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A comparison of early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities

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Abstract The spread of early agriculture from the Mediterranean to central Europe is still poorly understood. The new subsistence reached western central Europe during the second half of the 6th millennium cal B.C. This paper presents a comparison of crop and weed species from 33 Bandkeramik sites from Austria and Germany and six Bulgarian Neolithic sites. The aim is to investigate whether the early cultivation system brought in from the eastern Mediterranean was adapted to European conditions in Bulgaria or further West. Some characteristics of the potential weeds are interpreted with respect to the cultivation systems and the origin of the species.

Keywords *Early Neolithic - Bulgaria - Germany - Austria - Cultivation systems – Weeds*

Introduction

The introduction of early agriculture to central Europe is still not known in detail. The first „station" during the spread of this new subsistence outside the eastern Mediterranean is represented by the Early Neolithic of Bulgaria at the beginning of the 6th millennium cal B.C. The Bulgarian Neolithic lasted for about eleven hundred years (about 6000 to 4900 cal B.C.; Görsdorf and Bojadžiev *1996*). The new subsistence reached western central Europe during the second half of the 6th millennium cal B.C. (Lüning *2000*, p 5ff.; Stäuble *1995*; Stöckli *2002*, p 55). There, the earliest agricultural finds are of the Bandkeramik culture, also called Linearbandkeramik or LBK (Fig. 1). The changing ornamental style of the pottery allowed a differentiation of both cultures into phases (for the Bandkeramik, *Meier-Arendt 1966*; for the Bulgarian Neolithic see, for example Georgiev *1981*; Nikolov *2000*, *2002*, *2004*). For the following comparison it is important that the Late Neolithic of Bulgaria is contemporary with the whole Bandkeramik period (about 5400 to 4900 cal B.C.). The earliest Bandkeramik phase I lasted for about half the time span of the whole Bandkeramik culture (Stäuble *1995*; Stöckli *2002*, p 55).

From recent excavations in Bulgaria new archaeobotanical evidence is available (Marinova *2000*, *2001*; Marinova et al. *2002*; Popova *1995a*, *b*; Thanheiser *1997*). It allows a comparison of agricultural data from the Bulgarian Neolithic with that of the early Neolithic in Germany and Austria. This comparison offers the opportunity to investigate whether the early cultivation system brought in from Turkey and Greece was adapted to European conditions in Bulgaria or further West. The spread of the Neolithic to the western Mediterranean is not discussed in this paper.

Archaeological evidence

The Karanovo Culture, named after the famous tell site at the border of the Thracian plain, became a synonym for the Neolithic and Chalcolithic of Bulgaria (Fig. 1). Today, different regional groups are differentiated. They all have in common a similar settlement structure and architecture as well as a red-slipped pottery with white, later dark red, ornamentation (Georgiev *1981*; *Lichardus-Itten et al. 2002*; Nikolov *2000*, *2002*, *2004*; Todorova *1981*). In addition some early groups apparently produced monochromatic pottery (for a critical review see *Lichardus-Itten and Lichardus 2003*). In the following we will use the terms Early, Middle and Late Bulgarian Neolithic to avoid these group names.

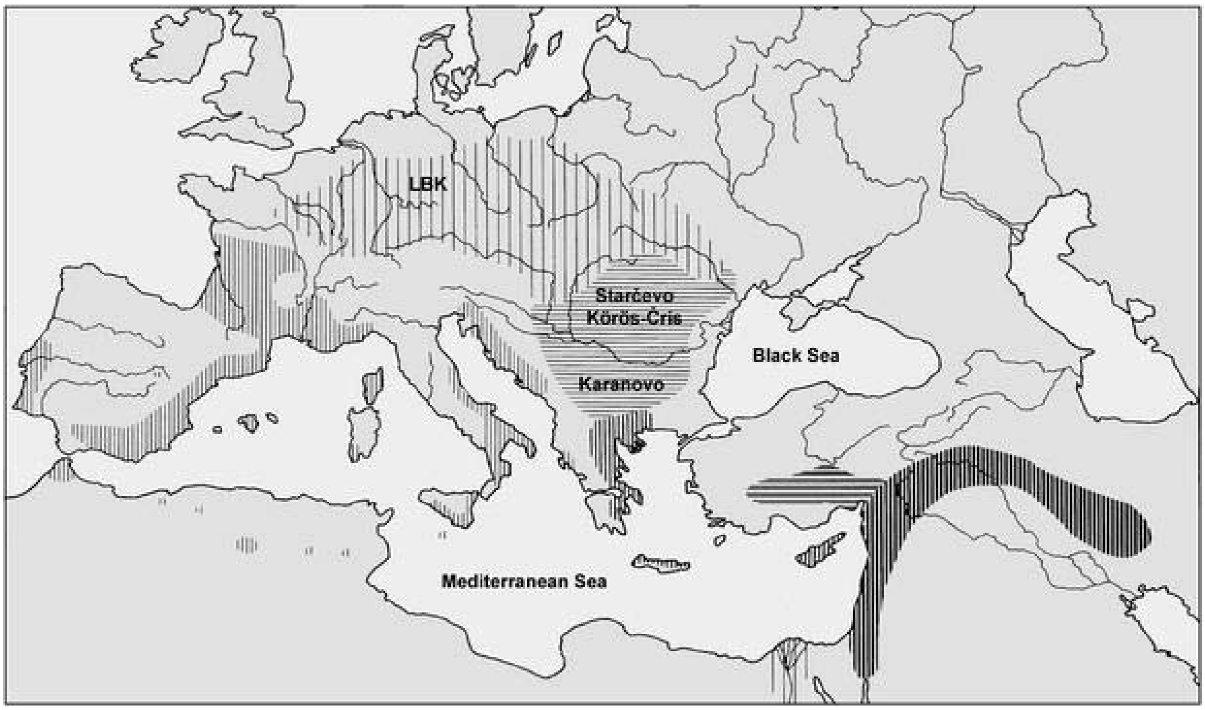

Fig. 1 Archaeological cultures at the beginning of the Neolithic from the Near East to western central Europe. Indicated are the area of the Bandkeramik culture at its maximum extension and the area of the Bulgarian Neolithic Karanovo culture and the Starčevo-Körös-Čris complex (modified from *Raetzel-Fabian 1988*, Fig. 15)

The first farmers of Bulgaria settled in the foothills around the Thracian plain and in those of south-western Bulgaria. Possibly the Struma valley played an important role during the introduction of Neolithic subsistence from Thessaly to Bulgaria (Perles *2001*; Nikolov *2004*). It is still a matter of dispute whether the new subsistence arrived from Greece exclusively or from Anatolia via Turkish Thrace or from both regions (for example Parzinger *1993*, p 84). The state of research does not allow a final statement concerning this question. Recent excavations, for example at the Early Neolithic site of Yabalkovo at the southern border of the Bulgarian part of the Thracian plain, will provide new insights into this subject (K. Leshtakov personal communication).

Finds of the earliest Bandkeramik have been made in a huge area of western central Europe. In the second part of the Bandkeramik from phase II to phase V (chronological phases based on the pottery after *Meier-Arendt 1966*) the distribution area became even larger (Lüning *2000*). Finds and settlements are spread between the Paris Basin and the Black Sea (Fig. 1).

Archaeological and botanical evidence points to western Hungary as the centre of Bandkeramik origin. This Hungarian Bandkeramik culture was possibly strongly influenced by the Neolithic Starčevo-Körös-Čris complex of eastern Hungary, Serbia and Romania (Fig. 1; Bánffy *2001*; Kalicz *2001*; *Lichardus-Itten and Lichardus 2003*; Lüning *1991*, *2000*; Lüning et al. *1989*).

Similarities and differences of both the Bandkeramik and the Bulgarian Neolithic cultures are reflected for example by the structures of settlements and buildings. In both early Neolithic cultures the houses were built with a timber framework. This is an important difference to the mud-brick houses of Greece and Turkey (Parzinger *1993*, pp 294ff.; Perles *2001*, pp 172ff.). The Bandkeramik sites are open flat settlements each comprising just a few houses. The houses were about 30 m long and 6 m wide. There are postholes and wall-ditches as well as some pits (see papers in Eckert et al. *2003*), but the ground surface is eroded, so that the house floors are not preserved. In contrast to the Bandkeramik, the Bulgarian Neolithic sites are either multilayer flat settlements or tell sites (Georgiev *1961*, *1981*; Hiller *1993*; *Lichardus-Itten et al. 2002*; Todorova *1981*, Todorova and Vaissov *1993*). It is still open to discussion why some Neolithic settlements in Bulgaria stopped gaining height before becoming a real tell.

In both areas botanical material can be recovered from rubbish pits. In addition, in Bulgaria, culture layers of levelled houses as well as ground floors of buildings and their surroundings are preserved *in situ* as they have been covered by layers of settlement waste. The latter are the places where the storage finds or other massive concentrations of plant remains can be found, if the house had burnt down (Dennell *1978*; Dotcheva *1990*; Marinova *2001*; Thanheiser *1997*; Tschakalova and Božilova *2002*; Tschakalova and Sârbinska *1986*).

In contrast to Bandkeramik settlements characterized by single standing long-houses, the Bulgarian Neolithic villages consist of rows of houses (Georgiev 1961, 1981; Hiller 1993; Lichardus-Itten et al. 2002; Todorova 1981, Todorova and Vaissov 1993). The Bulgarian Neolithic rectangular houses were about one third the size of the Bandkeramik long-houses. All these differences have important social implications (Parzinger 1993, p 295). They could imply for example different family or group sizes and structures.

Ecological conditions

The first farmers of both cultures - the Bulgarian Neolithic and the Bandkeramik - settled in landscapes very well suited for agriculture. In Bulgaria these are mostly regions with brown soils (Cambisols) and a sub-Mediterranean to sub-continental climate. Present-day average mean temperature covers the range between 10 and 14°C, average precipitation—with two maxima, the main in May/June and a secondary one in November/December—between 500 and 700 mm (Egger *1997*; Horvat et al. *1974*; N. Ninov *2002*; Velev *2002*; Kopralev *2002*).

In Germany and Austria the landscapes settled first were mostly characterized by Chernozem soils, developed from loess or fluvial sediments, and by today's warm and dry climate. Present-day average mean temperature lies between 7 and 9°C, average precipitation - with a maximum during (June/)July/August—between 550 and 650 mm (Bakels 1978; Kreuz 1990, p 7ff.; Lüning 2000; Sielmann 1971). High lake levels could be interpreted as signs of a wetter climate in central Europe at that time. This might have been induced by precipitation, possibly in form of heavy rainfalls (Beug et al. 1999; Bouzek 2001; Haas et al. 1998; Hormes et al. 2001; Kalis et al. 2003; Kreuz 1990, p 8; Magny 1998; Maise 1998; Schmidt and Gruhle 2003; Spurk et al. 2002).

The reconstruction of the temperatures around 6000 b.c. suggests that in south-eastern Europe the mean winter temperatures might have been almost at today's level and the summer temperatures were slightly lower than today. Cooler and wetter conditions than today are discussed (Davis et al. *2003*).

Landscapes of both areas have been reconstructed by palynologists and anthracologists as more or less densely wooded. As in central Europe, early Neolithic human impact is difficult to trace by pollen analysis in Bulgaria, as there are only weak signals indicating cultivation. In both regions this might be due to the fact that the deposits analyzed are not adjacent to the settlements and fields, and the former woodland canopy had acted as a pollen filter.

In Bulgaria, pollen diagrams are available from the hilly zones and the higher mountain areas. Only very few diagrams cover the early and middle Holocene (e.g. Božilova et al. 1996; Huttunen et al. 1992; Filipovitch 1996; Filipovitch and Lazarova 2001, p 170, Fig. 2; Stefanova and Ammann 2003; Tonkov and Božilova 1992). The regions settled by the first farmers were dominated by thermophilous to mesophilous and submediterranean to subcontinental bitter oak forests as well as mixed forests with Quercus cerris, Q. petraea, Q. frainetto, Q. pubescens, Carpinus orientalis and Fraxinus ornus (see also Bohn et al. 2003, „Klimatyp VI").

In Germany and Austria, the forest cover was also formed by deciduous woodland of comparable species to those in Bulgaria like Quercus petraea and Q. robur, Fraxinus excelsior, Ulmus sp., Tilia sp. Acer sp. and others (Bakels 1978; Beug 1986, 1992; Kreuz 1990 pp 17ff., 1995, in press a; Liese-Kleiber 1997; Litt 1990; Schäfer 1996; Schweizer 2001; Van Zeist 1967; Van Zeist and Van der Spoel-Walvius 1980). There are different opinions concerning for example the percentages of Quercus (oak) and Tilia (lime) trees and other woodland species or the kind of woodland cover of the flood plains, but this subject is not of interest here. In our investigation areas, the forest cover on Chernozems was formed by deciduous woodland. The results of charcoal analysis can be interpreted as managed hedges serving as supply of firewood (Groenman-van Waateringe 1970; Kreuz 1988, 1992).

Archaeozoological investigations from settlements of both cultures revealed that the spectra of domestic and wild animal species are comparable (Arbogast et al. 2001; Benecke and Ninov 2002; Kovachev and Georgiev 2002; Ninov 1992, 1999). It is difficult to estimate what was the main domestic animal at the different sites. This is due to the fact that preservation of bones differs not only between sites but also within one single excavation area due to changing soil conditions. It has to be stressed that there is no dominance of sheep or goat detectable in either region.

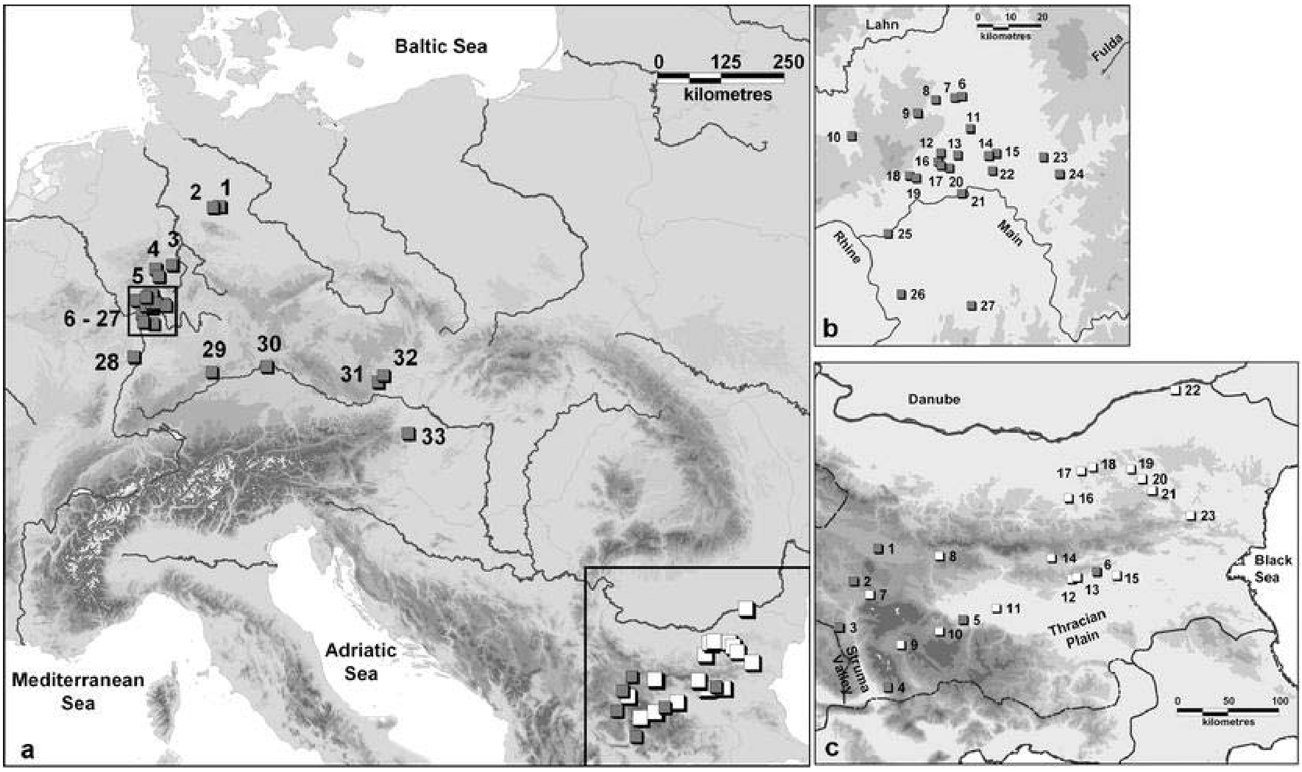

Fig. 2 German and Austrian Bandkeramik and Bulgarian Neolithic sites mentioned in the text. **a, b** Archaeobotanically investigated Bandkeramik sites in **Germany** and **Austria**. *Northern Harz area*: **1** Eitzum, **2** Klein Denkte; *Hessen*: **3** Wernswig, **4** Bracht, **5** Mardorf 23, **6** Steinfurth, **7** Nieder-Mörlen, **8** Fauerbach, **9** Usingen, **10** Würges, **11** Bruchenbrücken, **12** Ober-Erlenbach, **13** Kloppenheim, **14** Windecken, **15** Ostheim, **16** and **17** Nieder-Eschbach (AK2, AK123), **18** Kronberg, **19** Niederhöchstadt, **20** Harheim, **21** Fechenheim, **22** Mittelbuchen, **23** Niedergründau, **24** Hailer, **25** Raunheim, **26** Goddelau, **27** Wembach-Hahn; *Pfalz* (*Palatinate)*: **28** Herxheim; *Nördlinger Ries*: **29** Enkingen; *Danube valley*: **30** Mintraching; *Waldviertel/ Austria*: **31** Rosenburg, **32** Strögen; *Burgenland/Austria*: **33** Neckenmarkt. **c** Archaeobotanically investigated Neolithic sites in **Bulgaria**. Sites studied by E. Marinova are indicated in grey. **1** Slatina, **2** Gâlâbnik, **3** Drenkovo Plosteko, **4** Kovačevo, **5** Kapitan Dimitrievo, **6** Karanovo, **7** Sapareva Banya – Kremenik, **8** Čavdar, **9** Elešnica, **10** Rakitovo, **11** Yassa Tepe, **12** Okrâžna bolnica, **13** Azmak, **14** Kazanlâk, **15** Ezero, **16** Samovodene, **17** Orlovec, **18** Koprivec, **19** Drinovo, **20** Podgorica, **21** Poljanica Platoto, **22** Malâk Preslavec, **23** Vesselinovo. For references see Table 1

Archaeobotanical dataset

In Bulgaria, 23 Neolithic sites have been investigated archaeobotanically to date (Fig. 2c; for references see Table 1). The assemblages of crops are almost identical at the different sites. The following calculations are based on the data available from six recent excavations (Table 2). Some weed taxa were not included, because their occurrence in Neolithic sites from Bulgaria needs to be confirmed.

Figures 2a and b show the location of the 33 Bandkeramik settlement sites investigated archaeobotanically. Determinations have been carried out by Nicole Boenke (Götzis, Austria), Angela Kreuz, Elena Marinova, Ursula Thanheiser (Wien, Austria) and Julian Wiethold. The data from Hesse, northern and southern Germany and south-western Austria are methodologically comparable to each other. Therefore all data have been included in the following evaluation which has been carried out with the help of our archaeobotanical database programme ArboDat (Kreuz and Schäfer 2002; for the explanation of terms see also there). As it is often difficult to differentiate the Bandkeramik phases III to V based on fragmentary pottery finds, we combined the archaeobotanical results into one later Bandkeramik group LBK III–V. Features which could not be dated archaeologically more exactly than phases „LBK IIff.“ or „LBK II/III“ are not included in the calculations.

Due to the soil conditions in settlements of both cultures plant remains are preserved by charring or mineralization only. The contexts sampled at the Bulgarian Neolithic sites are often not „real“ archaeological features but parts of bigger stratigraphic units such as layers or floors. There the squares excavated were taken as context units or „features“.

Early Bulgarian Neolithic 1	
Azmak (13)	Hopf 1973
Elešnica (9)	Dotcheva unpubl.
Gâlâbnik (2)	Marinova et al. 2002
Karanovo (6)	Arnaudov 1938; Thanheiser 1997
Koprivec (18)	Marinova unpublished
Kovačevo (4)	Popova 1992; Thiébault 1997; Marinova 2000
Orlovec (17)	Marinova unpublished
Poljanica Platoto (21)	Hopf 1988
Slatina (1)	Dotcheva 1990
Early Bulgarian Neolithic 2	
Azmak (13)	Hopf 1973
Čavdar (8)	Hopf 1973; Dennel 1978
Kapitan Dimitrievo (5)	Arnaudov 1949; Hopf 1973; Marinova 1999, 2001
Karanovo (6)	Hopf 1973; Renfrew 1973; Thanheiser 1997
Kovačevo (4)	Marinova 2000, 2001
Malâk Preslavec (22)	Panayotov et al. 1992
Okrâžna Bolnica (12)	Lisitzyna and Lestnikova unpubl. in Lisitzyna and Filipovitch 1980
Rakitovo (10)	Tschakalova and Božilova 2002
Sapareva Banya/Kremenik (7)	Tschakalova and Sârbinska 1986
Slatina (1)	Marinova 2001
Middle Bulgarian Neolithic	
Karanovo (6)	Hopf 1973; Marinova 2001, 2002
Kazanlâk (14)	Hopf 1973
Samovodene (16)	Marinova unpublished
Late Bulgarian Neolithic	
Azmak (13)	Hopf 1973; Renfrew 1979
Drenkovo-Ploshteko (3)	Marinova 2001
Drinovo (19)	Popova 1995b
Ezero (15)	Hopf 1973
Kapitan Dimitrievo (5)	Marinova 1999, 2001
Karanovo (6)	Arnaudov 1936; Arnaudov and Vassileva 1948; Popova 1995a; Thanheiser 1997; Marinova 2001, 2002
Kazanlâk (14)	Hopf 1973; Dennel 1978
Podgorica (20)	Popova 1995b
Samovodene (16)	Marinova unpublished
Vesselinovo (23)	Arnaudov 1936
Yassa tepe (11)	Hopf 1973; Renfrew 1973

Table 1 Archaeobotanical studies of 23 Neolithic sites in Bulgaria (after Marinova *2001*). Numbers refer to the location of the sites in Fig. 2c; for references see the bibliography

Sample contents from both cultures represent something called „background or noise“ (Bakels *1991*, p 281). There are always charred mixtures of crop remains of several species and of by-products and waste. In the case of so-called storage finds we are possibly dealing with residues of accidents caused by fire. Storage finds occur in 27 Bulgarian Neolithic and two Bandkeramik features (Tables 2 and 3). Due to the occurrence of storage finds there, the number of plant remains identified is comparatively high at the Bulgarian sites (Table 2).

Site	phase	number of features	number of samples	volume of samples	number of taxa	number of plant remains	number of features with storage finds	number of plant remains in storage finds	average concentration of plant remains per feature, storage finds excluded	References
Kovačevo	Early Neolithic I	6	26	481	61	2301			6,22	Marinova (2001)
Slatina	Early Neolithic I	5	22	233	51	4945			31,66	Marinova (2001)
Gâlâbnik	Early Neolithic I	3	3	100	17	695			7,41	Marinova (2001)
Karanovo I	Early Neolithic I	7	20	449	34	2484			4,10	Thanheiser (1997)
Kapitan Dimitrievo	Early Neolithic II	15	37	304	85	67813	7	60524	29,60	Marinova (2001)
Karanovo II	Middle Neolithic	14	40	694	42	3724			17,88	Thanheiser (1997)
Karanovo II-III	Late Neolithic	3	9	114	68	2783			26,32	Marinova (2002)
Karanovo III	Late Neolithic	24	48	263	78	130881	20	126350	20,91	Thanheiser (1997); Marinova (2001, 2002)
Karanovo III-IV	Late Neolithic	8	12	178	40	3159			17,86	Marinova (2001, 2002)
Karanovo IV	Late Neolithic	2	5	76	32	1823			24,22	Marinova (2001, 2002)
Kapitan Dimitrievo	Late Neolithic	2	14	275	62	3905			14,00	Marinova (1999, 2001)
Drenkovo-Ploshteko	Late Neolithic	4	6	105	24	1179			13,12	Marinova (2001)
total		93	242	3272	/	225692	27	186874	/	

Table 2 The archaeobotanical dataset from six Bulgarian sites used in this study

It has to be mentioned that post-holes and ditches contain very few or mostly no plant remains at Bandkeramik sites. Their density of plant remains is not comparable with that of pits, which—in their last function—were used for deposition of settlement waste. Therefore concentration values are based on samples from pits only (Table 3) and are always calculated without storage finds (66 Bulgarian Neolithic, 458 Bandkeramik features). The other calculations are based on samples from 93 Bulgarian Neolithic and 494 Bandkeramik features (see Tables 2 and 3).

Figure 3a shows the average concentration of plant remains per feature or context calculated for Bulgarian Neolithic and Bandkeramik sites. Grey bars represent only seeds, white bars show values for chaff. The apparently low average concentration values of chaff from both regions are similar to those from Iron Age and Roman sites in Hessen (*Kreuz in press b*), so they are „normal“ within a usually observed range. On the contrary, it is only in Bandkeramik phase II and to a certain degree phases III–V that the values are extremely high (see also Fig. 3b; for the discussion see *Kreuz in press a*).

Surprisingly, the seed concentrations of the two areas resemble each other. Extremely low seed concentration values occur only at sites of Bandkeramik phase I (Fig. 3a). Due to unknown reasons, fewer charred seeds were deposited in pits at that time.

The samples are rarely sufficiently rich in crops and weeds for statistical analysis. In addition they almost never derive from a single crop species or crop processing stage. So we are dealing with mixtures of crop remains and by-product material, waste and residues caused by accidents involving fire which were found in open contexts. For all these reasons and due to the different state of research and the different datasets of our Bandkeramik and Bulgarian Neolithic sites, the following comparison has to be more of a qualitative character.

Site code	site	LBK-phase	total number of features	number of features (pits only)	total number of samples	number of samples (pits only)	total volume of samples	volume of samples (pits only)	total number of taxa (plant-codes)	number of taxa (plant-codes), pits only	total number of plant remains	number of plant remains (pits only)	average concentration of plant remains per pit (storage finds excluded)
AK1 BB	Bruchenbrücken, Friedberg (11)	LBK I	22	19	206	179	4127	3630	38	38	109113	109000	7,68
AK2 NES	Nieder-Eschbach, Frankfurt (17)	LBK I	127	127	144	144	2799	2799	18	18	1341	1341	0,49
AK3 GO	Goddelau, Riedstadt (26)	LBK I	5	5	67	67	1370	1370	16	16	5974	5974	1,36
AK7 SU2	Steinfurth, Bad Nauheim (6)	LBK I	3	3	59	59	811	811	23	23	5083	5083	3,75
AK66 MB	Mittelbuchen, Hanau (22)	LBK I	6	6	12	12	158	158	17	17	217	217	1,04
AK167 NIO	Ostheim, Nidderau (15)	LBK I	7	4	9	6	50	24	9	8	254	204	5,85
AK184 WÜ1	Würges, Bad Camberg (10)	LBK I	29	25	48	42	499	441	30	28	17501	17473	32,16
AK2001 EI 2	Eitzum, Schöppenstedt (1)	LBK I	6	3	113	108	2174	2101	34	34	17812	17606	7,52
AK2002 KD	Klein Denkte, Denkte (2)	LBK I	3	3	19	19	320	320	7	7	87	87	0,23
AK2003 EN1	Enkingen (29)	LBK I	3	3	100	92	1742	1731	18	18	11076	11076	9,32
AK2004 MT1	Mintraching (30)	LBK I	2	2	107	106	1816	1816	23	23	373	373	0,19
AK2005 RB1	Rosenburg (A) (31)	LBK I	7	7	55	55	1100	1100	9	9	78	78	0,06
AK2006 ST1	Strögen (A) (32)	LBK I	7	7	37	37	695	695	7	7	62	62	0,04
AK2007 NM1	Neckenmarkt (A) (33)	LBK I	4	4	32	32	772	772	13	13	1932	1932	2,31
AK1 BB	Bruchenbrücken, Friedberg (11)	LBK II	2	2	11	11	201	201	10	10	866	866	4,81
AK114 HAR 6	Harheim, Frankfurt (20)	LBK II	8	8	10	10	328	328	14	14	553	553	1,08
AK123 NES	Nieder-Eschbach, Frankfurt (16)	LBK II	16	16	26	26	275	275	64	64	78719	78719	177,64
AK134 NM	Nieder-Mörlen, Bad Nauheim (7)	LBK II	35	30	56	47	519	437	69	65	41314	41112	134,94
AK175 OE1	Ober-Erlenbach, Bad Homb. (12)	LBK II	17	13	36	31	366	313	33	32	4882	4776	16,80
AK1 BB	Bruchenbrücken, Friedberg (11)	LBK III-V	9	9	88	88	2287	2287	76	76	6950	6950	3,08
AK27 RAU	Raunheim (25)	LBK III-V	2	2	5	5	36	36	14	14	448	448	9,75
AK33 FEC 14	Fechenheim, Frankfurt (21)	LBK III-V	20	20	48	48	899	899	57	57	18074	18074	24,37
AK41 EBN	Niederhöchstadt, Eschborn (19)	LBK III-V	1	1	1	1	32	32	42	42	13404	13404	/
AK49 NIGRÜ	Niedergründau, Gründau (23)	LBK III-V	5	5	7	7	166	166	21	21	1031	1031	6,70
AK57 KLOK	Kloppenheim, Karben (13)	LBK III-V	5	5	8	8	215	215	21	21	928	928	6,60
AK66 MB	Mittelbuchen, Hanau (22)	LBK III-V	43	41	49	45	498	460	41	41	3469	3435	7,27
AK76 WINI	Windecken, Nidderau (14)	LBK III-V	3	3	3	3	1	1	9	9	67	67	67,19
AK84 GH	Hailer, Gelnhausen (24)	LBK III-V	2	2	3	3	47	47	31	31	6524	6524	66,41
AK85 MAR23	Mardorf, Amöneburg (5)	LBK III-V	2	2	2	2	10	10	7	7	36	36	3,60
AK99 US1	Usingen (9)	LBK III-V	19	16	85	52	1070	509	62	49	24985	10550	16,34
AK102 KRON	Kronberg/Taunus (18)	LBK III-V	1	/	12	/	164	/	16	/	263	/	/
AK134 NM	Nieder-Mörlen, Bad Nauheim (7)	LBK III-V	18	18	21	21	209	209	55	55	43852	43852	193,96
AK152 HERX	Herxheim/Landau (28)	LBK III-V	9	7	81	10	689	26	66	19	5468	752	21,27
AK154 FAU	Fauerbach v. d. H., Butzbach (8)	LBK III-V	35	32	46	43	515	457	68	68	17833	17101	24,56
AK168 WEM	Wembach-Hahn, Ober-Ram. (27)	LBK III-V	1	1	3	3	30	30	22	22	1931	1931	64,37
AK176 WW	Wernswig, Homberg (Efze) (3)	LBK III-V	5	3	12	10	115	97	30	30	1075	1017	9,71
AK194 BRA	Bracht, Rauschenberg (4)	LBK III-V	5	4	6	4	107	88	22	22	1208	1199	18,65
total			494	458	1627	1436	27210	24888	/	/	444783	423831	/

Table 3 The archaeobotanical dataset from 33 Bandkeramik sites in Germany and Austria used in this study. Numbers refer to the location of the sites in Fig. 2a, b. Plant codes of taxa are counted according to the archaeobotanical database program ArboDat (Kreuz and Schäfer 2002)

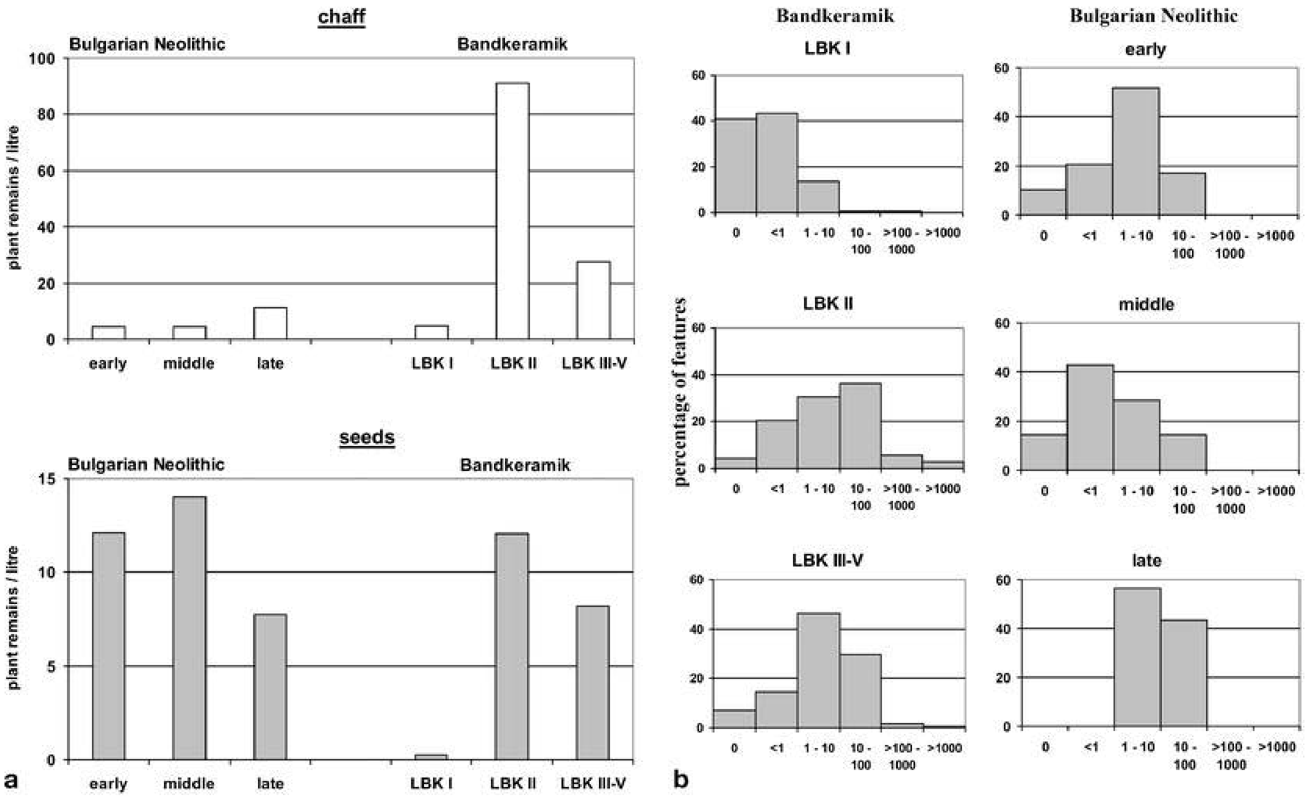

Fig. 3 **a** Average concentration of chaff and seeds per feature or context calculated for the Bulgarian Neolithic and for the Bandkeramik sites. **b** Percentage of features with different ranges of chaff concentrations (number of chaff remains per litre)

Crop species

We may assume that crops were a major component of early Neolithic nutrition in both cultures. Local production is expected for all sites investigated. Cultivated species occurring as solitary finds only are not interpreted as intentionally grown crops. At Bulgarian Neolithic sites these are *Panicum miliaceum* (broomcorn millet) and *Coriandrum sativum* (coriander) (Table 4, Fig. 13). At Bandkeramik sites these are *Hordeum* sp. (barley), *Panicum miliaceum* (broomcorn millet), *Secale cereale* (rye), *Vicia ervilia* (bitter vetch) and *Vicia faba* (Celtic bean) (Table 5, Fig. 13). These single finds are interpreted as weeds which were introduced in seedcorn. Nevertheless they are interesting for considerations concerning supra-regional contacts.

The range of cultivated crop species is different in the two cultures (Tables 4–6). The Bandkeramik assemblage comprises five crop species only: *Triticum dicoccum* (emmer) and *T. monococcum* (einkorn) (partly of a two-seeded form: Kreuz and Boenke *2002*, for Bulgaria: Marinova *2001*; see also Tables 4 and 5), *Pisum sativum* (pea) and *Lens culinaris* (lentil) as well as *Linum usitatissimum* (flax). At one earliest Bandkeramik site (AK184 Bad Camberg-Würges, unpubl.) and one Bulgarian Neolithic site (Karanovo 99/23) glume bases of the „new type“ wheat have been found (Fig. 13; for identification criteria, see Jones et al. *2000*; *Kohler-Schneider 2003*).

There are some hints given by storage finds, that einkorn and emmer were sometimes grown as maslins (mixed crops) by Bandkeramik as well as Bulgarian Neolithic farmers, partly even together with pea (*Kreuz in press a*; Marinova *2001*, p 98; for the general discussion of maslins see Jones and Halstead *1995*). In addition, the Bandkeramik farmers maintained lentil and flax fields. *Papaver somniferum* (opium poppy) is not recorded before Bandkeramik phase II. It may point to direct or indirect contacts with the western Mediterranean (Bakels *1982*; Kreuz *1993*). Opium poppy is absent from all Balkan Neolithic sites.

Site	phase	Hordeum distichon/vulgare	Hordeum vulgare, hulled barley	Hordeum vulgare, naked barley	Hordeum distichon/vulgare	Triticum aestivum s.l./durum/turgidum	Triticum aestivum s.l./durum/turgidum	Triticum dicoccum	Triticum dicoccum	Triticum monococcum	Triticum monococcum, two-grained	Triticum monococcum	Triticum monococcum/dicoccum	Triticum monococcum/dicoccum	Triticum spec., hulled wheat	Triticum spec.	Panicum miliaceum	Cerealia indet.	Cicer arietinum	Lathyrus sativus/cicera	Lens culinaris	Pisum sativum	Vicia ervilia	Fabaceae indet., cultivated	Linum usitatissimum	Coriandrum sativum
		gr	gr	gr	ra	gr	ra	gr	gb	gr	gr	gb	gr	gb	gb	gr	gr	gr	s	s	s	s	s	s	s	fr
Kovačevo	**Early Neolithic I**	38			6	2	6	100	616	58		276			306	130				104	44	11	5	26		
Slatina	**Early Neolithic I**	24	74	11		117		1158	412	334		160			172	205				78	1245	76	14		6	
Gâlâbnik	**Early Neolithic I**	34				5		156		75						19			350	1	29	8	3			
Karanovo I	**Early Neolithic I**	252	44	3	42	15		229	2	57	40	92	18	189	226	121		508		71	134		200			
Kapitan Dimitrievo	**Early Neolithic II**	307	2515	1364	1316	10	42	17085	1066	18187	5001	944			318	6967				9259	73	607	18			
Karanovo II	**Middle Neolithic**	72	30		4	2	1	178	958	81	46	92	35	135	352	213		637		20	244		15			
Karanovo II-III	**Late Neolithic**	77	8		32	2	13	277		392	24	1130			226	84				3	65	3	33	7	4	
Karanovo III	**Late Neolithic**	98	64	4741	74	21	62	55551	80	19477	2694	1988	1		690	5106		10		2627	2539	14020	19454	10	2	
Karanovo III-IV	**Late Neolithic**	62			30	7	38	347		324	27	1512			362	126				5	29	1	50	3	2	
Karanovo IV	**Late Neolithic**	19			8	1	11	177		62	4	1162			212	28				1	30		5			
Kapitan Dimitrievo	**Late Neolithic**	41	27	29	49	4	37	138	486	211	24	1546			172	81				43	42	1	33	8		6
Drenkovo-Ploshteko	**Late Neolithic**	5						46	116	73	9	172			340	52	4			242	30	4				

Table 4 Archaeobotanical records of cultivated plants from six Neolithic sites in Bulgaria (see also Table 2 and Fig. 2)

Site code	site	LBK-phase	Triticum dicoccum	Triticum dicoccum	Triticum dicoccum/spelta	Triticum dicoccum/spelta	Triticum monococcum	Triticum monococcum, 2-grained	Triticum monococcum	Triticum monococcum	Triticum monococcum/dicoccum	Triticum monococcum/dicoccum	Triticum monococcum/dicoccum	Triticum spec., hulled wheat	Triticum spec., hulled wheat	Triticum spec.	Hordeum distichon/vulgare	Hordeum distichon/vulgare, naked barley	Panicum miliaceum	Secale cereale	Secale cereale	Cerealia indet.	Cerealia indet.	Cerealia indet.	Lens culinaris	Pisum sativum	Vicia ervilia	Vicia faba	Fabaceae indet., cultivated	Linum usitatissimum	Papaver somniferum
			gr	gb	gb	gr	gr	gr	gb	ra	gr	gb	ra	gb	ra	gr	gr	gr	gr	gr	ra	gr	ra	no	s	s	s	s	s	s	s
AK1 BB	Bruchenbrücken, Friedberg	LBK I	572				354				451	103645				1				1		2261	182		226	34					
AK2 NES	Nieder-Eschbach, Frankfurt	LBK I	5				1				2	1069										207			2	2					
AK3 GO	Goddelau, Riedstadt	LBK I	53				14				32	5708					2		1			124			1	2					
AK7 SU2	Steinfurth, Bad Nauheim	LBK I	3	433			4	1	1482			815		2043	87							120	1		10	2			13	11	
AK66 MB	Mittelbuchen, Hanau	LBK I	1	25					52			53		48	2	1						12							1		
AK167 NIO	Ostheim, Nidderau	LBK I	9	23			1		27		4	146			4	6						31				1					
AK184 WÜ1	Würges, Bad Camberg	LBK I	22	1780			12		3416		16	10928		68	908	19	4				3	192		1	5	3					
AK2001 EI2	Eitzum, Schöppenstedt	LBK I	61				9				45	16051					3		1			1026			3	5				49	
AK2002 KD	Klein Denkte, Denkte	LBK I	1									38										34									
AK2003 EN1	Enkingen	LBK I	112				19				74	9437					9					1326			20					1	
AK2004 MT1	Mintraching	LBK I					1				2	134					6		1			178			9				3		
AK2005 RB1	Rosenburg (A)	LBK I	1								1	14										43									
AK2006 ST1	Strögen (A)	LBK I										6										44				1					
AK2007 NM1	Neckenmarkt (A)	LBK I	22				11				17	1422										439			3						
AK1 BB	Bruchenbrücken, Friedberg	LBK II	2				1					834				1						17									
AK114 HAR6	Harheim, Frankfurt	LBK II	49				18	15			64	170				11						167			3	3					
AK123 NES	Nieder-Eschbach, Frankfurt	LBK II	296	12826			566	178	40108	1	624	19589	16				16					366			29	8			4	196	
AK134 NM	Nieder-Mörlen, Bad Nauheim	LBK II	26	3590			89	5	13968		13	2646		13576	348	16						1392	3		19	5			5	31	34
AK175 OE1	Bad Homburg v. d. H.	LBK II	203	523			32		382		353	1949			18	346						808			3	6			1	1	
AK1 BB	Bruchenbrücken, Friedberg	LBK III-V	145				66				30	4141				1	4		1	1		658	1		137	37		1		21	2
AK27 RAU	Raunheim	LBK III-V	3	15			14	2	63		9	151			1	3						60				48			69		
AK33 FEC14	Fechenheim, Frankfurt	LBK III-V	21	474			38	1	1744		140	8619			73	31			1			1295		2	38	3			27	7	1
AK41 EBN	Niederhöchstadt, Eschborn	LBK III-V	146	1537		5	1078	373	2531	20	34	2355		856	131	63						461			2	415			1478		
AK49 NIGRÜ	Niedergründau, Gründau	LBK III-V	13	14			13		26		4	253				57						227				4			11	1	
AK57 KLOK	Kloppenheim, Karben	LBK III-V	25	57			4		84		28	431			2	27						173		10		1			1		
AK66 MB	Mittelbuchen, Hanau	LBK III-V	48	219			74	14	595		21	203	1	827	22	29						265			9	410			428	1	1
AK76 WINI	Windecken, Nidderau	LBK III-V		9					6		1	33										6				4					
AK84 GH	Hailer, Gelnhausen	LBK III-V	437	468		5	801	106	387		104	94		151	23	47				1		1989	2	1		1082	25		628	1	
AK85 MAR23	Mardorf, Amöneburg	LBK III-V							1			8										11									
AK99 US1	Usingen	LBK III-V	889	2246			871	83	5335		198	1806	2	2533	467	431		1				1825			142	968	1		1124	2	2
AK102 KRON	Kronberg/Taunus	LBK III-V	3	7			5		40		4	130			3							43								1	
AK134 NM	Nieder-Mörlen, Bad Nauheim	LBK III-V	7	4260			57	2	20606		3	4468		11083	530	8						801	1		11	6			6	3	4
AK152 HERX	Herxheim/Landau	LBK III-V	12	356			68	8	787		5	328		1181	28	15						502	1		4	17			21	2	2
AK154 FAU	Fauerbach v. d. H., Butzbach	LBK III-V	82	1084			260	3	6361		33	1261		1992	165	39						1010			26	5			7	1	2
AK168 WEM	Wembach-Hahn, Ober-Ramstadt	LBK III-V	1	59			1		514		12	1138			17	9						47		1							
AK176 WW	Wernswig, Homberg (Efze)	LBK III-V	4	14			3		39		5	90			1	11						247			7	11			4	1	
AK194 BRA	Bracht, Rauschenberg	LBK III-V	41	150	1		17		125		35	209			1	14						367			62	8					

Table 5 Archaeobotanical records of cultivated plants from 33 Bandkeramik sites in Germany and Austria. LBK I Bandkeramik phase I, LBK II Bandkeramik phase II, LBK III-V Bandkeramik phases III-V; phases according to the chronology of *Meier-Arendt (1966)*. Types of plant remains: *gr* grains, *gb* glume bases, *ra* rachis fragments, *no* culm fragments, *s* seeds

	Greece	Turkish Thrace (1 site)	former Yugo-slavia	Bulgaria	Romania	East-Hungary	West-Hungary	Germany/ Austria
***Hordeum* spec.**	■	■	■	■	■	■		
T. aestivum* s.l./*dur./turg.	■	??	■	■	■	■		
Triticum dicoccum	■	■	■	■	■	■	■	■
Triticum monococcum	■	■	■	■	■	■	■	■
Cicer arietinum	■			■				
Lathyrus sativus/cicera	■	■		■				
Vicia ervilia	■	■	■	■	■			
Lens culinaris	■	■	■	■	■	■	??	■
Pisum sativum	■	■	■	■	■	??	??	■
Linum usitatissimum	■	??	■	■	■	??	??	■
Papaver somniferum								■ LBK II ff.

Table 6 Comparison of crop species in Neolithic Europe (for explanation and references see text)

The Neolithic crop assemblage of Bulgaria comprises two additional cereals: *Hordeum* sp. (barley) and *Triticum aestivum* s.l./*durum*/*turgidum* (naked wheat), as well as three additional pulses: *Cicer arietinum* (chickpea), *Lathyrus sativus* vel *cicera* (grass pea) and *Vicia ervilia* (bitter vetch) (Table 4, Fig. 13; Marinova *2001*). All in all, these five more crop species grown by the farmers of the Bulgarian Neolithic imply a different agricultural system.

If we look at the countries adjacent to Bulgaria and outside the Linearbandkeramik area we can see that the two additional cereals, barley and naked wheat, were grown in the sphere of influence of all cultures belonging to the Starčevo-Körös-Čris complex including eastern Hungary (Table 6 and Fig. 1). The pulses do not all reach eastern Hungary, but it is difficult to decide whether this is due to the state of research or to other reasons (data from Greece: Evi Margaritis unpublished data from the site Dispilio/Kastoria; Hubbard and Housley *2000*; Valamoti *2004*, *Valamoti and Jones in press*; Hungary: Amy Bogaard and Ferenc Gyulai unpublished data (see also Bogaard et al. in press); former Yugoslavia: F. Bittmann and D. Kučan unpublished data from Okoliste/Visoko in Bosnia; Ksenija Borojevič, Dragana Filipovič from the Vinča site (Borojevič *1998*; *Borojevič and Filipovič in press*); Van Zeist *2003*; Romania: Cârciumaru *1995*; Cârciumaru and Monah *1987*; F. and D. Monah *1996*; Turkish Thrace: Reinder Neef personal communication for the site Aşaği Pinar; general overviews: Hopf *1991*; Kroll *1991*; Wasylikowa et al. *1991*).
The spectrum of Bandkeramik crop species is limited. Only some of the species cultivated in Neolithic Bulgaria finally reached the area of the Bandkeramik in Austria and Germany in early Neolithic times. This phenomenon has to be discussed further (see below).

The relationship of einkorn and emmer
Figure 4 presents the relative quantities of chaff remains from emmer and einkorn per settlement for those sites where both species were recorded. It is evident that at most sites more remains from einkorn than from emmer occur. This holds true for most Bandkeramik sites (see also Knörzer *1991*, *1997* for the Rhineland area) and also for the contemporary late Neolithic Bulgarian sites (Fig. 4; see also for example Van Zeist *2003* for Gomolava and surrounding regions). If one looks at the same calculation based on grains (without figure) the result is not that clear. Nevertheless most sites of the second half of the Bandkeramik culture have higher values of einkorn too.

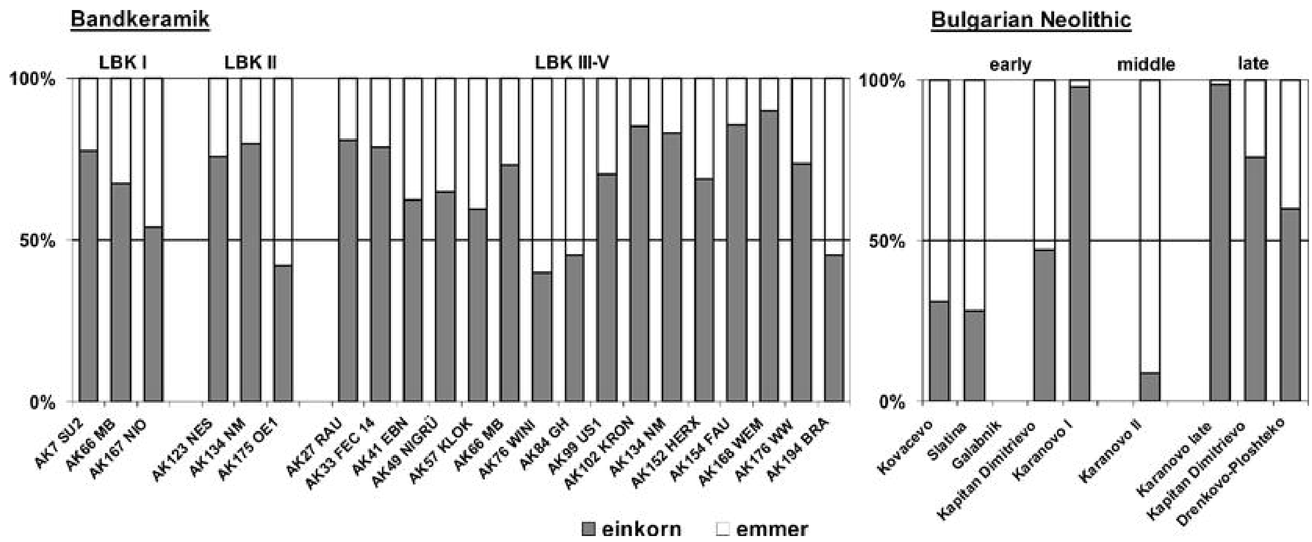

Fig. 4 Relative quantities of chaff remains from emmer and einkorn per settlement calculated for Bandkeramik and for Bulgarian Neolithic sites (for the abbreviations of the sites see Table 3, for the location of the sites see Fig. 2)

The results suggest that einkorn was the dominant Bandkeramik cereal. This is quite surprising, as einkorn would seem to be the worse choice. The yield of einkorn is almost half of that of emmer (*Körber-Grohne 1988*; Van der Veen *1997*; organic farmers personal communication). In addition the lower tillering rate of einkorn allows more weeds to grow in the fields in relation to emmer (organic farmers personal communication). So why should anyone prefer einkorn? Einkorn is considered to be more winter hardy than emmer (*Körber-Grohne 1988*, pp 322ff.). But another characteristic seems even more important. Einkorn is the only cultivated cereal which, due to the characteristics of its straw, keeps standing after heavy rainfall (Fig. 10 in *Kreuz in press a*). Emmer on the other hand, as all other cereals, tends to lodge (personal communication of organic farmers and own observation). Lodging of cereal plants may reduce the yield seriously. In the event of frequently occurring heavy rainfall during the Atlantic period (see above) einkorn would have been the better choice (*Kreuz in press a*). Due to that possible climatic interpretation of einkorn dominance it seems worthwhile to explore this question further.

Potential weeds as indicators for agricultural practices

Storage finds of crops with associated weeds are almost absent from Bandkeramik sites. In the data from both regions no relationship is evident between certain species and the different crops. How can we know if a taxon found in „normal" samples was a weed or not? To answer this question we need chorological and ecological data for each potential weed species (Kreuz *1990*, pp 143ff.).

The central European flora can be divided into two groups: there are plants which came into a region without anthropogenic influence and help. These are the indigenous species called idiochores (*Idiochoren*; for the terms see Schroeder *1969*, *1974*). Some of them are able to establish themselves as ruderals or weeds in the fields. Such potential weeds are called apophytes (*Apophyten*).

Secondly there are species which could only come to a region and persist by direct or indirect human influence. These species, which do not grow in natural stands, are called anthropochores according to their method of dispersal (*Anthropochoren*). We can expect that all anthropochores of the Neolithic were brought in with seeds or by other means during the colonization of the landscapes. That is why they might represent weeds. In addition in the Neolithic they almost certainly indicate a movement of people (see below).

Based on Oberdorfer (1990, *2001*) we grouped all species found at Bandkeramik sites into apophytes and anthropochores. All in all 64 anthropochores and 19 apophytes were identified (Table 7). For the Bulgarian area we have not yet found satisfactory information on this subject.

In Fig. 5 the number of anthropochores and apophytes is presented for the Bandkeramik phases. It is evident that most species are anthropochores, which were brought in from elsewhere. Apophytes from the natural vegetation form only a minor part of the spectra. In addition it is interesting that in phases III–V significantly more anthropochores have been found. If we look at the single sites, this is also the case: many more species per site are found from phase II onwards (Fig. 6).

Botanical name	APO/ANT	height	life-form	area	LBK I	LBK II	LBK III-V
Agrostis stolonifera/capillaris	ANT	medium	per	/			7
Asperula arvensis	ANT	low	/	med et al.			1
Atriplex patula/hastata	ANT	medium	s	euras-(s)med	1	4	10
Atropa bella-donna	APO	high	per	eurassubozean-smed		4	
Avena spec.	ANT	high	s	med et al.			2
Avena/Bromus	ANT	high	/	/			1
Brassica spec.	ANT	high	/	med et al.			7
Bromus cf. *arvensis*	ANT	medium	/	euras-(s)med		31	112
Bromus cf. *secalinus*	ANT	medium	/	euras	158	405	1671
Bromus spec.	/	medium	/	/	35	188	4850
Bromus sterilis	ANT	low	/	med et al.		128	249
Bromus sterilis/tectorum	ANT	low	/	med et al.		57	343
Bupleurum falcatum s.str.	APO	medium	per	kont			1
Calystegia sepium	APO	high	s	eurassubozean-smed			2
Capsella bursa-pastoris	ANT	low	s	med et al.			3
Carex muricata agg.	APO	medium	per	eurassubozean		2	
Centaurea spec.	ANT	/	/	/	1		1
Cerastium spec.	/	low	per	/			1
Chenopodium album	ANT	high	s	euras-(s)med	960	4903	9544
Chenopodium hybridum	ANT	medium	s	euras	2	2	4
Digitaria sanguinalis	ANT	low	s	med et al.			1
Echinochloa crus-galli	ANT	medium	s	euras-(s)med	2	51	50
Echinochloa/Setaria	ANT	medium	s	med et al.			1
Eleocharis palustris agg.	APO	medium	per	euras	1		
Euphrasia/Odontites	ANT	low	s	/			2
Festuca/Lolium	ANT	/	/	/			6
Fragaria vesca	APO	low	per	euras		4	12
Galium aparine/spurium	ANT	high	s	euras	5	5	211
Galium cf. *aparine*	ANT	high	s	euras	14	31	152
Galium cf. *verum* agg.	ANT	medium	per	euras-(s)med		132	190
Galium mollugo/verum	/	high	per	med et al.			7
Galium palustre	APO	low	per	eurassubozean	2		
Galium spurium	ANT	high	s	euras-(s)med	17	113	1398
Hordeum spec.	ANT	high	/	med et al.		1	
Hyoscyamus niger	ANT	medium	s?	euras-(s)med			2
Knautia arvensis	ANT	medium	per	eurassubozean		1	
Lapsana communis	APO	high	w	eurassubozean-smed	1	173	576
Lolium spec.	ANT	medium	/	med et al.			17
Lotus corniculatus s.str.	ANT	low	per	eurassubozean-smed			1
Lotus uliginosus	APO	medium	per	eurassubozean-smed		1	
Malva spec.	ANT	/	/	/		4	11
Malva sylvestris	ANT	high	per	euras-(s)med		2	
Matricaria perforata	ANT	medium	s	kont	1		
Medicago lupulina	ANT	low	/	euras-(s)med			1
Myosoton/Stellaria	/	low	/	euras			1
Nepeta cf. *cataria*	ANT	high	per	kont	13		9
Papaver dubium/rhoeas	ANT	medium	/	med et al.			1
Phleum pratense s.l.	ANT	high	per	euras	356	1872	1784
Phleum pratense/Poa annua	ANT	/	/	euras	1	15	7
Picris hieracioides s.l.	ANT	medium	per	euras-(s)med	1	1	
Plantago lanceolata	/	low	per	eurassubozean			2
Plantago major s.str.	APO	low	per	eurassubozean			1
Plantago major ssp. *intermedia*	APO	low	s?	eurassubozean			2
Poa annua	ANT	low	/	euras-(s)med	9	5	6
Poa spec. non *annua*	/	/	per	/		2	11

Botanical name	APO/ANT	height	life-form	area	LBK I	LBK II	LBK III-V
Poaceae *Bromus/Festuca* type	ANT	/	/	/		13	10
Polygonum aviculare agg.	ANT	medium	s	euras-(s)med	2	5	14
Polygonum convolvulus	ANT	medium	s	euras	410	728	945
Polygonum dumetorum	APO	high	s	euras-(s)med	70	16	6
Polygonum convolvulus/aviculare	ANT	medium	s	euras	6	44	395
Polygonum convolvulus/dumetorum	/	/	s	euras		7	12
Polygonum hydropiper/mite	/	medium	s	/		1	1
Polygonum lapathifolium agg.	APO	medium	s	eurassubozean	9	40	17
Polygonum lapathifolium/persicaria	/	medium	s	/	2	3	16
Polygonum persicaria	ANT	medium	s	euras			3
Rhinanthus cf. *minor*	ANT	low	s	eurassubozean			2
Rumex acetosella agg.	ANT	low	per	euras	3		1
Rumex conglomeratus/sanguineus	APO	medium	per	med et al.		34	3
Rumex crispus/obtusifolius	APO	high	per	/	1		37
Sambucus ebulus	APO	high	per	med et al.	3		3
Scirpus spec.	APO	/	/	/			5
Scleranthus annuus s.str.	ANT	low	s?	eurassubozean-smed	1		3
Setaria verticillata/viridis	ANT	medium	s	euras-(s)med	9	13	138
Sherardia arvensis	ANT	low	s?	med et al.			1
Sinapis arvensis	ANT	medium	s	med et al.	1		
Sisymbrium spec.	ANT	/	s?	/		4	
Solanum nigrum	ANT	medium	s	euras-(s)med	3	124	194
Solanum spec.	/	/	/	euras-(s)med	3	3	11
Stachys arvensis	ANT	low	s	eurassubozean			1
Stellaria graminea	ANT	low	per	eurassubozean	1		12
Stellaria media agg.	ANT	low	/	euras-(s)med	1	2	
Stipa spec.	ANT	medium	per	kont	11		
Thlaspi arvense	ANT	low	/	euras-(s)med	1		1
Torilis arvensis/japonica	/	high	/	med et al.			1
Trifolium campestre/dubium	ANT	low	s?	eurassubozean-smed			2
Trifolium campestre/dubium/arvense	ANT	low	s?	eurassubozean-smed	4	2	14
Trifolium medium/pratense	APO	low	per	eurassubozean-smed		1	
Trifolium spec.	/	low	/	/		1	5
Urtica dioica	APO	high	per	euras	1	2	3
Valerianella dentata	ANT	low	w	med et al.			4
Valerianella locusta	ANT	low	w	med et al.			1
Verbascum spec.	/	high	per	/			4
Veronica arvensis	ANT	low	/	eurassubozean-smed	1		79
Vicia hirsuta	ANT	medium	s?	euras-(s)med		2	9
Vicia tetrasperma	ANT	medium	s?	eurassubozean-smed	1		
Vicia hirsuta/tetrasperma	ANT	medium	s?	/	4	1	57
Viola spec.	/	low	/	/			1

Table 7 Bandkeramik potential weed species and their characteristics (following Oberdorfer 1990, *2001* and Kästner et al. *2001*) and numbers of plant remains. *APO* apophyte, *ANT* anthropochore; **height**: *low* 0–40 cm, *medium* 50–80 cm, *high* >80 cm; **life-form**: *s* summer-annual, *w* winter-annual/biennial, *per* perennial, */* indifferent; **area**: *euras* eurasiatic, including no-euras, euras-smed, euras(...); *eurassubozean* eurasiatic-suboceanic, including *subatl* subatlantic; *kont* kontinental; *med et al.* mediterranean, including med-smed, smed-med, med(...); *smed* submediterranean; *omed* eastern mediterranean, including eastern submediterranean

Botanical name	height	life-form	area	Early Neolithic I	Early Neolithic II	Middle Neolithic	Late Neolithic
Adonis flammea/A. aestivalis	medium	/	(o)(s)med		6		4
Agrimonia eupatoria	low?	per	eurassubozean-smed		3		6
Ajuga chamaepitys	low	s	med et al.		23		13
Ajuga genevensis	low	per	euras-(s)med		4		
Anagallis arvensis	low	w	eurassubozean-smed	3	1		2
Aphanes arvensis	low	/	med et al.	5			
Asperula arvensis	medium	w	med et al.	8	12		19
Bromus cf. *arvensis*	high	w	euras-(s)med	15	10		21
Bromus sterilis	medium	w	med et al.	1	4		11
Bromus sterilis/tectorum	high	w	/	4	25		181
Chenopodium album	high	s	euras-(s)med	129	150	50	500
Chenopodium hybridum	medium	w	euras			12	
Chenopodium polyspermum	medium	w	eurassubozean-smed	42	33		81
Chenopodium ficifolium	medium	w	med et al.	36	12		26
Cirsium cf. *arvense*	high	per	euras-(s)med				11
Cirsium cf. *vulgare*	high	per	eurassubozean-smed		1		
Convolvulus arvensis	high	per	euras-(s)med				4
Coriandrum sativum	medium	s	(o)(s)med				6
Coronilla cf. *scorpioides*	high	per	/				6
Echinochloa crus-galli	high	s	euras-(s)med	6	11		12
Festuca /Lolium	/	/	/	12	11	5	5
Fragaria vesca	low	per	euras	38	14		13
Fumaria spec.	low	w	/	5	8		34
Galega officinalis	/	per	(o)(s)med	6			
Galium cf. *aparine*	high	w	euras	8	88	23	78
G.mollugo/G. album/G. heldreihii	medium	per	/	2	35		29
Galium cf. *spurium*	high	w	euras-(s)med	30	69		59
Heliotropium cf. *europaeum*	medium	s	(o)(s)med		16		34
Hyoscyamus niger	medium	w	euras-(s)med	2	3		61
Lapsana communis	high	w	eurassubozean-smed	2	4		4
Lithospermum arvense	medium	w	(o)(s)med	33	12		21
Phleum cf. *phleoides*	medium	s	euras	8	4		11
Physalis alkekengi	medium	per	euras-(s)med	4	1		5
Plantago cf. *lanceolata*	medium	per	eurassubozean		2		9
Poa annua	low	w	euras-(s)med				5
Polycnemum arvense	low	s	(o)(s)med	8	93		49
Polygonum aviculare	medium	w	euras-(s)med	45	42		35
Polygonum convolvolus	medium	w	euras	106	337	13	420
Portulaca oleracea	low	s	(o)(s)med	89	10		3
Rumex cf. *acetosella* agg.	medium	per	euras		6		
Sambucus ebulus	high	per	med et al.	5	15	15	55
Scirpus lacustris	high	per	euras-(s)med				9
Scleranthus cf. *annuus*	low	w	eurassubozean-smed	4			
Setaria cf. *pumila*	medium	s	med et al.	3	10		10
Setaria viridis/verticillata	medium	s	euras-(s)med	85	227		214
Sherardia arvensis	low	s	med et al.	7	9		
Silene alba	medium	w	euras-(s)med	5			1
Solanum nigrum	high	s	euras-(s)med		10		10
Teucrium chamaedrys	low	per	med et al.	11	239		30
Thymelaea passerina	medium	w	med et al.	3	22		39
Trifolium cf. *aureum*	low	s	kont	4	4		0
Trifolium cf. *campestre/repens*	medium	per	eurassubozean-smed	17	27		
Trigonella /Astragalus	medium	/	/				4
Valerianella dentata	low	w	med et al.	8	8		42
Verbena officinalis	/	/	eurassubozean-smed	4	1		5
Vicia tetrasperma/hirsuta	medium	w	/	15	244		43
Vicia villosa/angustifolia	high	w?	(o)(s)med		2		3

Table 8 Bulgarian Neolithic potential weed species and their characteristics and numbers of plant remains (for explanations see Table 7)

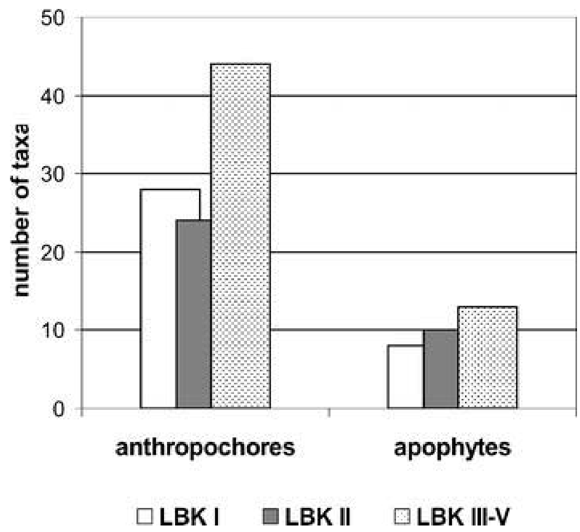

Fig. 5 Number of anthropochores and apophytes recorded from Bandkeramik phases I, II and III–V (see also Table 7)

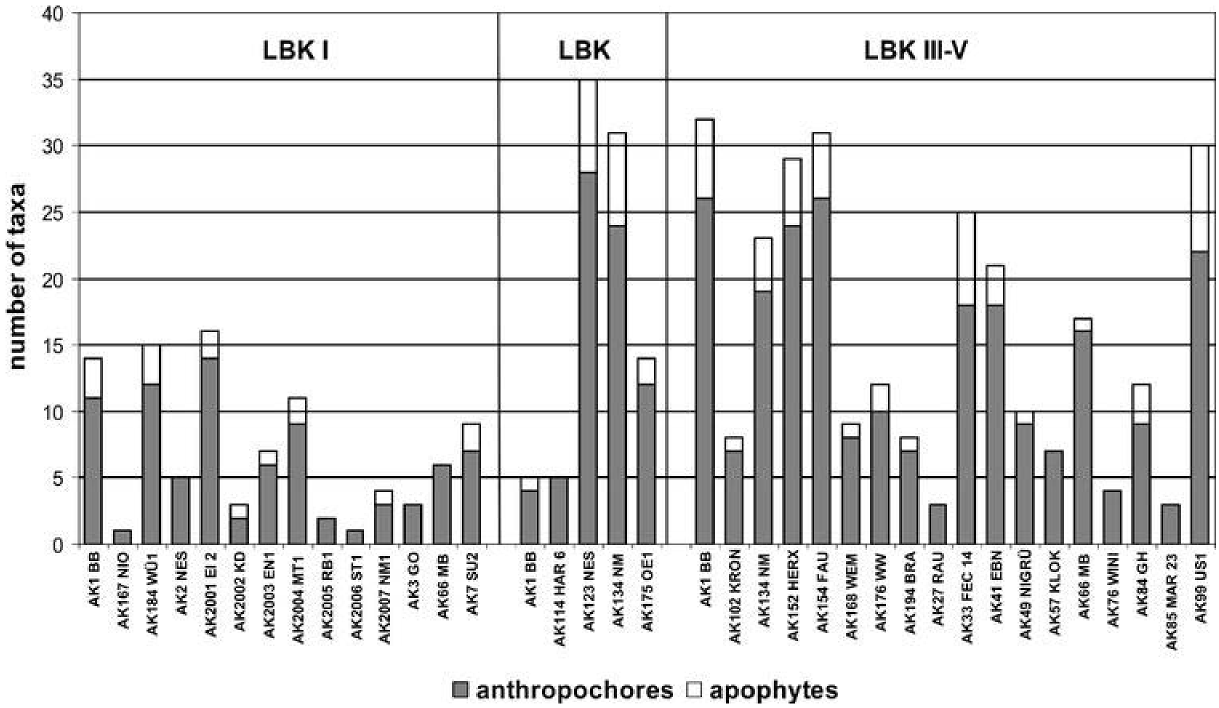

Fig. 6 Number of anthropochores and apophytes recorded per site for the Bandkeramik phases I, II and III–V (for the site codes see Table 3, for the location of the sites see Fig. 2)

Among the apophytes there are no real woodland species. This is probably due to the fact that woodland species are not adapted to grow as weeds under the „steppe-like" (Van Zeist *1987*) and regularly disturbed conditions of a field (shrubs and trees are excluded from the data set presented here). On the contrary, almost all Bandkeramik apophytes today normally grow in the floodplains of river valleys. Possibly they were brought to the fields with the dung of cattle which grazed the floodplains as well as the harvested fields.

Figure 7 shows the growth height of the potential weeds compared for the Bulgarian Neolithic and the Bandkeramik cultures. Looking at the Bulgarian data, no chronological variation can be detected. It has to be mentioned that the only middle Neolithic site revealed very few species. That is why the apparent decrease of taxa there is an „artefact".

On the contrary, the Bandkeramik data show a chronological development (see also Fig. 8 for the single sites). As mentioned before, there are some more weeds in the later Bandkeramik phases III–V. It is evident that many of these newcomers are low-growing plants of about 40 cm maximum height (Figs. 7 and 8).

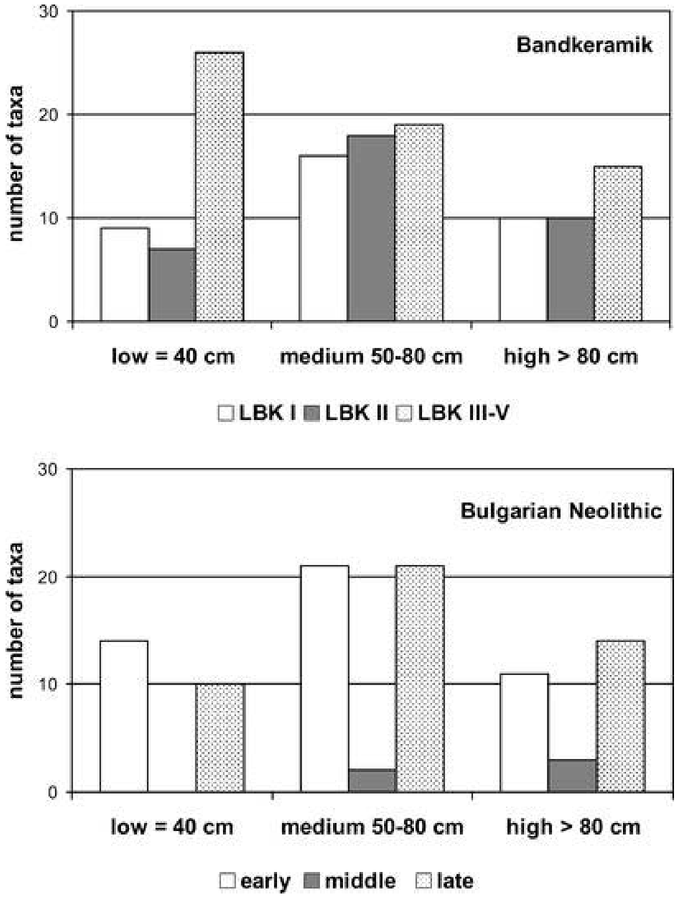

Fig. 7 Number of potential weed taxa of different growth height for the Bandkeramik and for the Bulgarian Neolithic phases (see also Tables 7 and 8)

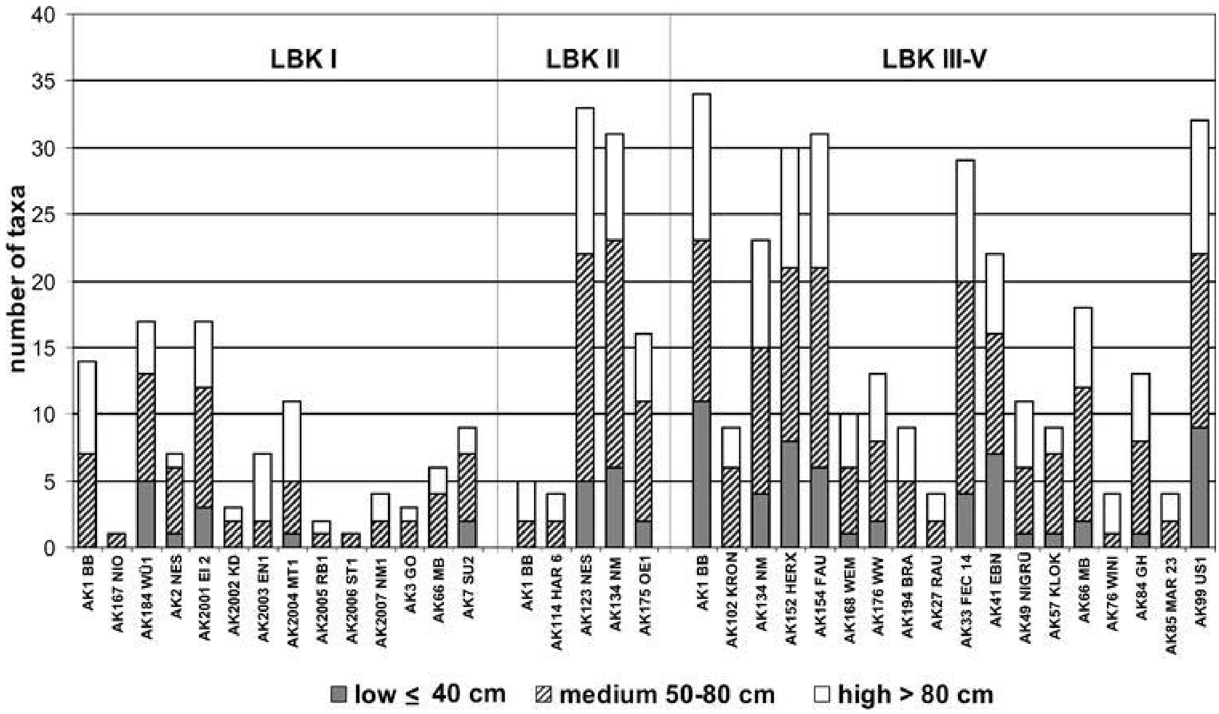

Fig. 8 Number of potential weed taxa of different growth height per site for the Bandkeramik phases I, II and III–V (for the site codes see Table 3, for the location of the sites see Fig. 2)

Possibly we have recorded here a change in the harvesting technique (*Kreuz in press a*). Following Hillman (*1981*) and Reynolds (*1985*, *1993*, p 189), many more and also lower- as well as medium-growing weed plants and their seeds are collected by sickle- than by ear-harvesting. There is archaeological evidence that such a change in harvest technique took place. Flint working techniques and the quantities of lithic artefacts changed markedly between Bandkeramik phase I and the following phases: in earliest Bandkeramik settlements the percentage of sickle blades is lower and less standardized (de Grooth *2003*, p 402; Gronenborn *1997*, p 102 and pers. comm.; Kind *1997*, p 140). Possibly, sickles were less in use for harvest during Bandkeramik phase I than in the later Bandkeramik phases.

In contrast many fewer low growing species were found at the contemporary late Bulgarian Neolithic sites (Fig. 7). That is why we cannot exclude the possibility that ear harvesting remained important to the Bulgarian Neolithic farmers. Ear-plucking is an efficient method for harvesting the hulled wheats when fully ripe, as it prevents more ears from falling to the ground. It is for example written in the Bible that ear-plucking was practised by the disciples of Jesus (the gospel according to St. Mark, mk.02, 23–28).

On the other hand, experimental harvesting has revealed that harvesting with flint sickles is three times faster than ear-plucking (L. Peña-Chocarro, Como (I), and L. Zapata-Peña, Vittoria-Gasteiz (E) personal communication, see also Ibánez et al. *2001*). The point in question is whether the use of this technological innovation was of different importance to the Bandkeramik compared with the Bulgarian Neolithic farmers.

There exist different opinions concerning the intensity of field management and the time of sowing during the Neolithic; their discussion goes beyond the scope of this paper (Bogaard *2004*, chapter 7; Bakels and Rousselle *1985*, p 55; Behre and Jacomet *1991*, p 86; Willerding *1980*; Lüning *2000*). Important information derives again from the characteristics of the potential weeds.

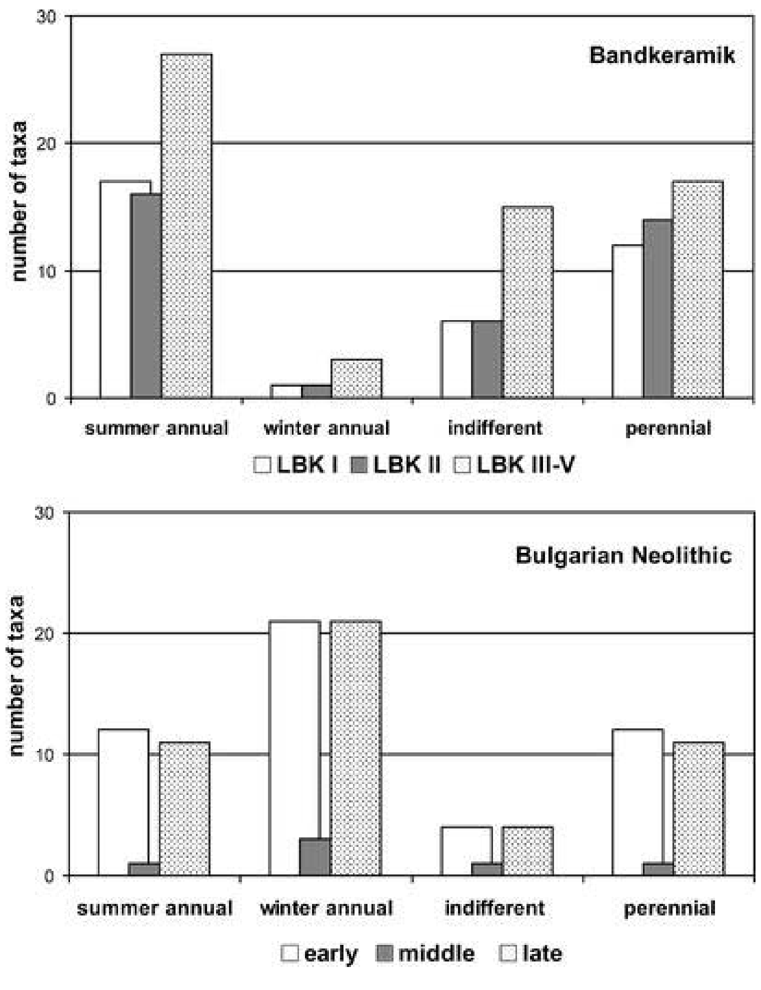

Fig. 9 Number of potential weed taxa of different life forms for the Bandkeramik and for the Bulgarian Neolithic phases (see also Tables 7 and 8)

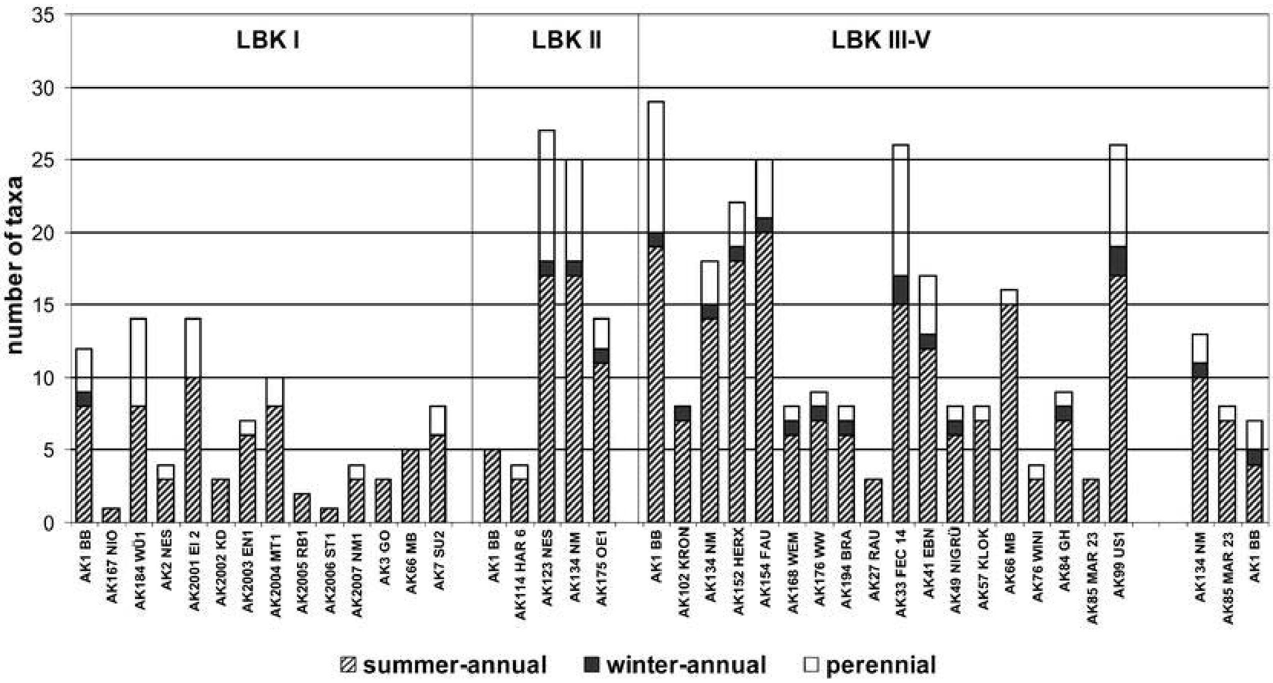

Fig. 10 Number of potential weed taxa of different life forms per site for the Bandkeramik phases (for the site codes see Table 3, for the location of the sites see Fig. 2). Indifferent taxa are excluded here, for clarity

The recorded potential weed species can be differentiated into four groups: summer annuals, winter annuals or biennials, indifferent species and perennials (after Oberdorfer *1990*; Kästner et al. *2001*). Figures 9 and 10 show again an important difference between the Bulgarian Neolithic and the Bandkeramik cultivation systems. At the Bulgarian sites the winter annual species are the dominant group, while summer annuals occur too. We may expect summer and winter crop growing there. At the Bandkeramik sites there are not more than three winter annuals but predominantly summer annuals. Figure 10 shows their occurrence per site. The only one of the three winter annuals occurring regularly is *Lapsana communis*. This is an apophyte and a common weed of diverse, especially ruderal, vegetation stands. It is not characteristic of winter crop cultivation. The other two species are *Valerianella dentata* (AK99 USI) and *V. locusta* (AK33 FEC) both occurring just as single finds in features of Bandkeramik phases III–V (Table 7). Therefore it seems to be likely that nothing but summer crop cultivation was practised by the Bandkeramik farmers. In both cultures, perennials form an essential part of the weed assemblage. Therefore we should ask whether at least parts of the fields were not cultivated intensively. Characteristics of vegetative propagation and dispersal of the species concerned indicate whether they are able to reproduce, for example from their rhizomes or runners. Such species could possibly survive under intensive soil treatment by hoeing or similar activities. Actually, some of the Bandkeramik perennial species as for example *Agrostis capillaris/stolonifera*, *Carex muricata*, *Galium verum*, *Lotus uliginosus* or *Plantago lanceolata* are able to propagate vegetatively, but others are not. To decide whether their occurrence in the samples really is a sign of the intensity of field management (Bogaard *2004*; Jones et al. *1999*), further research is needed.

Geographical origins of the potential weeds

Finally, it is necessary to ask where the early Neolithic weed species originated geographically. To answer this question their actual centres of distribution „*Pflanzengeographische Hauptverbreitung*" according to Oberdorfer *2001*), their chorological areas, are of interest. Figure 11 shows a map with the chorological areas of central Europe and adjacent areas after Oberdorfer (*2001*).

We can state that most Bandkeramik potential weeds and many of the Bulgarian Neolithic weeds were introduced with seeds into the fields and settlement sites from elsewhere. There is again no visible chronological development concerning the species of the early and late Bulgarian Neolithic sites. In contrast there is a strong increase of Mediterranean species during the Bandkeramik phases III–V (Fig. 12). More introduced species per site—especially Mediterranean ones—occur from Bandkeramik phase II onwards (without figure).

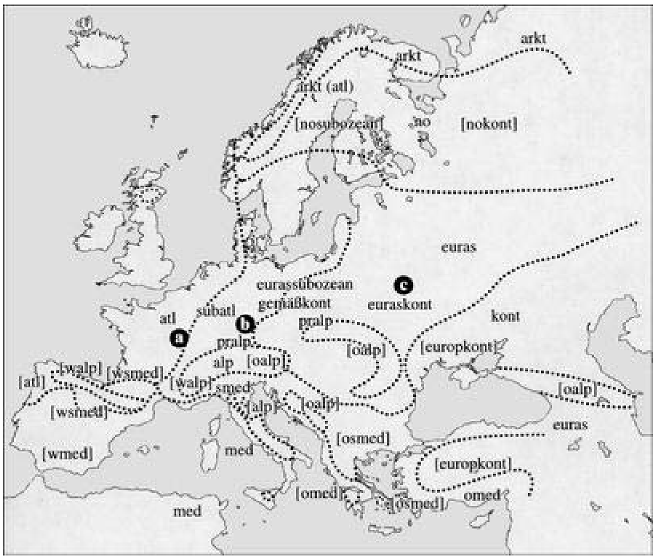

Fig. 11 Chorological areas of central Europe and adjacent areas (after Oberdorfer *2001*). For abbreviations see Fig. 12 and Table 7

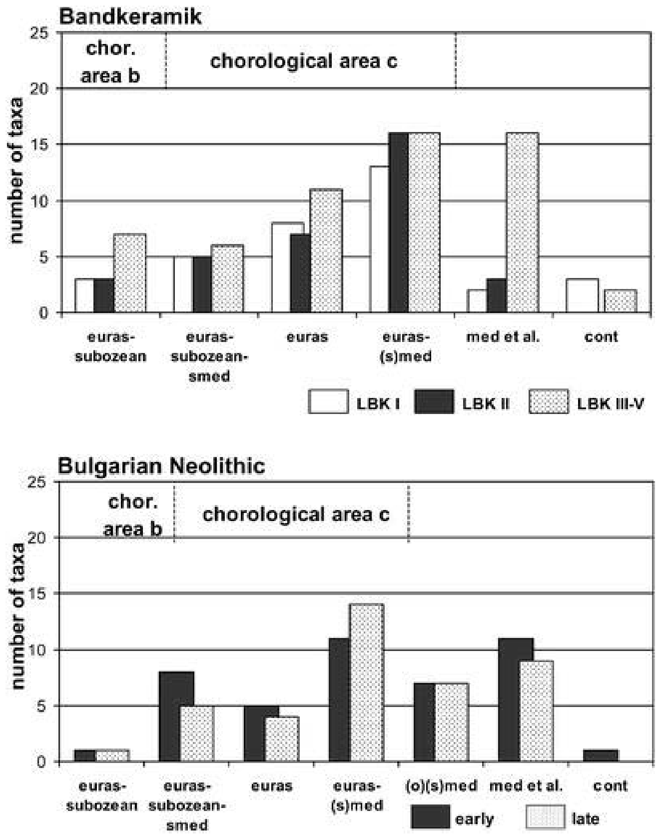

Fig. 12 Number of potential weed taxa of different chorological areas for the Bandkeramik and for the Bulgarian (Middle Neolithic excluded) Neolithic phases (see also Tables 7 and 8)

In this context Papaver somniferum, the western Mediterranean opium poppy, (see above) and possibly *Vicia faba*, the Mediterranean Celtic bean (Buxó 2004), which have been found at later Bandkeramik sites (Fig. 13), have to be remembered. These archaeobotanical phenomena still have to be connected with an archaeological counterpart to explain these new external influences. New waves of immigrants in the second half of the Bandkeramik period could be a possible explanation (*Kreuz in press a*).

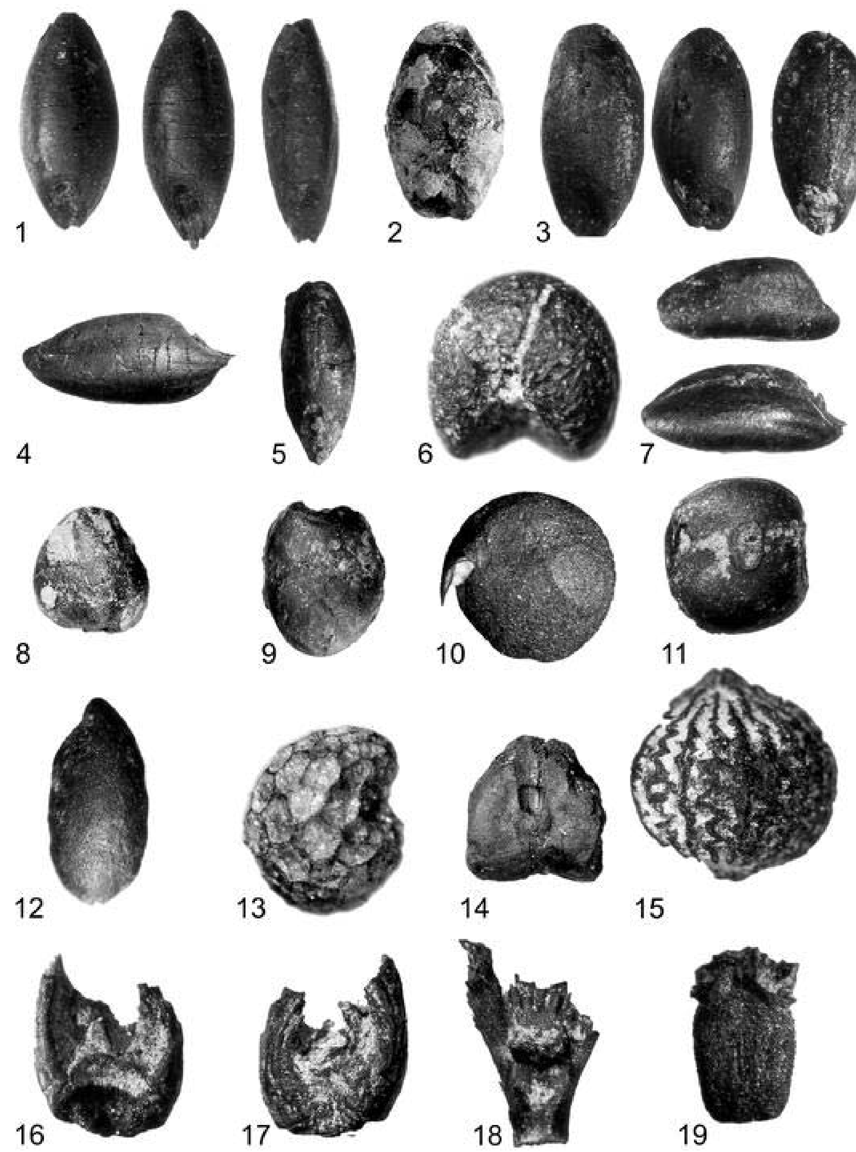

Fig. 13 Charred plant remains from Bandkeramik sites in Hessen (Germany) and from Bulgarian Neolithic sites. **Hessen: 1***Triticum monococcum* dorsal, L central grain 5.6 mm, AK41EBN; **2***Hordeum vulgare*/*distichon* dorsal, L4.9 mm, AK1BB; **3***Triticum dicoccum* dorsal, L central grain 6.1 mm, AK99US1; **4***Triticum monococcum* lateral, L5.6 mm, AK41EBN; **5***Secale cereale* dorsal, L4.9 mm, AK1BB; **6***Panicum miliaceum* dorsal, L1.5 mm, AK3 GO; **7***Triticum dicoccum* lateral, L lower grain 5.7 mm, AK41EBN; **8***Vicia ervilia*, L3.6 mm, AK99US1; **9***Vicia faba* lateral, L4.5 mm, AK1 BB; **10***Lens culinaris*, L2.1 mm, AK134 NM; **11***Pisum sativum*, L3.1 mm, AK76WINI; **12***Linum usitatissimum*, L2.95 mm, AK134NM; **13***Papaver somniferum*, L0.9 mm, AK134NM; **Bulgaria:** 1**4***Cicer arietinum*, D4.1 mm; **15***Coriandrum sativum*, L3.05 mm; **16***Triticum* sp., new type, spikelet ventral, L2.6 mm; **17***Triticum* sp., new type, spikelet dorsal, L2.6 mm; **18***Hordeum distichon* rachis fragment, L3.0 mm; **19***Triticum aestivum* s.l./*durum*/*turgidum* rachis fragment, L1.8 mm. Kapitan Dimitrievo 14, 15, 18; Karanovo 16, 17, 19. For site codes and dating see Tables 2 and 3

Conclusion

The agricultural system of the Bulgarian Neolithic culture is based on 10 crop species (Fig. 13). Naked wheat and barley are higher yielding than emmer and einkorn, which are the only Bandkeramik cereals. However, they need more nitrogen than the hulled wheats, and naked wheat needs more careful weeding (*Körber-Grohne 1988*; *Kreuz in press b*). The characteristics of these additional cereals therefore have important consequences for a cultivation system. The additional pulses of the Bulgarian Neolithic, *Cicer arietinum*, *Lathyrus sativus*/*cicera* and *Vicia ervilia* also have special demands of cultivation.

Different dietary customs can be derived from the different crops: barley and naked wheat have a different taste and other requirements of processing and preparation than emmer and einkorn. The number of pulse species in the Bulgarian Neolithic might indicate that they were a certain substitute for meat in the diet.

The earliest Bandkeramik cultivation system with only five species was different from the neighbouring Starčevo, Körös, Čris cultures and the Bulgarian Neolithic. We could speculate whether manpower was a problem for Bandkeramik groups, which later even led to a time-saving change in lithic technology and harvest technique (see above). On the other hand there might also have been other priorities concerning parts of the agricultural system.

The weed assemblages let us assume that ear-plucking remained an important harvesting method throughout the Bulgarian Neolithic. At least some of the cereals were grown as winter crops there. In contrast the sowing time of the Bandkeramik farmers—as indicated by the weeds—points to (at least mainly, more likely exclusively) summer crop cultivation. In this case the fields could be grazed after harvest until the next spring. This would have been useful for the farmers if they put more emphasis on stock breeding.

Comparing the two cultivation systems, the Bulgarian Neolithic system seems more time-consuming than that of the Bandkeramik. This has important social implications. Social differences between the Bulgarian Neolithic and Bandkeramik are also indicated by different settlement structures and house types (see above).

To summarize, we can state that an important agricultural and social change of early Neolithic subsistence occurred somewhere in the transition area from eastern to western Hungary. It took several centuries until cultivation of barley and naked wheat crossed the rivers Tisza and Danube. In western central Europe this was the beginning of the middle Neolithic with the rising of the Großgartach and the Rössen Cultures, including—among others—settlement structures, technologies and ritual practices different from the Bandkeramik ones (Eisenhauer *1999*; Lüning *2000*, p 16ff.). The background of this delayed adaptation of two important cereals—*Hordeum* sp. (barley) and *Triticum aestivum* s.l./*durum*/*turgidum* (naked wheat)—in western central Europe is not yet understood. Future archaeobiological and archaeological work—especially in the key area of Hungary - is therefore urgently needed.

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