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PLANTS OF THE FUNNEL BEAKER CULTURE IN POLAND

ABSTRACT

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Neolithic communities appeared in Polish territories around the mid-6th millennium BC. However, until the beginning of the 4th millennium BC, they inhabited only small enclaves. This situation changed within the first half of the 4th millennium BC, when the most of the Polish territories became settled by Neolithic groups attributed to the Funnel Beaker culture (TRB). There is a fairly large amount of data on plants cultivated by TRB people. Based on this, one can conclude that mainly *Triticum dicoccon*, *T. monococcum* and *Hordeum vulgare* were grown. *T. dicoccon* and *T. monococcum* could be sown together. It should be noted that large amounts of weeds typical of cereal fields have been recorded. It is much more difficult to determine the economic importance of other cultivars because of their low numbers. Nevertheless, the TRB inventories contain remains of *Pisum sativum*, *Lens culinaris*, *Linum usitatissimum* and *Papaver somniferum*.

Keywords: Poland, Neolithic, Funnel Beaker culture, cultivated plants, cultivation model
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INTRODUCTION

Neolithic communities appeared in Polish territories after the mid-6th millennium BC. The early phase of the Neolithic is represented by the Linear Band Pottery culture (*Linearbandkeramik* = LBK), like in other parts of Central Europe (*e.g.* Czekaj-Zastawny *et al.* 2020; Bogucki 2008a). Settlement of the LBK can be described as island-like, because the majority of sites concentrate in relatively small enclaves, which are characterized by ecological conditions favourable for agriculture. After the disappearance of the LBK in the early 5th millennium BC, the pattern of spatial distribution of Neolithic settlement remained basically unchanged. A substantial majority of sites of the Stroke Band Pottery culture and archaeological groupings belonging to the so-called Lengyel-Polgár complex (L-PC) still occurred in the same enclaves as sites of the LBK (*e.g.* Bogucki 2008b; Pyzel 2010; 2018, 138-200).

In the very late 5th millennium BC and onwards, this pattern began to change. The area of Neolithic settlement was gradually expanding, and tended to cover the whole landscape. Consequently, the island-like settlement pattern disappeared. At about 3500 BC *ca.* 80% of territories in the Vistula and Oder basins were included into the Neolithic formation. It is possible to say that during the first half of the 4th millennium BC, the Second Stage of Neolithisation took place in east-central Europe, which was equally as important as the first one (Kozłowski and Nowak 2019; Nowak 2001, 2009). This stage is connected with the Funnel Beaker culture (*Trichterbecherkultur* = TRB), which covers not only Poland, also but vast territories from the Netherlands to western Ukraine, and from southern Sweden to Lower Austria.

MATERIALS AND METHODS

Currently, there is a relatively large amount of data on plants connected with the TRB. In the paper, analyses made on 57 sites will be used. However, our study is first and foremost based on sites where more than 10 specimens of all taxa were found, although in the literature other methods of material selection have also been applied (*e.g.* Kirleis and Fischer 2014; Mueller-Bieniek and Walanus 2012; Wasylikowa *et al.* 1991). Sites that meet this requirement are concentrated in western Lesser Poland, in Lower and Upper Silesia as well as in Kuyavia and Greater Poland (Fig. 1). We are aware that this situation is disadvantageous in terms of the spatial representativeness of these data. The vast territories in which quantitatively and qualitatively substantial remains of TRB communities have been recorded – important for our knowledge of this phenomenon – such as Pomerania, Chełmno Land, Central and Eastern Lesser Poland, have provided little, if any, relevant information. Notwithstanding the absence of sites that correspond to the above criterion, this state of affairs is also due to a somewhat objective factor, *i.e.* the low number of archaeobotanical

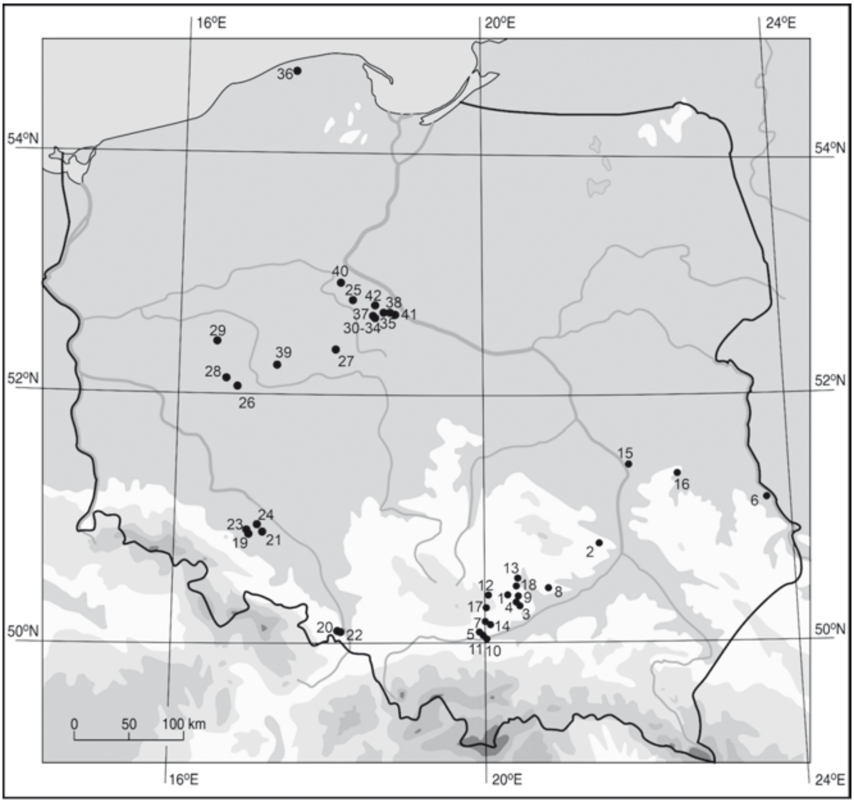


Fig. 1. Locations of the TRB sites on which the sum of the preserved specimens of all taxa exceed 10 pieces. **Lesser Poland**: 1. Bronocice (Lityńska-Zając 2007a; Kruk *et al*. 2016); 2. Ćmielów (Podkowińska 1961); 3. Donatkowice, site 23 (Mueller-Bieniek, unpublish.); 4. Donosy, site 3 (Lityńska-Zając 2007a); 5. Giebułtów, site 1 (Lityńska-Zając unpublish.); 6. Husynne, site 1 (Klichowska 1969a); 7. Iwanowice-Klin (Lityńska 1990), 8. Kawczyce, site 1 (det. by Lityńska-Zając in: Nowak 1994); 9. Kobylniki, site 4 (Kruk *et al*. 2016); 10. Kraków-Mogiła, site 62 (Gluza *et al*. 1988; Kapcia and Mueller-Bieniek 2018); 11. Kraków-Prądnik Czerwony (Rook and Nowak 1993); 12. Miechów, site 3 (Moskal-del Hoyo *et al*. 2017; Mueller-Bieniek *et al*. 2018a); 13. Mozgawa, site 1-3 (Kotynia 2016; Moskal-del Hoyo *et al*. 2018); 14. Niedźwiedź (Burchard and Lityńska-Zając 2002); 15. Parchatka, site 12 (Lityńska-Zając 1995); 16. Pliszczyn, site 9 (Sady 2015); 17. Smroków, site 17 (Lityńska-Zając 2010); 18. Zawarża, site 1 (Lityńska-Zając 2002); **Silesia**: 19. Janówek (Klichowska 1968); 20. Pietrowice Wielkie (Klichowska 1969b); 21. Polwica-Skrzypnik (Lityńska-Zając 2009a); 22. Racibórz, site 423 (Sady 2014); 23. Strachów, site 2 (Lityńska-Zając 1997b); 24. Wojkowice, site 15 (Lityńska-Zając 2009b); **Kuyavia, Greater Poland and Pomerania**: 25. Inowrocław-Mątwy, site 1 (det. by Klichowska in: Kośko 1981); 26. Kokorzyn, site 2 (Klichowska 1972); 27. Kopydłowo, site 6 (Abramów 2015); 28. Kotowo, site 1 (Klichowska 1972); 29. Mrowino, site 3 (Klichowska 1972; det. by Dzięczkowski in: Wierzbicki 2013); 30. Opatowice, site 1 (Koszałka 2007a); 31. Opatowice, site 3 (Koszałka 2014); 32. Opatowice, site 12 (Klichowska 1979); 34. Opatowice, site 42 (Koszałka 2007b); 35. Osłonki, site 2 (Mueller-Bieniek 2016); 36. Poganice, site 4 (Klichowska 1985, det. by Luijten, Polcyn and Wasylikowa in: Wierzbicki 1999); 37. Radziejów Kujawski (Klichowska 1970); 38. Smólsk, site 2/10 (Mueller-Bieniek 2016; Mueller-Bieniek *et al*. 2016); 39. Szlachcin, site 3 (Klichowska 1966); 40. Tarkowo, site 23A-23B (det. by Klichowska in: Kośko 1981); 41. Wolica Nowa (Bieniek 2007; Mueller-Bieniek 2016); 42. Zarębowo, site 1 (Klichowska 1972)

samples. However, it is our belief that waiting for this situation to improve is unrealistic, or in any case it would take too long. The available database, despite its uneven dispersion, is so extensive and scientifically valuable that it deserves to be synthesized these days.

The identification of cultivated and wild plants was possible thanks to the examination of charred remains and/or plant impressions on burnt clay. Charred remains were either scattered in different kinds of features (pits, postholes, fireplaces) or found concentrated in storage pits. Different numbers of samples were analysed at archaeological sites. These were either single samples or numerous samples, collected systematically in many features. At some sites only imprints preserved in daub and/or on pottery were taken into account. Archaeobotanical analyses of only four graves were executed; all these graves come from Bronocice (Lityńska-Zając *et al*. 2016). This makes consideration of social and ritual behaviours connected with plants impossible (see *e.g*. Kirleis *et al*. 2012).

The cereal remains were preserved as the charred caryopsis and fragments of spike and spikelet as glume, palea, lemma, spikelet forks, spike (rachis internodes) and stem fragments. Other cultivated and wild plant remains preserved as charred seeds and fruits. Only fruits of *Lithospermum arvense* (field gromwell) and *L. officinale* (common gromwell) were mostly uncharred. Other uncharred remains found in settlements are considered to be younger or present-day contaminations. Burnt clay fragments and ceramics contained cereal impressions of caryopsis and vegetative part of plants. Some of them contained charred plant fragments preserved inside.

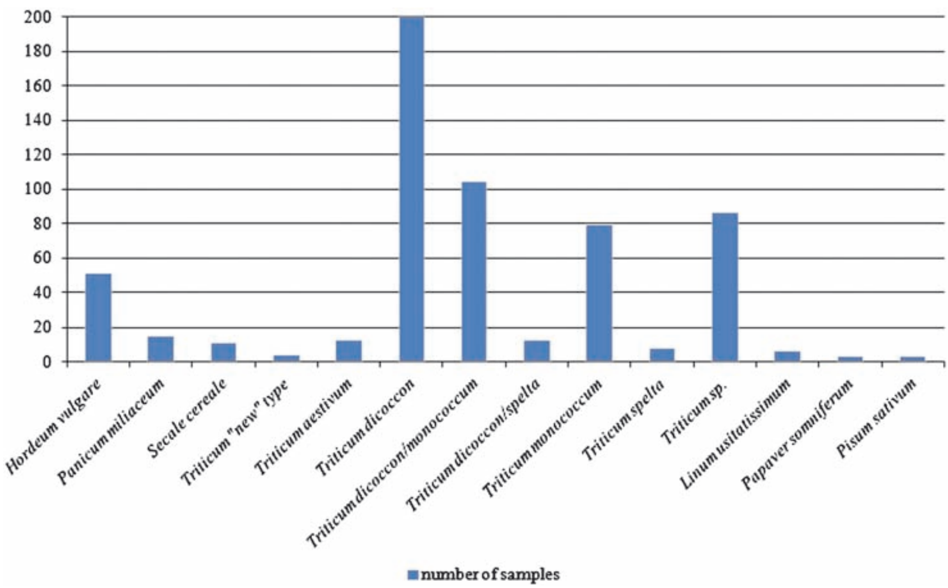


Fig. 2. Frequency of cereals and other cultivated plants, in number of samples with cultivated plants in the LBK

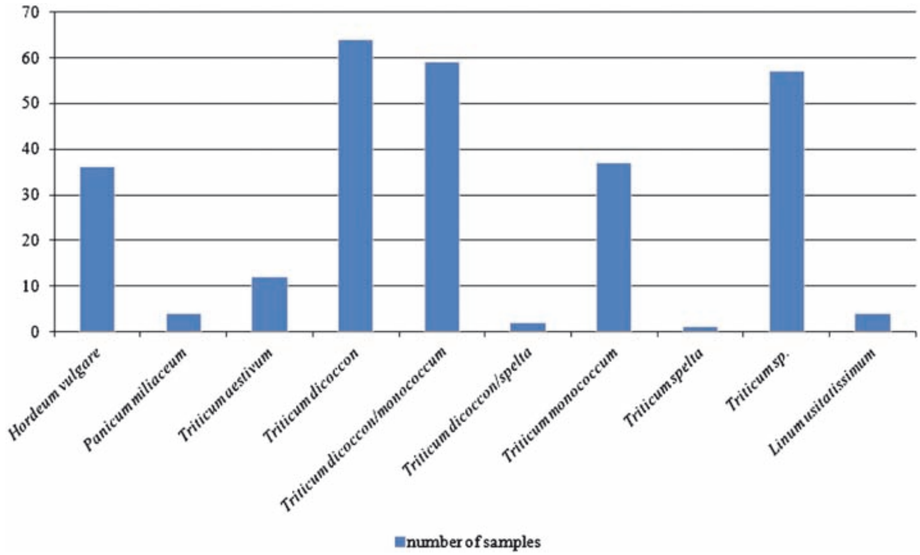


Fig. 3. Frequency of cereals and other cultivated plants, in number of samples with cultivated plants in the L-PC

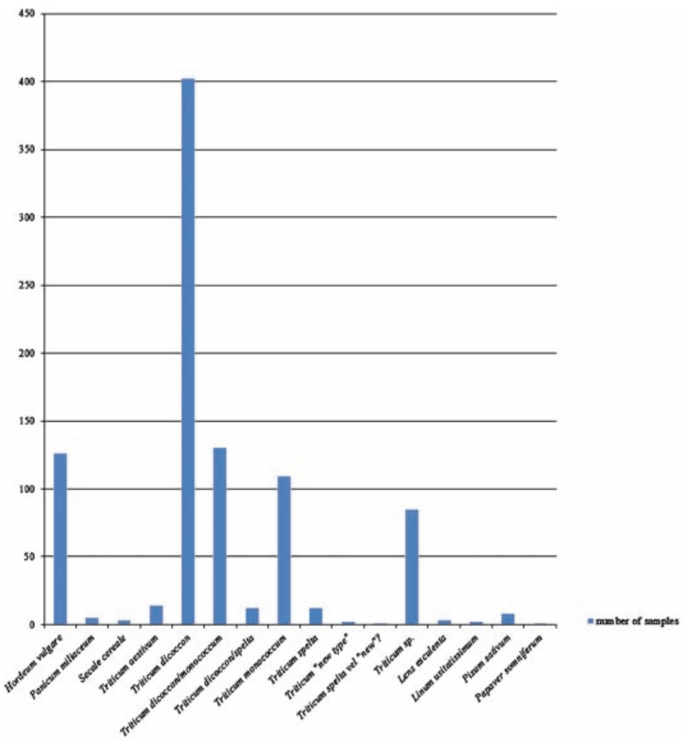


Fig. 4. Frequency of cereals and other cultivated plants, in number of samples with cultivated plants in the TRB

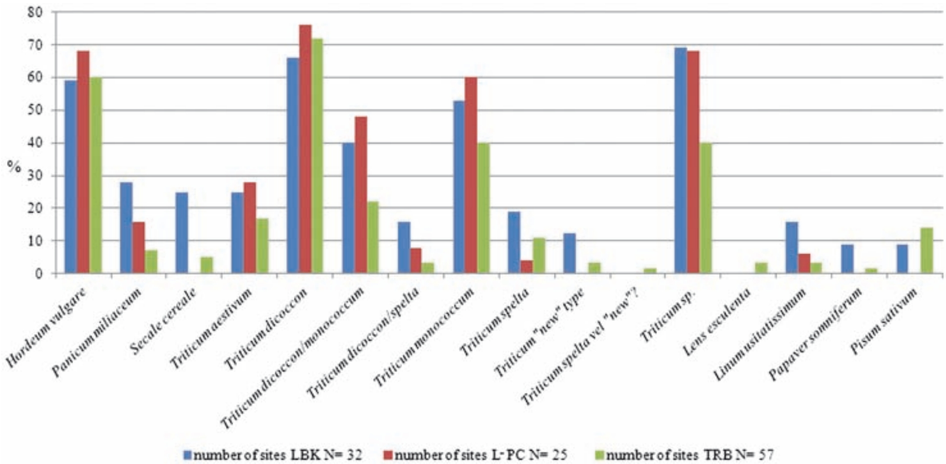


Fig. 5. Frequency of cereals and other cultivated plants by percent, calculated in relation to the total number of sites with cultivated plants in three archaeological Neolithic phenomena

Based on the TRB sites from Poland, 8 species of cereals, 4 of other cultivated plants, as well as 13 species and 18 genera of wild herbaceous plants were identified (see Lityńska-Zając 2005, table VI). Due to aforementioned regional concentrations of sites with archaeobotanical data analysis of the structure of crops was carried out with regard to the division into three regions: Lesser Poland (Table 1), Upper and Lower Silesia (Table 2), and Greater Poland, Kuyavia and Pomerania (Table 3).

Numbers of plant remains have not been compared. This is due to two reasons: 1. For some sites we do not have quantitative data; in some cases, we know only that there were numerous findings of particular species, 2. Comparison of the number of specimens from storage pits – occurring in the thousands in each pit – with single remains, preserved scattered in different features, would mean that a given deposit of grain can be crucial for the alleged dominance of a particular species, found in this deposit. Deposits of this kind usually are not very representative, even for a specific site, and are not relevant to the structure of cultivated plants in a particular village, because they probably contain grain from only one harvest (Lityńska-Zając 1997a).

In order to standardize results of analyzes and facilitate further interpretations, a comparison method was used (Tables 1-3) in which remains of cereals were grouped into caryopses and chaff. State of preservation was omitted. Consequently, burned and imprinted specimens were treated together. The following numerical intervals were used: 1. Up to 10 specimens, 2. 11-100, 3. 101-1000, 4. Over 1000 specimens. Remains described only as *Cerealia* indet. or *Cerealia* indet. vel. Poaceae indet. were also skipped. For a given taxon, remains identified to the species level and probably to the species ("cf.") level were included.

The TRB in many respects differs from the so-called Danubian Neolithic, *i.e.* the LBK and L-PC. It is interesting to investigate, therefore, whether the crystallisation and development of the TRB correlate with changes in plant economy. Thus, the TRB data were compared to data from these two older phenomena. Such comparison was made taking into account the number of samples with cereals and other crops, calculated for these three archaeological units, across all of Poland (Figs. 2-4). The mutual quantitative proportions of cereals and other crops are shown in Fig. 5.

RESULTS

Cereal crops

In Lesser Poland, seven cereal species were identified (Table 1). Remains of plants occur mainly scattered in various kinds of anthropogenic features. At some sites, they were found in storage pits. *Triticum dicoccon* (emmer) was discovered very frequently (16 of 18 sites taken into consideration) and in large amounts. At five sites, several hundred caryopses and imprints were recorded, not to mention the foregoing deposits where the number of identified specimens exceeded 1,000. An extreme case is feature 32 at Kraków-Prądnik Czerwony, where this figure is estimated at 150,000 (Rook and Nowak 1993). *T. monococcum* (einkorn), preserved also as caryopses and chaff, co-occurred with *T. dicoccon* at 13 sites. There are no cases of the exclusive occurrence of *T. monococcum*. Einkorn was generally less numerous than emmer. The quantity of *Hordeum vulgare* (barley) is relatively small. Its most numerous assemblage was found at Niedźwiedź (267 imprints on daub – Burchard and Lityńska-Zając 2002). Despite small numbers, *H. vulgare* occurred relatively frequently, *i.e.* at 13 sites, in two of which neither emmer nor einkorn was identified. At a few sites, finds of *T. spelta* (spelt), *Secale cereale* (rye), as well as – at one site – *Panicum miliaceum* (millet) were recorded.

In the case of the multi-phase settlement at Bronocice (Kruk *et al.* 2016), *T. dicoccon*, *T. monococcum* and *H. vulgare* were present in all phases. In the very first (BR I) phase, dated, according to different views (Kruk and Milisauskas 2018; Kruk *et al.* 2018; Nowak 2017 – these quotations refer also to later Bronocice phases), to *ca.* 3950/3750-3800/3700 BC, *H. vulgare* is the most frequently found, but in the subsequent phases of BR II (*ca.* 3700/3600-3500 BC), BR III and BR IV (*ca.* 3500/3400-3200/3100 BC), *T. dicoccon* is the most important cereal crop. In the last phase (BR V – *ca.* 3200/3100-2850/2750 BC), *H. vulgare* "returns," but in lower frequency than in phase BR I. Starting from BR III, specimens of *T. spelta* were also found in plant assemblages.

In all of the analysed sites in Silesia (Table 2), *T. dicoccon* and *H. vulgar*e were recognized, whereas *T. monococcum* occurred in only two sites. The numbers of identified charred remains and imprints were low. Only on the sites of Strachów and Polwica were more than 10 specimens of *T. dicoccon* found.

Table 1. Occurrence of cultivated plants on sites of the TRB in Lesser Poland. Explanations: State of preservation: ch – charred remains, i – imprint; kind of remains: c – caryopsis, s – seed, chaff – including fragments of spike and spikelet as glume, palea, lemma, spikelet forks, spike rachis. Frequency X: up to 10 specimens, XX: 11-100 specimens, XXX: 101-1000 specimens, XXXX: over 1000 specimens

taxa name	state of preservation	kind of remains	Bronocice	Ćmielów	Donatkowice, site 23	Donosy, site 3	Giebułtów, site 1	Husynne, site 1	Iwanowice-Klin	Kawczyce, site 1	Kobylniki, site 4	Kraków-Mogiła, site 62	Kraków-Prądnik Czerwony	Miechów, site 3	Mozgawa, site 1-3	Niedźwiedź	Parchatka, site 12	Pliszczyn, site 9	Smroków, site 17	Zawarża, site 1
Hordeum vulgare	ch, i	c	XX		XX	XX	X	X		X	X	X			X	XXX		XX	XX	X
	i	chaff			X						X					X		X	X	
Panicum miliaceum	ch	c									X									
Secale cereale	i	c	X												X					X
Triticum aestivum	ch	c	X					X						X				X		XX
Triticum dicoccon	ch, i	c	XXX	XXXX	XX	XX	X		X		X	XXXX	XXXX		XXX	XX	XXXX	XX	XXX	XX
	ch, i	chaff	XX		XXX	XX					XX	XX	?	XX	X	XXX	XXX	XX	XXX	XX
Triticum dicoccon vel *T. spelta*															X					
Triticum monococcum	ch, i	c	XX		XX	X					X	XX	XX		XX	X	XX	X	X	X
	ch, i	chaff	XX		XXX							X		XX	X	X	X	XX	X	X
Triticum dicocoon vel *T. monococcum*	ch, i	c	XX			XXX									XX	X	XXX			
	s	wkł			XXX	XXX										XX	XX		XXX	

taxa name	state of preservation	kind of remains	Bronocice	Ćmielów	Donatkowice, site 23	Donosy, site 3	Giebułtów, site 1	Husynne, site 1	Iwanowice-Klin	Kawczyce, site 1	Kobylniki, site 4	Kraków-Mogiła, site 62	Kraków-Prądnik Czerwony	Miechów, site 3	Mozgawa, site 1-3	Niedźwiedź	Parchatka, site 12	Pliszczyn, site 9	Smroków, site 17	Zawarża, site 1
Triticum spelta	ch, i	c	XXX															X		X
	i	chaff																		X
Triticum sp.	ch, i	c	X		XX		X		X			?			XX	XX		XX		X
	ch, i	chaff			XX					X				XX	XX					X
other cultivated plants																				
Lens culinaris	ch	s	X												XX					
Linum usitatissimum	ch	s		?											X					
Pisum sativum	ch	s		?											XX					

Table 2. Occurrence of cultivated plants on sites of the TRB in Silesia; explanations in Table 1

taxa name	state of preservation	kind of remains	Janówek	Pietrowice Wielkie	Polwicea-Skrzypnik	Racibórz, site 423	Strachów, site 2	Wojkowice, site 15
Hordeum vulgare	ch, i	c	X	X	X	X	X	X
	i	chaff		X	X			
Triticum dicoccon	ch, i	c	X		X		XX	X
	ch, i	chaff		X	XX	X	XX	X
Triticum monococcum	ch, i	c			X		X	
	ch, i	chaff					X	
Triticum dicoccon vel *T. monococcum*	ch, i	c			X	X	X	XX
	ch, i	chaff			X	X		X
Triticum sp.	ch, i	c				X		X

In Kuyavia, Greater Poland and Pomerania, seven species of cereal crops were identified (Table 3). *T. dicoccon* occurred in 13 of the 18 investigated sites. On eight of these 13 sites charred remains and imprints of *T. monococcum* were recorded. *T. monococcum* was found without emmer on only one site (Szlachcin). On the other hand, there were sites in Kuyavia where *T. monococcum* predominates and *T. dicoccon* is scarcely represented, *e.g.* Osłonki 2 (159 specimens of einkorn *vs.* 14 of emmer – Mueller-Bieniek 2016). *H. vulgare* was recorded on 10 sites. *T. aestivum, T. spelta* and "new" glume wheat were identified in a smaller number of plant assemblages, similar to *P. miliaceum*.

The numbers of remains of the aforementioned taxa in single assemblages usually did not exceed a few dozen specimens, even in the case of emmer. This is a situation similar to Silesia, and different from Lesser Poland, where amounts of identified finds were generally higher. This observation applies, interestingly enough, even to those sites in Kuyavia and Greater Poland that have been investigated in recent years, *i.e.* sites in which systematic sampling has been performed (Kopydłowo, Osłonki, Smólsk, Wolica Nowa), though no doubt this resulted in a greater taxonomical diversity (*vide* Kopydłowo, Wolica Nowa). The exceptions are constituted by hundreds of charred grains and imprints of *H. vulgare* at Mrowino 3 (Wierzbicki 2013, 251) and thousands of charred grains of *T. dicoccon* on the Pomeranian site of Poganice 4 (Wierzbicki 1999). Certainly, deposits discovered at Opatowice 12, Radziejów Kujawski, Zarębowo 1, and Poganice 4, containing several thousand specimens of *T. dicoccon* mixed with *T. monococcum* (but not at Poganice 4), constitute another exception.

Other cultivated plants

Only four taxa of other cultivated plants were identified on the TRB sites (Tables 1-3): *Linum usitatissimum* (flax), *Papaver somniferum* (opium poppy), *Lens culinaris* (lentil) and *Pisum sativum* (pea). The numbers of identified specimens were very low. The only exception is at the newly investigated site of Mozgawa, due to a higher amount of *L. culinaris* and *P. sativum* (Kotynia 2016). We cannot exclude, however, that this results from the extensive sampling strategy.

Wild plants

On the whole, 31 weed taxa were identified at TRB sites,, including 19 archaeophytes and 12 apophytes (see the full list in: Lityńska-Zając 2005, table VI). Table 4 presents the 10 species of weeds that were found at the highest number of sites (sites of the LBK and L-PC were also included there). In the examined materials, remains of *Bromus secalinus* (rye brome)*, Agrostemma githago* (corn-cockle)*, Echinochloa crus-galli* (cockspur)*, Chenopodium album* (goosefoot) and *Fallopia convovulus* (wild buckwheat) were most often represented. Of the other wild plants that might have had alimentary importance, *Malus sylvestris* (wild apple), *Pyrus* sp. (wild pear) and hazelnuts should be mentioned (Bieniek 2007; Bieniek and Lityńska-Zając 2001; Kruk *et al.* 2016; Wierzbicki 1999, 220, 223-226).

Comparison with earlier Neolithic units

Turning to the comparison between the TRB and the earlier, Danubian Neolithic units, we find that the L-PC is characterized by the lowest taxonomical variability. However, this could be the result of the L-PC having the lowest number of investigated sites, as the variability for the LBK and TRB is similar. In other words, we should not interpret this observation as a reflection of any trends or changes within the plant economy of the L-PC. In general, there are no conspicuous differences between the TRB and earlier Neolithic units. In all of them, emmer is the most important crop, while einkorn and barley are ranked in second and third place, respectively (see Figs. 2-4). Only minor differences can be postulated. The importance of einkorn seems to be lowest in the TRB. In case of the absolute number of sites, these ratios are 53% for the LBK, 60% for the L-PC and 42% for the TRB. On the other hand, if we calculate the ratio of einkorn to emmer by the number of samples, it turns out that it amounts to over 50% for the LBK and the L-PC, and approx. 30% for the TRB. These trends are clearly visible in specimens identified as *T. dicoccon* vel *T. monococcum*. In the TRB, there are even lower proportions of einkorn as compared to barley. In turn, barley seems to have a bit lower share in the LBK, at least when we consider quantity of samples.

Table 3. Occurrence of cultivated plants on sites of the TRB in Kuyavia, Greater Poland, and Pomerania; explanations in Table 1

taxa name	state of preservation	kind of remains	Inowrocław-Mątwy, site 1	Kokorzyn, site 2	Kopydłowo, site 6	Kotowo, site 1	Mrowino, site 3	Opatowice, site 1	Opatowice, site 3	Opatowice, site 12	Opatowice, site 33	Opatowice, site 42	Osłonki, site 2	Poganice, site 4	Radziejów Kujawski	Smólsk, site 2/10	Szlachcin, site 3	Tarkowo, site 23A-23B	Wolica Nowa, site 1	Zarębowo, site 1
Hordeum vulgare	ch, i	c	XXX	XX	X	XX	XXX					X		X		XX	X	XXX		
	i	chaff	XX		X		XXX											XX		
Panicum miliaceum	ch	c	X														XX	X		
Triticum aestivum	ch, i	c								XX		X			XX		X			X
Triticum dicoccon	ch, i	c		X	X		X	X	X	XXXX	X	X		XXXX	XXXX				X	XXXX
	ch, i	chaff			XX					XX		X	XXX	XXXX					X	
Triticum dicoccon vel *T. spelta*														X						
Triticum monococcum	ch, i	c			X			X		X		X			XXX		X		X	XXX
	ch, i	chaff			XX			X				X	XX						XX	
Triticum "new" type																			X	
Triticum spelta	i	c				X						X								
Triticum spelta vel "new"?	i	chaff											X							
Triticum sp.	ch, i	c	X			X	XX	X	X			X	X						XX	
	ch, i	chaff			X			X	X			X							XX	
other cultivated plants																				
Lens culinaris	i	s									X									
Pisum sativum	ch, i	s		X								X					X		X	
Papaver somniferum	ch	n																	X	

Table 4. Frequency of weeds in archaeological sites representing the LBK, L-PC, and TRB and their present day phytosociological classification (after Matuszkiewicz 2001 and Zarzycki *et al*. 2002). Present day phytosociological classification: A – *Aperion*, Bt – *Bidention tripartiti*, Caucalid – *Caucalidion lappulae*, Cc – *Centuretalia cyani*, L – *Linion*, Pan-Setar – *Panico-Setarion*, Pol-Chen – *Polygono-Chenopodietalia*, Stel med – *Stellarietea mediae*

species name	phytosociological classsification	LBK	L-PC	TRB
Agrostemma githago	Cc	2	3	14
Bromus secalinus	A	5	3	21
Chenopodium album	Stel med, Pol-Chen	15	13	13
Echinochloa crus-galli	Stel med, Pol-Chen	9	4	12
Fallopia convolvulus	Stel med	7	11	12
Galium spurium	L, Caucalid	7	3	3
Lithospermum arvense	Cc	1	1	4
Polygonum lapathifolium s.l.	Pol-Chen, Bt	8	2	4
Polygonum persicaria	Stel med	6	2	2
Setaria pumila	Pan-Setar	10	1	3

An interesting observation is connected with other crops. Most of them seem to be the least important in the TRB (see especially Fig. 4). This applies particularly to *P. miliaceum*, *S. cereale*, *T. aestivum*, "new" glume wheat, *L. usitatissimum* and *P. somniferum*. Against this background, the predominance of emmer, as well as the considerable importance of barley and einkorn, is seen even more convincingly.

As regards cultivated plants other than cereals, it should be emphasized that from a general perspective, their significance was low in all three cultural units. In the TRB, *L. usitatissimum* and *P. somniferum* seem to comprise a slightly smaller share and Fabaceae a slightly higher one than in the earlier Neolithic.

DISCUSSION

Crops in the TRB

In the TRB in Polish territories, three cereal species clearly predominate: *T. dicoccon*, *T. monococcum* and *H. vulgare*. This is also reflected by the high shares of *T. dicoccon* vel *T. monococcum*. *T. dicoccon* is definitely ranked first. The importance of the other two crops is similar, perhaps with a slight predominance of barley. These three cereals occurred at a significant majority of the analyzed sites. There are only three sites where emmer was not "accompanied" by einkorn and barley, and four sites where einkorn or barley occurred "alone".

The great importance of cereal cultivation can be demonstrated by storage pits containing deposits of grain. They were discovered in at least eight sites of the TRB (Ćmielów, Kraków-Mogiła 62, Kraków-Prądnik Czerwony, Opatowice 12, Parchatka 12, Poganice 4, Radziejów Kujawski and Zarębowo 1). In these deposits, emmer distinctly predominates, but there is almost always an admixture of einkorn. Certainly, this suggests joint cultivation of these taxa (maslin), since both have similar edaphic requirements and similar life cycles (sowing, flowering, harvesting). One pit at Ćmielów, where clean grain of emmer was recorded, is an exception. Similarly, of the cereals, only emmer grains were registered in three or four pits at the site of Poganice 4. However, in addition to emmer, quite a number of hazelnut shells were discovered in these pits. It is worth noting that only three pits of this kind were found in the LBK and L-PC (Gluza 1984; Godłowska and Gluza 1989; Grygiel 2008, 550, 664-665; Lityńska 1990). In the TRB deposits, there is no barley. We should add, however, that barley deposits were recorded in the TRB context in the Czech Republic (Dreslerová and Kočár 2013).

Other cultivated plants formally appear to have minimal significance. Of course, the question arises whether a small share of other wheats, millet, pulses, flax, and poppy in macroscopic remains may result from their marginal role in past crops or from other causes, i.a. the number of tested samples, or certain taphonomic disturbances. For example, in the multi-cultural site 3 at Miechów (Fig. 1), some grains of millet were found in the Lublin-Volhynian features. However, one grain was ^{14}C dated and the result clearly indicated a chronology of the Late Bronze Age (Mueller-Bieniek *et al.* 2018a, 605).

In the case of pulses, there are suggestions that their poor representation in sub-fossil materials is conditioned by the fragility of the charred Fabaceae seeds. For instance, at the site of Tell el-Kerkh, 29 specimens of *Vicia faba* (broad beans) were obtained through flotation. However, after the transportation and unpacking of samples, only four pieces survived (Tanno and Wilcox 2006). On the other hand, at the TRB site at Mozgawa, pulses were found quite often and in a good state of preservation. In addition, we cannot forget that on many archaeological sites from later periods, numerous remains of pulses were present (*e.g. L. culinaris* at the Bronze Age site of Sobiejuchy in eastern Greater Poland – Palmer 2004). This corresponds to the views of some authors (*e.g.* Kohler-Schneider 2001), that pea and lentil became popular only in the late Bronze Age, simultaneously with the spread of millet. Besides, these plants (in the full, "Near Eastern" set, *i.e. Lathyrus sativus*, *L. culinaris*, *P. sativum*, *Vicia ervilia* and *V. faba*) are represented in the First Temperate Neolithic in the Balkans (*e.g.* Conolly *et al.* 2008). Thus, in these cases, the fragility of charred seeds did not negatively affect their preservation.

Altogether, one could wager that pea and lentil were probably sown in gardens by the TRB people, as was the case of the LBK and L-PC (Bogaard 2004; Kruk and Milisauskas 1999; Kruk *et al.* 2016, 147; Nowak 2009, 184, 392), but their importance in the diet was lower than in subsequent ages.

The status of *S. cereale*, *T. aestivum* and *T. spelta*, not only in the context of TRB, remains debatable. It is common belief that rye and spelt were only weeds of cereal crops in the Neolithic (Behre 1992; Lityńska-Zając 2007b, 213; Wasylikowa *et al.* 1991, 222-224), and we cannot rule out that such status should be assigned to all three aforementioned plants (Lityńska-Zając 2007a, 323). On the other hand, the identification of *T. spelta* in three phases at Bronocice (Kruk *et al.* 2016) suggests that this wheat could be grown, at least locally. The relatively early presence of *T. spelta* in eastern Central Europe should be studied in detail in the light of other European findings (Akeret 2005). Let us add that spelt is not very demanding in terms of soil, and it is resistant to low temperatures and excessive humidity (Janushevich 1976); furthermore, it produces a luxurious flour. For Neolithic people, these factors could be arguments for its cultivation.

Wild herbaceous plants

The frequent presence in the sub-fossil materials of herbaceous taxa, such as *B. secalinus*, *E. crus-galli*, *Ch. album* and *F. convovulus*, may result from their economic usefulness. Even *A. githago*, also frequently represented, can be used therapeutically and as a poison (Mueller-Bieniek 2012, 100; Zemanek 2012). Diasporas of these plants could have been intentionally collected (Behre 2008; Colledge and Conolly 2014; Mueller-Bieniek *et al.* 2018b; 2019a), or perhaps stored food was not cleaned of them, because they were fit for human consumption. Some of them are characterized by high fertility, *e.g.* one specimen of goosefoot produces about 100,000 seeds (Tymrakiewicz 1962, 31-32).

Regardless of their potential usefulness, the presence of field weeds in macroscopic assemblages provides important information about the patterns of cultivation. Cereal predominance in the plant economy of the TRB is implied not only by deposits and taxa structures, but also by weeds found in the context of the TRB, including the foregoing deposits as well. As we already know, the degree of weed infestation in grain found in deposits is insignificant. This could be due not only to the very good cleaning of grain by the farmers of the time, but also due to low (natural) contamination of crops. The degree of infestation of fields depends *i.a.* on the duration of their use. Therefore, a small number of weeds typical of cereal crops may reflect the short use of these fields.

According to M. Lityńska-Zając (2005, 264-267) plants found in cereal deposits of the TRB are linked (acc. to the current phytosociological perspective) with different environments: field, ruderal and forest. The large share of apophytes from riverine grasslands, meadows, and forest communities, and the predominance of perennial species among them, indicate that new stretches of land were taken for tillage. Native species, undamaged in the course of preparing the soil for sowing, could grow there. At the same time, a modest number of sites containing large amounts of weeds can be, to some extent, an argument for the sowing of cereals on freshly prepared fields. This aspect somewhat resembles the LBK

(Lityńska-Zając 2005, 267). Generally, all these facts and interpretations may mean that fields were located in different ecological conditions, including areas not previously exploited for agricultural purposes.

Trajectories and models of the plant economy

A serious deficiency in our knowledge on the plant economy of the TRB in Poland is due to the almost complete lack of information about early stages of this culture. Data obtained from the first phase of the TRB settlement at Bronocice point to the existence of a cereal economy as early as the first quarter of the 4th millennium BC (Kruk *et al.* 2016), similar to the not-so-distant site of Kawczyce (Nowak 1994). As regards the early phase of the eastern group of the TRB, currently only one imprint of *T. aestivum* on a pottery fragment at Łącko 6 (Domańska and Kośko 1983), and only two imprints of supposed *T. dicoccon* and *T. monococcum* on pottery fragments at Redecz Krukowy 20 (Mueller-Bieniek 2018) can be mentioned, which does not prove the everyday usage of cereals or their by-products. Perhaps it is significant that in the meticulously investigated site of Dąbki (north-central Pomerania), there are no domesticated plants in the context of the local early TRB, up to approx. 3700 BC (Czekaj-Zastawny *et al.* 2013, 423). Most probably, what we see here is the continuation of patterns of the local Mesolithic (Kalis *et al.* 2015). The cereal economy in the early TRB is also supported by pollen spectra obtained from ploughing furrows in the monumental, unchambered tomb no. 8 at Sarnowo 1 (Kuyavia), as well as from anthropogenic features at the settlement on the same site. They provided i.a. pollen of wheat and barley (Dąbrowski 1971). Similarly, an analysis of phytolites from ploughing furrows under the barrows of the monumental tombs at Zagaje Stradowskie (western Lesser Poland) suggests a cultivated field with wheat and probably barley (Polcyn *et al.* 1999).

Overall, the scarce data from the early TRB seem to demonstrate that cultivation was practiced by TRB people since the very beginning, although the significance of cereal cultivation, particularly in the Lowland zone, may have been moderate until *ca.* 3700/3600 BC. This interpretation closely mirrors observations made in northern Germany (Kirleis and Fischer 2014; Kirleis *et al.* 2012).

If we consider the global (*i.e.* not restricted to early stages) relationships to other groups of the TRB, we should indicate some similarities to the southern groups of this culture (Dreslerová and Kočár 2013), and some differences in relation to the northern group. In the latter, in addition to the noticeable importance of free threshing wheats in the Early Neolithic I, the share of barley is incomparably higher. In a large part of the Early Neolithic II and Middle Neolithic sites, it is the dominant species. On the other hand, the share of einkorn is surprisingly low (Kirleis and Fischer 2014).

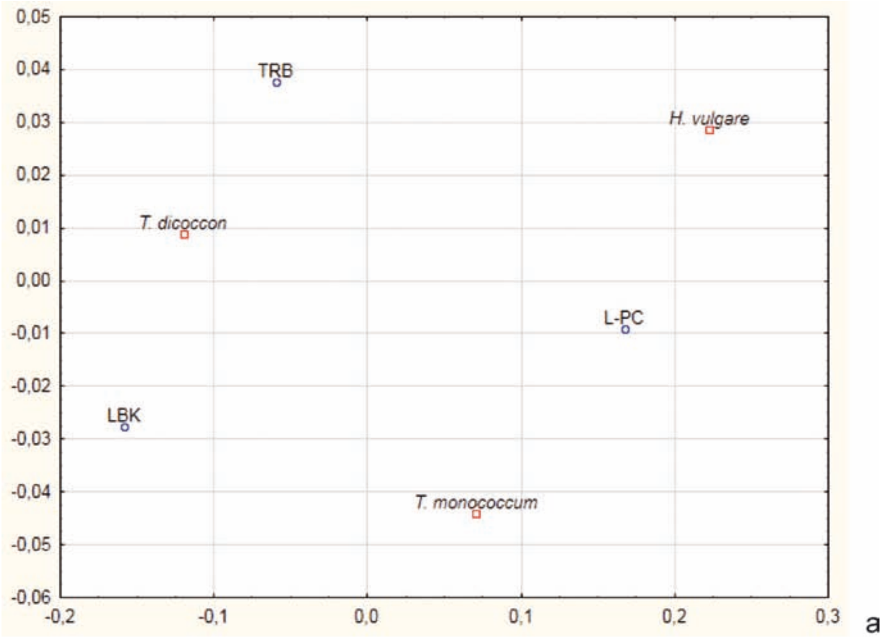
Differences between the "Polish" archaeobotanical assemblages of the LBK, L-PC, and TRB seem to be small, both in quantitative and qualitative terms. They consist of a slightly greater predominance of emmer, and a slightly greater importance of barley, in the case of the TRB. Interestingly enough, this impression has been confirmed by χ^2 test, performed on the basis of the data presented in Figs. 2-4 for emmer, barley, and einkorn. The resulting *p*-value of 0.0244 means that there is a statistically significant difference between the LBK, L-PC and TRB. This conclusion is also visible in the correspondence analysis for the same data (Fig. 6: A). It shows that the differences between the LBK and L-PC are of the same order as that between the Danubian Neolithic units and the TRB. A similar picture has been obtained (Fig. 6: B) when complemented with the respective ratios for *T. aestivum*, *T. spelta*, *S. cereale* and *P. miliaceum* (due to the small sample sizes of these taxa, the χ^2 test cannot be applied).

The comparison of these three archaeological units with respect to weeds is perhaps more interesting (Table 4). In current phytosociological terms, segetal weeds are classified in two distinct groups. The first includes species characteristic of cereal crops, and the second comprises species related to root plants (Matuszkiewicz 2001). This division, in spite of various objections to its usefulness in palaeoecology (Jones 2002, see further literature), is reflected in analyses of fossil sources. To weeds associated with root-crop communities (*Polygono-Chenopodietalia* and *Panico-Setarion*) belong *Ch. album*, *E. crus-galli*, *Polygonum lapathifolium* (pale persicaria) and *Setaria pumila* (yellow foxtail). Segetal communities found in cereal crops (*Aperion*, *Caucalidion lappulae* and *Centauretalia cyani*) include *A. githago*, *B. secalinus*, *G. spurium* and *L. arvense*.

It turns out that some species associated with root crops (*P. lapathifolium* and *S. pumila*) occur more often on sites of the LBK and L-PC. On the other hand, some weeds occurring in cereal crops (*A. githago* and *B. secalinus*) were recognized more frequently on TRB sites. This may be related to changes in patterns of cultivation. Remains of the weeds of root-crop communities usually occurred in conjunction with remains of caryopses of hulled wheats and/or barley. Therefore, the presence of these weeds should rather be connected with cereal cultivation, in which soil was prepared with a technique similar to hoe farming (Kruk 1993). This was very close to the techniques used for root crops. In turn, the frequent presence of cereal weeds in the TRB was associated with cultivating fairly large amounts of land and giving up hoe farming techniques (*e.g.* Lityńska-Zając 2005, 367; Mueller-Bieniek 2016). In other words, in the TRB, an extensive cultivation of cereals would have prevailed.

The aforementioned data and interpretations, in themselves, do not give a clear answer to the question about patterns of plant cultivation in the TRB. The suggested picture of the dominant role of cereal crops might, however, compliment the classic model describing Neolithic settlement and economy, formulated in Polish literature by J. Kruk in 1970s (1973; 1980), and later developed in collaboration with S. Milisauskas (Kruk *et al.* 1996; Kruk and Milisauskas 1999).

This model assumes that the economy and settlement pattern of the TRB communities required the exploitation of extensive areas. The predominant type of farming was slash-



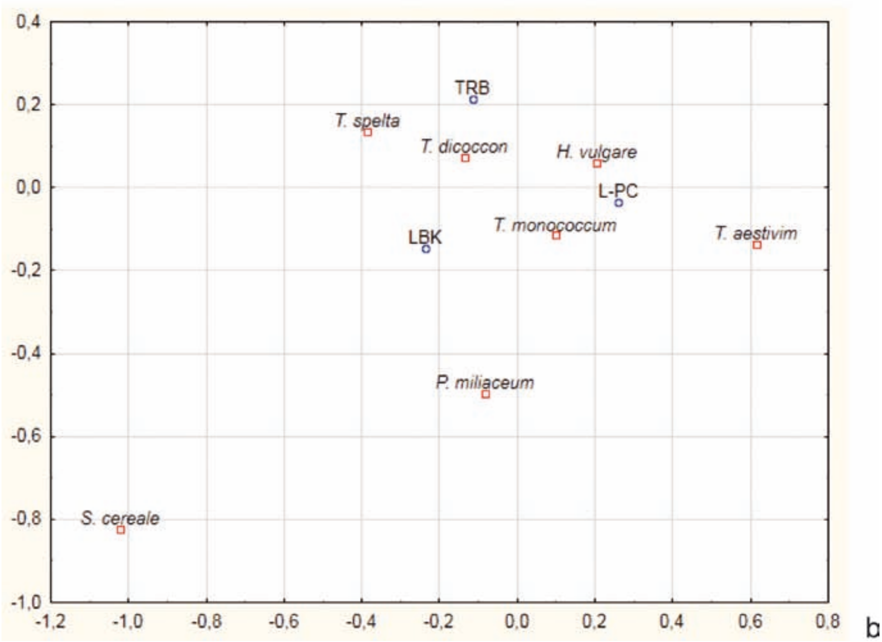


Fig. 6. Correspondence analysis of the LBK, L-PC, and TRB data (see Figs. 2-4) for a) emmer, einkorn, and barley and b) emmer, einkorn, barley, bread wheat, spelt, rye and millet

and-burn shifting cultivation practised on a massive scale, and the basic tool of agricultural technology was fire. Such a system was focused on cereal crops (Kruk and Milisauskas 1999, 147). The final result of this system was the significant deforestation of the landscape. The model under discussion referred primarily to the loess upland zone. However, some processes of anthropogenic deforestation could also have taken place in lowland areas (Kruk and Milisauskas 1999, 255-256).

It is worth mentioning at this point the recent analyses of isotopic compositions of carbonized cereal grains from the territory of Poland, including the TRB grains (Mueller-Bieniek *et al.* 2019b). The $\delta^{15}N$ values indicated that almost all cereal fields from which the TRB samples originated "could have received some inputs of fertilizer, including manure and household waste" (Mueller-Bieniek *et al.* 2019b, 11). This seems to contradict the above mentioned hypotheses of landscape deforestation, and implies intensive, permanent cultivation, at least in the upland zone of southern Poland, as almost all TRB samples come from there. On the other hand, in theory, it cannot be entirely ruled out that such isotopic signals of manuring may result from intentional burning of the vegetation to clear the land for agriculture (Mueller-Bieniek *et al.* 2019b, 2, 10, see further literature) the more so since δ13C values demonstrate that part of the TRB fields in southern Poland existed in more open, elevated landscapes, with lower water availability (Mueller-Bieniek *et al.* 2019b).

Obviously, this is a very complex issue among other reasons because not all categories of palaeoenvironmental data and not all palaeoenvironmental interpretations support Kruk's views. At present, his model seems to be supported more by geomorphological data, indicating intensive slope erosion in the 4th millenium BC (Kruk *et al.* 1996; Poręba *et al.* 2012; Szwarczewski 2009), than by palynological data, though of course there are some profiles with indicators of a substantial opening of woodland cover and traces of fire (*e.g.* Nowak 2001). On the other hand, we can easily point to many pollen profiles, obtained in regions with quite intensive TRB settlement, in which human traces are quite scarce (*i.a.* they contain little to no cereal pollen). This applies mainly to lowland areas (*e.g.* Herking 2004; Niewiarowski and Noryśkiewicz 1999; Noryśkiewicz 2006), but also upland ones (*e.g.* Nalepka 2003). We must remember, however, that palynological data are much less frequent in the loess highlands. It may therefore give a false impression of minimal human activity, based on the overrepresented lowland pollen data. For instance, the situation recorded in the recently investigated pollen profile at Mozgawa (*i.e.* in the loess zone) is very significant. The series of anthropogenic indicators seems to support the thesis of intense and widespread human environmental impact (Moskal-del Hoyo *et al.* 2018).

It should be emphasized that the lack of differences in palynological indicators of cereals between the LBK, L-PC and TRB (Milecka *et al.* 2004) does not necessarily imply similar cultivation systems. Palynological data do not reflect the actual species composition, nor the role of given crops (Grikpėdis and Motuzaitė Matuzevičiūtė 2016; Latałowa 2003; 2007). Species of the *Triticum* and *Hordeum* are self-pollinated; therefore, the possibility of dispersions of sporomorphs is significantly reduced. As a result, their real importance is undervalued. To an even greater extent, this applies to *P. miliaceum* (Latałowa 2003, 279; Milecka *et al.* 2004).

The discussion of the possibility of distinguishing between permanent and shifting cultivation, based on archaeobotanical, palynological and archaeological data, has been going on for years (Ehrmann *et al.* 2014; Robin and Nelle 2014; Rösch *et al.* 2014; Baum *et al.* 2016; Jacomet *et al.* 2016; Rösch and Lechterbeck 2016). Totally opposed opinions have occurred in this regard. Universal indicators of these two types of cultivation have not been worked out, despite the fact that, in many cases, incomparably superior sets of source data (*e.g.* Jacomet *et al.* 2016) were available, when compared, for example, with the "Polish" TRB. Therefore, we took the liberty not to propose a decisive hypothesis for the "Polish" TRB in this matter. We are of the opinion that the current state of data and interpretations do not authorize us to do so. Certainly, this does not mean that shifting cultivation could not be practiced by the TRB communities in the Vistula and Oder basins. We can suppose that there was a patchwork of agricultural techniques, which best fit the local environmental and social conditions.

CONCLUSIONS

The following are the most important conclusions that should be put forward as regards the plants and the plant economy of the Funnel Beaker culture in Poland.

1. There is a predominance of *Triticum dicoccon* in the TRB, both in scattered material and in deposits.

2. *Triticum monococcum* frequently co-occurs in deposits as an admixture in small amounts. The pattern of deposition of caryopses of these two species of wheat suggests that they could be sown together, in the form of maslin with a predominance of emmer (up to 90%).

3. *Hordeum vulgare* occurs in a slightly higher number of sites than *Triticum monococcum*, but in lower amounts (mostly detected as imprints); there are no confirmed deposits of *Hordeum vulgare*.

4. The proportions (and importance) of other cereals and other cultivated plants are insignificant.

5. Weeds connected with the extensive cultivation of cereals grow in importance when compared to the Danubian Neolithic.

6. New archaeobotanical data suggest that pulses (pea and lentil) and flax were locally cultivated.

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