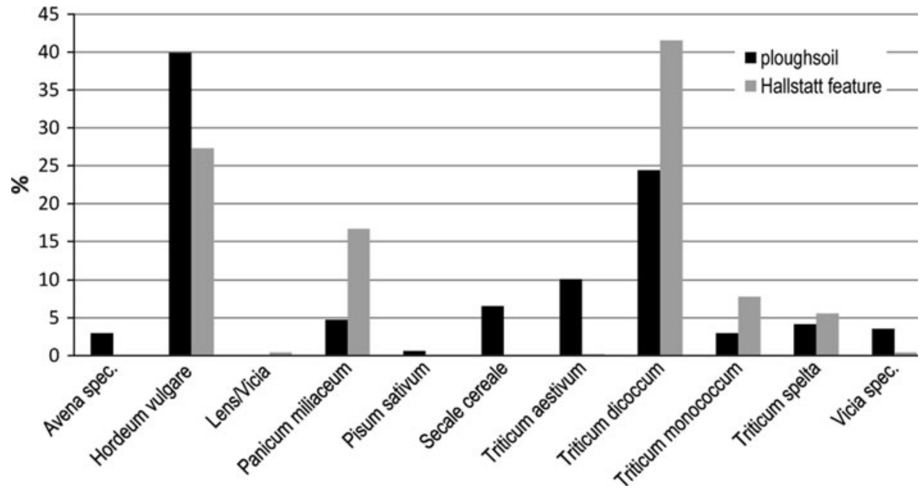

Fig. 4 Early Iron Age (Hallstatt Culture) site of Prague–Záběhlice. Appearance of cereal macroremains in Hallstatt period settlement feature fills (*grey*) and in plough soil (*black*). Numbers = proportion based on the numbers of grains; total number of the grains for the plough soil is 168, for the feature fills 450

finds suggests that some of the earlier identifications can be considered unreliable. Unfortunately, these are often cited in international literature. The credibility of the earliest finds of *Secale*, reported by Tempír (1979) has already been questioned by Hajnalová (in Wasylikowa et al. 1991) and Behre (1992). The data on the early records of *P. miliaceum* and *S. italica* millet by the same author (Tempír 1979) were recently cited by Hunt et al. (2008). However, none of the three sites cited in the latter study contain the earliest *P. miliaceum* finds. As a matter of fact the 13 grains from Březno near Louny (Early Neolithic LBK Culture) are not grains but only their imprints. The Early Neolithic Bylany site has no *Panicum* at all (data revisited) and at the Mohelnice site all archaeological contexts contain a mixture of three archaeological periods (Early Neolithic to Proto-Eneolithic), so all macro-remains can only be dated within the interval from 5600 to 3800 years B.C.

The newest finds of *P. miliaceum* in early archaeological contexts in the CR await radiocarbon dating [3 grains from Hulín–Pravčice II., 9 grains from Hulín I., both Moravian Painted Pottery I. (4700–4400 B.C.) and 10 grains from the Bell Beaker Moravian site Hulín–Pravčice II. (2500/2300 B.C.)]. Consequently the earliest clear evidence of *P. miliaceum* at present comes from a swamp site at Zahájí in northwest Bohemia dated to the Middle Bronze Age (radiocarbon date 1461–1383 B.C.), where a layer of uncharred *P. miliaceum* was discovered in a bog core sample (Bernardová 2009). This means that in the CR the first regular cultivation of *P. miliaceum* appears at about the same time as in the neighbouring countries (see below). The GLM *P. miliaceum* curve in the CR reminds one of the sudden appearances of a fashion fad and of its relatively quick demise thereafter (Fig. 3d).

At the middle Eneolithic site of Svodin-Busahegy, Slovakia, grains of *P. miliaceum* were found in such large numbers and at such high frequencies that cultivation as an individual crop may be suggested (Hajnalová 2007). In Slovakia, routinely, millet has been cultivated only since the Middle Bronze Age (Hajnalová 2012). Other early *P. miliaceum* finds near our region of investigation come from the sites of the Jevišovice Culture (3200–2800 B.C.) at the Kleiner Anzingerberg site in eastern Austria; grains were present frequently in the features. The archaeological situation there shows that *Panicum* was used as a regular crop. This would make it the oldest evidence for *P. miliaceum* cultivation in Austria (Kohler-Schneider and Caneppele 2009). In Poland occasional finds of *P. miliaceum* are known from the Neolithic onwards; larger (and pure) accumulations however appear much later, in sites of the Lusatian Culture ca. 1300–500 B.C. (Palmer 2004; Wasylikowa et al. 1991). Therefore it is rather difficult to specify the beginning of intentional cultivation within this time span. The earliest known occurrence of *Panicum* grains in Hungary also dates to the Neolithic (site at Zánka, Gyulai 2010), but within the Carpathian Basin *P. miliaceum* has been cultivated since the Middle Bronze Age (Gyulai 2010). *P. miliaceum* cultivation in Switzerland probably started in the Middle Bronze Age (Jacomet et al. 1998).

The sudden onset but short popularity of *P. miliaceum* in the CR lasted only for a few centuries. This corresponds with the development in France (Marinval 1992; Bouby et Marinval 2000; Matterne 2003; Ruas 2005; Bouby 2011). The decline of millet cultivation is also noticeable in the archaeobotanical data from southwestern Germany. Here the maximum presence values of *P. miliaceum* fall into the Bronze Age and the figures remain high until the Roman period. There was a marked and steady decrease afterwards (Rösch 1997). In Hessen, Germany, millet was one of the major crops in the La Tène period and dominated agriculture there. In Roman agriculture millet, as well *T. dicoccum*, tended to be of minor importance (Kreuz 2004). In Slovakia (Hajnalová 1999), Poland (Wasylikowa et al. 1991; Litynska-Zajac and Wasylikowa 2005) and possibly also in Austria (Schneider and Raunjak 1994; Kohler-

Schneider and Heiss 2010) and Switzerland (Jacomet and Brombacher 2009) the preference for *P. miliaceum* remained constant at least until the Late Iron Age, but most probably up until the medieval period. In conclusion, more data are needed in order to trace the history of *P. miliaceum* in Europe in more detail.

Another specific problem is the relatively late appearance of *Triticum spelta* (spelt) in the Czech record combined with its scarcity in all samples, especially those of the La Tène period. As Palmer (2004, p. 73) states, "The prevalence of *T. spelta* may be under-recorded since most previous identifications were based solely on grain morphology. In recent years, the validity of using only grains to identify wheat species has been questioned and chaff identification is generally considered more reliable". This may be the case for the Bohemian sites, because *T. spelta* begins to appear only in samples analysed in recent years by a new generation of specialists; there is a similar problem with the identification of *Triticum* "new type" or with *T. aestivum/turgidum*. Although the first individual finds of *T. spelta* in the CR are from the Neolithic, the earliest certain identification of *T. spelta* so far (including multiple glume bases) comes from the Middle Bronze Age Věteřov Culture (ca. 1650–1500 B.C.) site of Hulín I. In the regions around the CR, the earliest *T. spelta* finds are recorded in the Neolithic. The first finds of *T. spelta* glume bases (besides grains) are from the Neolithic Želiezovce Culture (ca. 5000–4700 B.C.) site of Bajč in Slovakia (Cheben and Hajnalová 1997; Hajnalová 2012). The first *T. spelta* in Austria was found at the Late Neolithic Jevišovice and Baden Culture sites (3600–2800 B.C.) in the form of some well-preserved chaff remains and less distinctive grains. These finds are still explained as unintentional admixtures to the crop (Kohler-Schneider 2007; Kohler-Schneider and Caneppele 2009).

It is at present possible to date the beginning of European *T. spelta* cultivation to approximately 2300 B.C., according to finds from the Swiss Bell Beaker site of Cortaillod/Sur les Rochettes-est (Akeret 2005). In the CR and neighbouring countries its intentional cultivation started later.

In Slovakia, *T. spelta* started being cultivated intentionally during the Late Bronze Age Lusatian Culture: the proportion of *T. spelta* grains in some features of this period reaches up to 60% (Hajnalová 1993). *T. spelta* and *P. miliaceum* were already of major importance at the Late Bronze Age site of Stillfried an der March, eastern Austria (Kohler-Schneider 2001). In Bavarian Early Bronze Age sites, apart from *Hordeum*, *T. spelta* occurred regularly as the second most important crop (Küster 1991). Since the Bronze Age until the end of the La Tène period these two cereals became staples in Bavaria (Kreuz 2006), southern Germany (Fischer et al. 2010), and in the La Tène period in Main-Franconia (Kreuz 2004). In contrast, this is not visible in the record from the CR, where it seems that the transition from *T. dicoccum* to *T. spelta* cultivation did not occur. *T. dicoccum* remained the dominant wheat crop in the CR during the whole of prehistory, despite its declining trend curve in the GLM model (Fig. 4b). If this is true, it must be confirmed by re-examination of the older finds, especially from the Iron Age *oppida*.

The first grain-rich finds of *T. aestivum/turgidum*, which may serve as evidence of intentional cultivation, appear in Czech assemblages in the late Bronze Age settlement sites of Roztoky (Kočár and Dreslerová 2010) and Loštice (Nekvasil and Opravil 1994). Similarly to *T. spelta*, cultivation of *T. aestivum/turgidum* appears rather late especially in comparison to regions more to the west, where the importance of *T. aestivum/turgidum* varieties was already high during the Early, Middle and Late Neolithic (see the compilation by Jacomet 2007). In Slovakia *T. aestivum/turgidum* has appeared regularly since the Early Middle Bronze Age. Storage finds which are supposed to be true evidence of cultivation are known only from the Late Bronze Age (Hajnalová 2012); the cultivation of *T. aestivum/turgidum* became common in the La Tène period. In Poland, *T. aestivum/turgidum* as an admixture in crops is known since the Neolithic, but the first rich finds are from Hallstatt Lusatian Culture sites, rather later than in the neighbouring countries (Lityńska-Zając and Wasylikowa 2005).

Conclusion

The method of evaluating the cereal finds from 279 prehistoric archaeological sites used in this study has proved suitable for a valuable reconstruction of the history of cereal cultivation in the CR, despite the fact that most samples were collected before the use of standardized flotation techniques. The gradual rise in diversity of the cultivated cereals over time (*Triticum dicoccum* and *T. monococcum*–*Hordeum*–*Panicum miliaceum*–*T. spelta* and *T. aestivum/turgidum*–*Secale* and *Avena*) corresponds well with the results of statistical analyses. The GLMs enabled the division of the cultivated taxa into four distinctive groups: the first consists of ones showing a gradual decrease in importance (*T. monococcum* and *T. dicoccum*), the second consists of crops with increasing representation on prehistoric sites (*Hordeum* and *T. spelta*) and the third consists of crops with a marked increase towards the end of prehistory (*T. aestivum/turgidum*, *Avena*, and *Secale*). The last group covers only *P. miliaceum*, demonstrating its individual position among other cereals.

In addition, we have tried to define clear criteria for the beginning of cultivation of each cereal taxon. In the literature, often the presence/absence of a taxon are the only data mentioned or the quantity of the finds may be referred to as "high density", "rather rich" or "high amounts". Consequently, it is difficult to say if a taxon was already cultivated or if it occurred in the archaeobotanical assemblages only accidentally. Problems may also appear due to the chronological differences in local dating of archaeological periods, cultures and cultural groups in various countries as well as the shortage of radiocarbon dates.

Despite these limitations, it can be stated that the development of prehistoric crop cultivation in Bohemia and Moravia is in accordance with the trends observed in the surrounding countries, Germany, eastern Austria, Slovakia, Hungary and Poland. The main differences with the Czech archaeobotanical assemblages are the late appearance of *Hordeum* cultivation, the rather marginal position of *T. spelta* among other prehistoric cereals and the relatively short popularity of *P. miliaceum*. We hope that these results will be supplemented in the future by new investigations in the CR, and also through a more intense international collaboration with the building up of databases.

Acknowledgments The study was funded by the Grant Agency of the ASCR, project no. M300020902 (Arbodat). For the statistical analysis we are grateful to Marek Bastl, for the graphics to Čeněk Čišecký, and to the reviewers for their comments and suggestions. Finally, we are very thankful to Malgorzata Latałowa for improving the manuscript and for editing the final version of the article.

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