MILLET AND WHAT ELSE?

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The wider context of the adoption of millet cultivation in Europe

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Contents

The earliest finds of millet and possible associated changes in material culture in Slovenia

Tjaša Tolar and Primož Pavlin

Abstract

We present an overview and review of archaeobotanical results on the earliest occurrence of crop plant remains from the area of what is today Slovenia, focusing primarily on the phenomenon of the appearance of millet and associated material culture in the Bronze Age and the Iron Age. In addition, we present an overview of the development of prehistoric harvesting tools and settlement patterns in Slovenia from the Neolithic to the Iron Age. Based on the available results from archaeological sites in Slovenia, the appearance of broomcorn millet and foxtail millet, together with oat, rye, lentil and faba bean, can be placed in the Late Bronze Age. In the Early Iron Age, the importance of millets increases, while the introduction of free-threshing wheat represents another agricultural innovation at this time. Just as emmer and einkorn are typical cereals of the Copper Age in the region, so millets are of the Late Bronze Age and, especially, of the Early Iron Age. Pulses were less common in the Copper Age and became more important in the Late Bronze and Early Iron Age. Barley seems to have been equally important through all of these periods. Collected wild fruits and nuts were more important for the diet during the Copper Age than during the Late Bronze Age and Early Iron Age. However, we emphasise that, the way in which archaeobotanical sampling/collecting, storing and sieving was done (if it was done at all) may have played an important role in the amount and type of results obtained. Even so, some major conclusions on the spectrum of crops used in different periods remain valid.

Introduction

Slovenia is located in southeastern Europe, along northernmost part of the Adriatic Sea, at the intersection of the Alpine, Mediterranean, Pannonian and Dinaric worlds (Fig. 1). It borders Italy to the west, Austria to the north, Hungary to the north-east and Croatia to the east and south. The topography of Slovenia is relatively diverse (including mountains, mountain plateaus, plains, valleys, karst fields, and the Adriatic coast), and the different landforms alternate over short distances. The transition between landscapes or parts of them is gradual. Due to its geographical position, Slovenia is a distinct transition country. Important transport links between Italy and central and eastern Europe have always passed through its territory. The climate is temperate, being a mixture of influences of the Alpine, Mediterranean and continental climates.

Little is known about the prehistoric plant economy (cultivation and gathering) in Slovenia, with the exception of that of pile-dwellings from the 4th millennium BCE (Copper Age). Therefore, the answers to the questions of when the first signs of cultivation appeared, where this cultivation came from and how it developed after its introduction are still incomplete. This study reviews and extends the earliest archaeobotanical data on cultivation and plant gathering in Slovenia. The aim is to provide a long-term perspective on plant-human interactions, together with archaeological information from specific sites in the area where archaeobotanical analyses were carried out, focusing on the earliest known evidence of broomcorn millet (*Panicum miliaceum*) cultivation.

The cultivation of plants (as well as the material culture) in what is today Slovenia most probably originated from the southeastern regions of the Balkans. It is also very likely that some influences arrived via the Mediterranean route, across the Adriatic Sea and from the Apennine Peninsula (*e.g.* Ihde 1995). Despite scarce archaeobotanical evidence, it is generally accepted that plant cultivation was practised in the territory of Slovenia by the Late Neolithic. The oldest flint stones with 'gloss' (referring to a characteristic shine that proves that they were used as harvesting tools) come from Late Neolithic layers (5th millennium BCE) at Moverna vas, in Bela krajina, and at Dragomelj, near Ljubljana (see Results).

Our contribution summarises archaeobotanical and archaeological evidence from Slovenia that could provide hints on when, how and why millet became one of the most common crops. The three main areas covered are the oldest ^{14}C-dated millet grains and their frequency through time; possible climatic changes in the period when millet appeared; and the oldest finds of harvest implements and their increasing efficacy through time, as a possible indicator for improving agricultural techniques.

Summary of economic activity and settlement patterns from the Neolithic to the Iron Age in Slovenia

The Neolithic in Europe was characterised by some major changes in the way people lived. They settled in permanent settlements, and agriculture and the keeping of livestock became the main economic activities. They cultivated cereals and pulses and raised animals, such as sheep, goats, cattle and pigs. The production and use of ceramic vessels was extremely important because the ability to cook foods radically changed eating habits. Easier access to food led to population growth and an incipient division of labour, while surplus production boosted trade, all of which led to social stratification (*e.g.* Bogaard and Styring 2017).

The territory of present-day Slovenia was influenced by the developing Neolithic cultures that surrounded it. The interior and the eastern part of Slovenia were connected with the Pannonian Basin, whereas the Karst and the Slovenian coastal area were connected with the eastern Adriatic coast and thus indirectly with the Mediterranean Sea. In western Slovenia, traces of Neolithic settlement have been found mainly during excavations of karst caves, while in central and eastern Slovenia settlement traces have been found either on the plain, on river terraces, at river bends or on naturally protected elevations (Guštin 2005). The settlement of Gradec, near Mirna, occupied in the middle of the 5th millennium BCE, was protected by a stone wall (Dular *et al.* 1991, 84-90, 119-128, 140-142). The first pile-dwelling settlement appeared on the shore of the lake in what is now known as the Ljubljansko barje [the Ljubljana wetlands] (Velušček 2006).

The first metal age was the Copper Age, also known as the Eneolithic. In addition to stone, horn and bone tools and weapons, copper objects appeared in small quantities. The first finds related to copper metallurgy in Slovenia date back to the middle of the 4th millennium BCE. The objects in question are a piece of copper slag and fragments of crucibles from the wetland pile-dwellings of Hočevarica (Šmit 2004), Maharski prekop (Velušček and Greif 1998, 31-33) and Stare gmajne (Velušček 2009, 18-25). Copper metallurgy experienced a real heyday in the first half of the 3rd millennium BCE. The so-called Dežman pile-dwellings, near Ig, produced numerous copper objects (awls, daggers, axes) and, even more importantly, typical metallurgical accessories, such as moulds, crucibles and clay blowpipes, which indicate the local production of copper objects there (Korošec and Korošec 1969). Compared with the Neolithic, Slovenia showed a much denser settlement pattern in the Copper Age. Settlements developed in a similar environment as in the Neolithic period, and pile-dwelling settlements flourished in the Ljubljansko barje.

Little is known about the settlement pattern of Slovenia in the Early Bronze Age. At that time, the pile-dwelling culture in the Ljubljansko barje declined, while the Prekmurje plains were relatively densely populated, as recent research has shown (Šavel 2009; Kerman 2011a-c; Guštin, Tomaž 2016; Pavlin 2015; Guštin *et al.* 2017). Both regions belonged to the same cultural area, which was characterised by the so-called Litzen pottery.

In the Middle Bronze Age, the Karst and Istria experienced the rise of the Kaštelir culture, which continued uninterrupted into the Iron Age. The culture is named after the *kaštelir*, a settlement fortified with stone walls. The Štajerska (Styria) region was part of the central European Tumulus culture, which was characterised by tumulus burials. The territory of Slovenia was at that time a transit zone on the trade route between Italy and the Danube Basin, as indicated by the characteristic sword and sickles found by a chance in the riverbed of the Ljubljanica (Pavlin 2006; Turk *et al.* 2009, 228) and by the short sword from Lavrica (Šinkovec 1996, 143, Fig 21.1).

Towards the end of the 14th century BCE, Europe experienced great changes related to the mass migrations of peoples. These caused the collapse of the Mycenaean culture in Greece, the Hittite kingdom, and numerous cities in the Middle East. The so-called Sea Peoples pushed as far as Egypt, where they were defeated by Rameses III.

Because of the nature of the burials at this time, the Late Bronze Age is also known as the Urnfield period. Central and eastern Slovenia were inhabited by people who cremated the deceased and buried their remains in urns in flat necropolises. They belonged to the cultural sphere that stretched from western Hungary, through Croatia to northern Bosnia.

In the Late Bronze Age in central and eastern Slovenia, settlements were located on naturally protected, elevated terrain, which was additionally fortified with wooden palisades. Recent excavations during the construction of motorways in northeastern Slovenia have revealed numerous lowland Bronze Age settlements along the rivers Drava and Mura (Dular 2013, 101-110, Figs. 44-48). The shape of these settlements, their spatial context, and the construction of their houses are illustrated by the following examples.

Near Orehova vas, there was a settlement on the plain, by a stream. Here, 27 floor plans of buildings were discovered, which had been built using earth-fast construction (Grahek 2015, 29-41, 349). The scattered settlement of Oloris was surrounded by a moat, over which a wooden fence stood. The walls of the houses consisted of upright beams carrying interwoven wattle and daub. The houses had a fireplace and a storage pit under the floor (Dular *et al.* 2002, 23-46). The settlement of Ormož had a slightly different kind of protection. In the south, it was protected by the river Drava, while the other three sides were surrounded by a dike and an earthwork. Inside the settlement, a network of roads up to 4 m wide and paved with gravel were documented. These streets were lined with houses of different sizes. They were built in the same way as at Oloris (Dular and Tomanič Jevremov 2010, 83-97). Excavations at the Tribuna site, in Ljubljana, have also brought to light a settlement from the Late Bronze Age (10th-8th century BCE) with an urban design. It consisted of houses of different sizes, also variously spaced, built in earth-fast construction. The houses were arranged in a grid, and the streets between them were paved (Vojaković *et al.* 2011, 26-31).

Contacts with the Mediterranean region also brought knowledge related to iron metallurgy. This and the abundance of easily accessible limonite iron ore formed the basis for the establishment of iron production towards the end of the 9th century BCE, which is thus taken as the start of the Iron Age locally. For a brief insight into Iron Age settlement, we can use data from the most researched region, Dolenjska. Here, new settlements were established either in the vicinity of older Urnfield settlements, which slowly died out, or in previously uninhabited areas. As a rule, they stood on elevated ground and were fortified by 2-3 m thick stone walls that followed the shape of the terrain. The walls were built using the dry-stone wall technique, from unworked stone blocks, and reinforced with vertical wooden beams driven into the ground. They were built in one go, and some were later repaired or supplemented. The surface areas of the settlements differ in size, from just a few to more than 10 ha. With an area of about 20 ha and 2.3 km long walls, Cvinger, near Vir, which is near Stična, was a real metropolis for that time. The houses were built in two ways. In the first method, which was adopted from the Bronze Age, upright posts were driven into the ground (earth-fast construction). In the second method, the upright posts were not driven into the ground, but stood on a horizontal beam (post-pad construction). This was laid on the bare earth or, sometimes, on a stone drainage bed. The floors of the houses were made of beaten clay. Near one of the walls was the fireplace, around which the kitchen equipment was arranged: ceramic vessels, hand mills for grinding grain, firedogs, clay rings and coils. The weights hanging on strings testify that looms were also among the household items (Gabrovec 1994).

The settlement with an urban character at Most na Soči, right on the border with Italy, was different. It stood on a naturally protected plateau above the confluence of two rivers. On the third side, access was protected by a stone wall. The houses were located on a sunny slope. They stood in rows along cobbled streets lined with ditches and canals. They had a stone foundation on which a wooden structure of horizontal and vertical beams and planks stood (Svoljšak and Dular 2016).

Short history of archaeobotanical investigations in Slovenia

The investigation of fossil plant macro-remains from archaeological sites is considered to have started relatively early in Slovenia, *i.e.* when the first pile-dwelling site in the Ljubljansko barje region was discovered, in 1875. The first results on its rich archaeobotanical remains, with a focus on wooden piles, were published soon after (Deschmann 1875, 1878). Since then, archaeobotanical reports from pile-dwellings have been common, but only isolated (occasional) plant macro-remains were collected during the excavations prior to 1998 (Schmid 1910, 1915; Korošec 1953; Šercelj 1981-1982; Culiberg 1984). The wet-sieving technique was first tested in Slovenia in 1989, at the Palaeolithic cave site of Divje Babe I (Turk 2007), where mainly charcoal fragments were extracted (Culiberg 2007). Thereafter, the flotation method was used at some other archaeological sites, *e.g.* at the Early Iron Age sites of southeastern Slovenia (Culiberg and Šercelj 1995; Dular and Tecco Hvala 2007).

Finally, in 1998, the wet-sieving method was employed at a waterlogged site as well – the Hočevarica pile-dwelling site (Velušček 2004). Thanks to the excellent preservation through waterlogging, the results for this site were outstanding (Jeraj 2004; Jeraj *et al.* 2009). In 2007, the method was supplemented with the semi-flotation technique, based on the Swiss model (Tolar *et al.* 2010). The first application of this method was at the Stare gmajne pile-dwelling settlement with rich assemblage of waterlogged plant material (Tolar *et al.* 2011). Since then, 6 cultivated and more than 20 gathered plant taxa have been regularly identified at the lake dwellings of the Ljubljansko barje (4th-3rd millennium BCE; Copper Age), which is comparable to the plant spectrum at other circum-Alpine lake dwellings (Tolar *et al.* 2011, 2016; Tolar 2018a).

Nowadays, most excavations in Slovenia use wet-sieving techniques and various methods of sampling (*i.e.* profile, systematic and judgement; Andrič *et al.* 2016, 62-65). On dry-land sites, plant remains are poorly preserved and mostly charred; charcoal predominates. Unfortunately, careful extraction of archaeobotanical remains is still not a standard, as some archaeologists do not pay enough attention to field sampling and subsequent proper processing of archaeobotanical sediment samples (*i.e.* fine wet sieving with semi-flotation using smaller than 2 mm mesh size). The loss of fragile and small seeds, such as millet grains, is certainly a consequence of negligence. Therefore, there is a great potential to find earlier archaeobotanical evidence of agriculture in Slovenia, especially given the geographical location of its territory.

Materials and methods

The main method used in this study is a review of archaeobotanical and archaeological investigations of selected prehistoric sites in Slovenia. We focused on the earliest evidence of cultivated plants and related agricultural tools, such as harvesting knives. We consider 14 sites in the archaeobotanical part of this study (Table 1; Fig. 1) and we include some additional ones in the archaeological review. They were selected according to the earliest absolutely dated evidence of crop macro-remains and the accessibility of archaeological and archaeobotanical data.

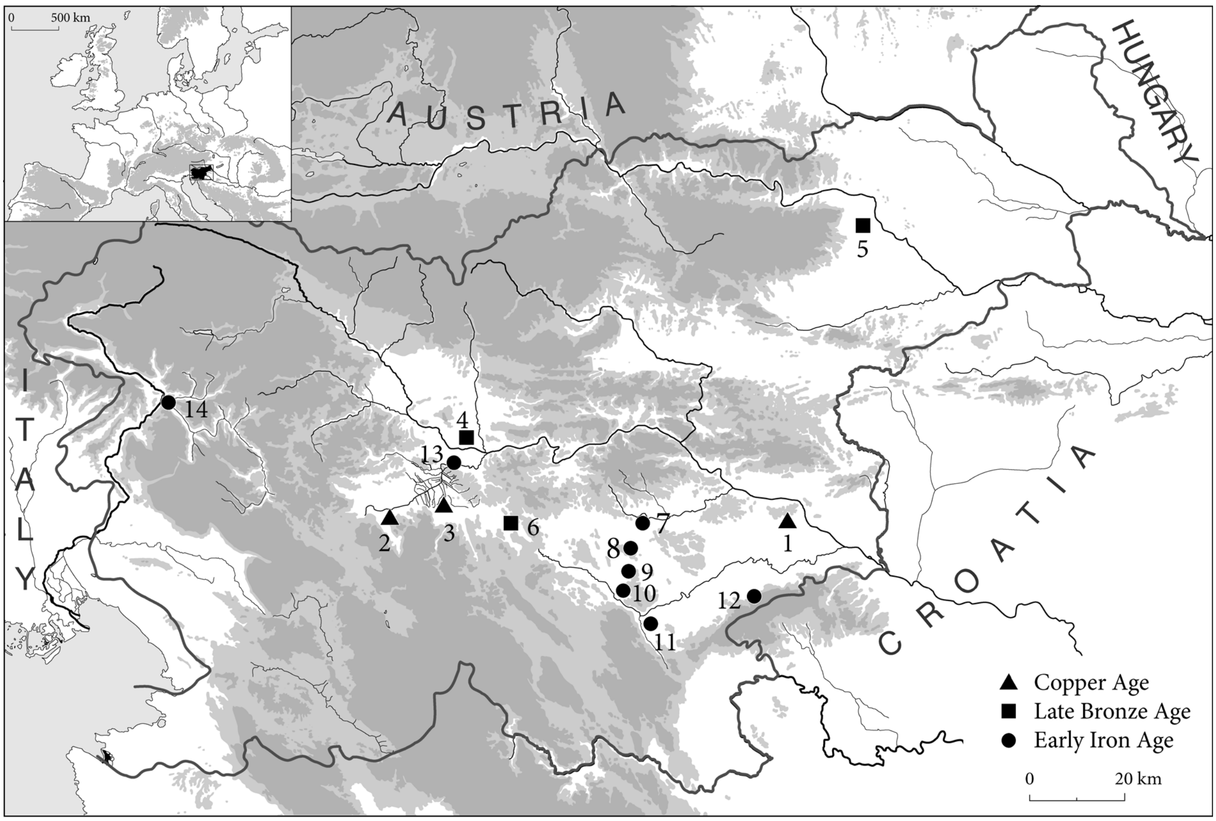
Data sources and study sites

The dataset on archaeological features and archaeobotany comes from existing publications and from manuscripts that are in preparation for publication. We have summarised our own results, including those unpublished (Archive of the Institute of Archaeology ZRC SAZU). Unfortunately, the quantification of the archaeobotanical results is not comparable, because some datasets are presented as absolute numbers of plant remains in an unknown amount of sediment, some as concentrations per litre of sediment, some as grams, and some as frequencies (see Table 2). The main objective is to make an inventory of the earliest finds of cultivated and gathered plant remains, focusing on the appearance of millet.

To track the earliest (Copper Age) absolutely dated traces of plant cultivation (remains of *e.g.* barley and wheat) in Slovenia, this study considers two different site types – dry-land and waterlogged. At the dry-land cave site of Ajdovska jama, excavated several times and over many years (from 1884 to 1990), less reliable archaeobotanical results from older excavations are available. Five cultural horizons were defined here, from the Late Neolithic to the Middle Ages, by different excavators (Horvat 1989; Culiberg *et al.* 1992 and references therein). The second horizon, radiocarbon dated to 5625±130 BP (after Culiberg *et al.* 1992) was determined to be the most intensively visited – the cave was used as a cemetery and ritual site in this period. At the time of the early excavations, flotation and wet sieving were not yet established and the recovered archaeobotanical material is scarce. In this study, we refer to a ^{14}C-dated

Table 1. The 14 sites with archaeobotanical data considered in this study (excavation years noted in parentheses).

Copper Age	Late Bronze Age	Early Iron Age
Ajdovska jama (1884, 1938, 1967, 1982-1990)	Dragomelj (1997, 2000-2001)	Six sites in southeastern Slovenia (1990-2000)
Strojanova voda (2012)	Orehova vas (2006-2007)	Ljubljana-Tribuna (2008)
Stare gmajne (2007)	Grosuplje (2011)	Most na Soči (1971-1984)



1 Ajdovska jama
2 Stare gmajne
3 Strojanova voda
4 Dragomelj
5 Orehova vas
6 Grosuplje
7 Kincelj above Trbinc
8 Kunkel near Vrhtrebnje
9 Cvinger above Korita
10 Gradec near Vinkov vrh
11 Cvinger near Meniška vas
12 Gradec above Mihovo
13 Ljubljana-Tribuna
14 Most na Soči

Figure 1. The location of archaeobotanically-studied sites mentioned in the text. The six Early Iron Age sites in southeastern Slovenia are those marked with numbers 7-12.

stratigraphic unit (labelled SE43), where most of the cultivated plant remains were found and identified (see Table 2). It yielded from 1 to 1050 carbonised grains of crop plants in an unknown amount of sediment. The frequencies of the seeds are listed in Table 2; for the original absolute numbers of seeds/fruits, see Culiberg *et al.* (1992).

The second-earliest crop cultivation sites so far recorded are the two waterlogged Copper Age pile-dwelling sites of Strojanova voda and Stare gmajne. Both were recently investigated and examined with fine flotation methods, using up to 0.355 mm mesh size (see Tolar *et al.* 2010). The results are representative and reliable, expressed in seed/fruit concentrations per litre of sediment sample (Table 2; Tolar *et al.* 2011; Tolar 2018a).

The earliest archaeobotanical evidence of millet cultivation in Slovenia comes from three locations, all from the 12th century cal BCE (Late Bronze Age): Dragomelj, Orehova vas and Grosuplje (Turk and Svetličič 2005; Tolar (in Grahek 2015); Archive of the Institute of Archaeology ZRC SAZU).

For the 'post-millet appearance' period, this study considers the Early Iron Age sites from southeastern Slovenia: Cvinger near Meniška vas; Kunkel near Vrhtrebnje; Kincelj above Trbinc; Gradec above Mihovo; Cvinger above Korita; Gradec near Vinkov vrh (Culiberg, Šercelj 1995; Dular and Tecco Hvala 2007); Ljubljana-Tribuna (available from the Archive of the Institute of Archaeology ZRC SAZU; Vojaković *et al.* 2011); and Most na Soči (Tolar 2018b) (see Table 2; Fig. 1). Numerous other sites either have been archaeobotanically analysed but not yet published due to the limited results and/or absence of absolute-dated archaeobotanical remains (Archive of the Institute of Archaeology ZRC SAZU).

Results and discussion

Overview of the archaeobotanical finds of cultivars in Slovenia from the Late Neolithic to the Early Iron Age

Before the appearance of millet

Wild plants were used throughout Slovenia during and after the Stone Age (Culiberg 1999, 2011). The earliest absolutely dated macro-remains of cultivated plants in Slovenia are naked and hulled barley (*Hordeum vulgare*), einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*). They were found at pile-dwelling settlements of the Ljubljansko barje (4th millennium cal BCE) and in the Ajdovska jama cave (5th-4th millennium cal BCE) (Table 2; Culiberg *et al.* 1992; Jeraj *et al.* 2009; Tolar *et al.* 2011; Tolar 2018a).

The earliest plant cultivation in dry locations in Slovenia is poorly understood. An example is the cave cemetery of Ajdovska jama, which was in use from the Late Neolithic onwards and where large assemblages of macro-remains of cultivated plants (such as wheat and barley) were discovered, but which were unfortunately insufficiently documented in terms of stratigraphy and chronology (Culiberg *et al.* 1992). This could be the site with the earliest evidence of plant cultivation in Slovenia. Barley and wheat predominate, but there are also remains of oat (*Avena sativa*) and faba bean (*Vicia faba*) that were not radiocarbon dated.

Dating to the well-researched Late Neolithic, Copper Age and Early Bronze Age (*i.e.* 4600-1700 cal BCE), the waterlogged pile-dwelling sites of the Ljubljansko barje provided a lot of representative data on plant, animal and cultural material. Most of the results come from the 4th millennium BCE (Copper Age) sites, where the cultivation of emmer, einkorn, barley (both naked and hulled), flax (*Linum usitatissimum*), pea (*Pisum sativum*) and opium poppy (*Papaver somniferum*), as well as the domestication of dog, sheep, goat, cattle and pig, has been established (*e.g.* Toškan and Dirjec 2004; Tolar *et al.* 2011). Archaeobotanical results from younger (3rd and 2nd millennium BCE) pile-dwellings are sparse due to the unsuitable recovery methods used prior to 2007 (Tolar *et al.* 2010) and because, subsequently, no excavations have been carried out of the youngest pile-dwelling sites.

Well-dated plant remains from pile-dwellings in Slovenia indicate a continuous cultivation of six crops from at least about 4000-3100 cal BCE (Tolar 2018a; Tolar *et al.* 2011). Even older pile-dwellings in the area of the Ljubljansko barje are known, such as the site of Resnikov prekop, from 4600 cal BCE (Velušček 2006), but with so far no crop macro-remains from this period, likely due to the taphonomic effect of the fluctuating nearby river (Culiberg 2006). It is assumed that plant cultivation in the Ljubljansko barje must have already started in the 5th millennium BCE.

There is a gap in knowledge on the use of plants in Slovenia for the period 1700-1200 cal BCE. Plant macro-remains from this period are poorly preserved (they come from dry sites), and archaeobotanical studies are rare and lacking in information.

	Copper Age		
Date or time-span	4356-3995 cal BCE	4000 cal BCE	3300 cal BCE and 3100 cal BCE
Site	**Ajdovska jama, cave cemetery; SE43**	**Strojanova voda, pile dwelling**	**Stare gmajne, pile dwelling**
Taxon / *measure of quantity*	*frequency*	*avg. concentration per 1 L of sediment in CL*	*avg. concentration per 1 L of sediment in CL*
Hordeum vulgare	1326	155	102
Triticum monococcum	3049	116	24
Triticum dicoccum	792	142	150
T. durum/turgidum/aestivum	2		
Cerealia	82		
Avena sativa	2		
Avena/Secale			
Avena/Bromus			
Secale cereale			
Papaver somniferum		820	635
Linum usitatissimum		32	75
Pisum sativum			1
Panicum miliaceum			
Sinapis arvensis			
Setaria italica			
Panicum/Setaria			
Lens culinaris			
Vicia faba (fragments)	1		
Lathyrus sativus			
Solanum sp.			1
Physalis alkekengi		115	14
Fragaria vesca		226	92
Rubus idaeus			1
Rubus fruticosus agg.		375	60
Cornus mas		13	1
Cornus sanguinea		4	1
Corylus avellana (fragments)		3	6
Juglans regia (fragments)			
Quercus sp.		33	92
Trapa natans		6	3
Sambucus sp.		550	1
Prunus sp.			1
Maloideae		56	141
Crateaegus sp.		6	2
Vitis vinifera sylvestris		2	1
REFERENCES	Culiberg ***et al***. 1992	Tolar 2018a	Tolar ***et al***. 2011
Notes about the dates	date cited after the reference	radiocarbon and dendro-date	radiocarbon and dendro-date

Table 2. Overview of the archaeobotanical evidence through time from Slovenia.

Late Bronze Age			Early Iron Age		
1190-900 cal BCE	1190-900 cal BCE	1130-970 cal BCE		1000-400 cal BCE	
Dragomelj	**Orehova vas**	**Grosuplje**	**sites in south-eastern Slovenia (7-12 in Fig. 1)**	**Ljubljana-Tribuna**	**Most na Soči**
absolute number of grains/seeds	*absolute number of grains/seeds*	*absolute number of grains/seeds*	*absolute number of grains/ seeds or, where presented as words, an estimate*	*absolute number of grains/seeds*	*weight or absolute number of grains/ seeds*
160	1	2	a lot	76	
			some		
1				1	
			63	7	
81	17	2		60	56.63 g of porridge + 5 g of food remains
			9		
					55.37 g of porridge
86					
32			1		
			2		
1			1	3	
80	34	258	many	120	37.12 g
			many		
8			some	28	52.74 g of porridge
3					70 g of food remains
10	5	5	38	78	
1			6	3	5
				1	
				2	
				3	
				1	
				279	
			13	4	
			10	5	
10		2		8	4
					2
				6	
1			4	17	
				1	
1					
Tolar unpublished data	Tolar data published in Grahek 2015	Tolar unpublished data	Culiberg and Šercelj 1995	Tolar and Vojakovič unpublished data	Tolar 2018b
radiocarbon date	radiocarbon date	radiocarbon date		radiocarbon date	

Site	^{14}C AMS-date on single (individual) millet grains	Overall quantity of millet grains in the dated deposits
Dragomelj	1192-919 cal BCE (95.4%) [Poz-104925, Poz-104926, Poz-104927]	Altogether 14 grains in two buildings
Orehova vas	1193-923 cal BCE (95.4%) [Poz-104924, Poz-104985]	A total of 25 grains from a fireplace
Grosuplje*	1134-971 cal BCE (83.1%) [Poz-45566: 2880 ± 35 BP]	More than 200 grains in a pit ('pithos')

*Table 3. Calibrated radiocarbon dates of carbonised millet grains from three Late Bronze Age sites in Slovenia (for the original data see Filipović et al. 2020; *details on the date for Grosuplje are kept in the Archive of the Institute of Archaeology ZRC SAZU).*

Appearance of *Panicum miliaceum* in Slovenia

The earliest finds of millet grains from Slovenia are known from three sites; they were all radiocarbon dated (Table 3).

In addition to millet, the Late Bronze Age inhabitants of Dragomelj cultivated nine more cultivars: barley, emmer, other wheats (*Triticum* ssp.), oat, rye (*Secale cereale*), pea, foxtail millet (*Setaria italica*), lentil (*Lens culinaris*) and faba bean. Wild plant gathering seems to have played a less important role, since only three wild plant taxa were recovered: hazel (*Corylus avellana*), elder (*Sambucus* sp.) and grape vine (*Vitis vinifera* ssp.) (Table 2). The sites of Orehova vas and Grosuplje show an absolute predominance of broomcorn millet (Table 2), signalling that it was already a very important, if not the main crop at that period.

After the appearance of millet

The Late Bronze Age and Early Iron Age can be considered as periods of agricultural expansion in Slovenia. The plant macro-remains from the Early Iron Age settlement at Most na Soči show that broomcorn millet and foxtail millet were already two of the main crops in that period. The charred remains of prepared food, *i.e.* porridge, from those two cultivars as well as from cereals (*Triticum* sp., wheat and *Avena/Secale*, oat/rye), were also found in two Early Iron Age houses at Most na Soči (Tolar 2018b). The find of charred crust resembling porridge has parallels in the find at the Late Bronze Age site of Stillfried, in Lower Austria (Kohler-Schneider 2001). There, the analysis showed a mixture of millet, barley and rye brome (*Bromus secalinus*) – a weed species that was probably tolerated, and therefore not removed, because of its nutritional value. The composition of the find from Most na Soči (Fig. 2) corresponds well to the one described from Stillfried. In addition to the remains of millets and wheats, legumes (*i.e.* faba bean) and two gathered plant taxa (hazelnut and walnut (*Juglans regia*)) were also recognised at Most na Soči (Table 2).

At all of the six Early Iron Age sites from southeastern Slovenia considered in this study (Fig. 1), systematic sampling and wet sieving of sediments was carried out, representing the second time this had been done in Slovenia (the first time was at the Palaeolithic cave site of Divje Babe I; see Introduction). Systematic excavations were carried out at these sites for more than ten years, starting in the early 1990s, under the supervision of J. Dular from the Institute of Archaeology ZRC SAZU, in Ljubljana (Dular and Tecco Hvala 2007). Colleagues from the Institute of Biology ZRC SAZU carried out the identification of plant macro-remains recovered with the 'initial flotation method' (Culiberg and Šercelj 1995), with which only larger and more resistant charred grains of cultivated plants were obtained (Dular and Tecco Hvala 2007, 30-31). They found that there are no significant differences between the crop spectra at the investigated Late Bronze Age and Early Iron Age sites in southeastern Slovenia. The species they identified were hulled and free-threshing wheats (*Triticum monococcum/dicoccum*, *T. aestivum/durum/turgidum*), barley, broomcorn millet, foxtail millet, flax, oat, rye, pea, faba bean, lentil and other Fabales (*e.g.* vetch (*Vicia* sp.)); they are all represented in both periods. The frequencies of plant remains differ between the periods, but the small sample and non-systematic recovery preclude any definite conclusions (Dular

Figure 2. Food remains ('porridge') from House 6 at Most na Soči made of foxtail millet (Setaria italica) *and other cereals (after Tolar 2018b, 448, Fig. 2).*

and Tecco Hvala 2007, 209). In any case, it could be stated that among the cereals at these sites, free-threshing wheats prevail, oat and rye are also present, but hulled wheats are almost absent (Table 2). Free-threshing wheat is more productive and highly nutritious, and its flour can be used for making leavened bread. Therefore, its increased presence may be related to a change in culinary practices (Megaloudi 2004, 155). Further, in comparison with hulled wheat, cultivation of free-threshing wheat requires a higher labour input and may reflect more intensive agricultural practices and perhaps also increased population density. Once harvested, however, its processing is easier and faster than that of other prehistoric cereal crops (Nesbitt 1995, 74). Among the gathered plants, only three taxa were recognised at Early Iron Age southeastern Slovenian sites (Table 2): blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*) and elderberry (*Sambucus nigra*).

Tribuna is a multi-phase archaeological site in Ljubljana and, among the Early Iron Age sites discussed here, one of the most recently excavated (in 2008). It has layers from the Late Bronze Age (ca. 1100 cal BCE), from the Iron Age to the Roman period, and from modern times. Lots of sediment samples from all four phases were wet sieved, but they were subsequently dried, which caused some loss of fine and fragile plant macro-remains, a factor that should be taken into account when interpreting the archaeobotanical results. The Early Iron Age settlers at Tribuna consumed different kinds of cereals (barley and wheats), legumes (lentil, faba bean, grass pea (*Lathyrus sativus*) and pea) as well as foxtail and broomcorn millet. The last seems to have been very important (see Table 2). Additionally, ten possibly gathered plant taxa were recognised, but except for raspberry, in smaller quantities (Table 2).

Possible climatic changes in Slovenia and adjacent areas in the Bronze Age

Very few palaeoclimatological studies are available for Slovenia and environs. It can be assumed that there were significant differences in past climatic conditions between the regions south and north of the Alps as well as between different altitudes within the Alps, where vegetation is sensitive to climatic fluctuations. Badino *et al.* (2018) have recognised a cold phase in the period ca. 2000-1500 cal BCE in the western Italian Alps. They have reconstructed temperatures suggesting a temperature decrease of

1.8 °C compared with the previous period. On the other hand, glaciers in the Alps experienced a reduction in size (making them smaller than today), during most of the Holocene and until ca. 2000-1000 cal BCE (Ivy-Ochs *et al.* 2009; Solomina *et al.* 2015), indicating melting due to warmer conditions. Badino *et al.* (2018) also detected a warm peak around 1280-1150 cal BCE. In Italy, there are additional indicators of a warm and dry environment during the Bronze Age (*e.g.* Mercuri *et al.* 2012), but this may not apply to neighbouring Slovenia (Andrič *et al.* 2017) or, if it does, can only be proposed for lowland regions in eastern and southern Slovenia.

Few studies so far have focused on environmental changes in the southeastern Alps. A 12 m-long core from the central part of Lake Bohinj, in northwestern Slovenia, reflects environmental conditions and human-environment interactions over the past 6600 years (Andrič *et al.* 2020). It has been suggested that at ca. 6000 cal BP, Lake Bohinj was surrounded by mixed forest (of conifers and deciduous oak (*Quercus*)). Beech (*Fagus*) became dominant after ca. 1300 cal BCE. In the Bronze Age and especially in the Iron Age (1500-500 cal BCE), when the region was densely populated, anthropogenic clearing of forest is detected. It is evident that, around 1000 cal BCE, river floods were not as common as before, but the proportion of beech did not fall, which means there was no increase in aridity, unlike what was documented in the marine core from the central Adriatic (Mercuri *et al.* 2012). The pollen record from that core shows a gradual, irreversible trend towards increasing aridity from ca. 3700 cal BCE and less cool conditions from around 3100 cal BCE. The reduction in precipitation has also been evidenced before and during the Early Bronze Age (ca. 1900-1600 cal BCE; Mercuri *et al.* 2012).

Archaeological evidence: Harvesting tools from the Mesolithic to the Late Bronze Age

Harvesting tools appeared at the same time that agriculture emerged. The predecessor of the sickle is the harvesting knife. Such knives are comprised of flat or slightly curved bone or wooden handles with a groove into which quartz wedges are glued with resin (Fig. 3.1-5). A characteristic shine (knowns as sickle gloss; German: *Sichelglanz*) is visible on the working edges of the wedges, which proves that they were used as harvesting tools. That this shine is the result of friction that occurs when cutting grass or harvesting cereals has been confirmed through experiments (Steensberg 1943, 10 f.; Unger-Hamilton 1988; Juel Jensen 1996; Petru 1997, 97; Anderson 1999). The oldest preserved harvesting knives belong to the Mesolithic Natufian culture in Palestine (Fig. 3.1). Variously shaped Neolithic harvesting knives are known from Egypt (Fig. 3.2), Asia Minor, Cyprus, the Balkans (Fig. 3.4), and pile-dwellings in Italy (Fig. 3.3) and Switzerland (Fig. 3.5) (Steensberg 1943, 126; Mellaart 1961, 45, Pl. 4a; Müller-Karpe 1968, 509; Rageth 1974, 193, Fig. 12, Pl. 103.1-3, Pl. 118.5; Egloff 1984, 64, Fig. 19; Perini 1987, 395, Fig. 186; Speck 1990, 262, Fig. 13; Ramseyer 2000, 218, Fig. 178; Gurova 2005).

The first Neolithic sickles, which have a concavely curved blade, originate from Mesopotamia. They were made of very hard, fired clay. The sharp edge is finely serrated (Fig. 3.6) (Steensberg 1943, 133). No completely preserved Neolithic sickles are known from central Europe. However, a reconstruction of the appearance of a Late Neolithic sickle is made possible by finds from two sites in northwestern Switzerland (Fig. 3.7). The stone wedge was found on the island of Werd, near Eschenz (Hasenfratz 1985, 110), and the wooden handle on the site of Niederwil-Egelsee, which belongs to the Pfyn culture (Pfahlbauquartett 2004, 49, cat. No. 45).

Sickles have been used in Egypt since at least the 1st Dynasty. A set of quartz wedges (Flinders Petrie 1891, 12, 54; Müller-Karpe 1968, 409) was inserted into a curved wooden handle, which may have consisted of one or more parts (Fig. 3.8-9).

Figure 3. Harvesting tools from the Mesolithic to the Late Bronze Age. 1. Kebara; 2. Fajum; 3. Lago di Ledro; 4. Karanovo; 5. Egozwill 3; 6. unknown site in Mesopotamia; 7. Eschenz-Island Werd and Niederwil-Egelsee; 8. Sakkara; 9. Kahun; 10. Barche di Solferino; 11. Fiavé; 12. Dunaújváros-Kosziderpadlás II; 13. Senomaty; 14. Balaton area (after: 1 – Mellaart 1961; 2, 5, 8 – Müller-Karpe 1968; 3 – Rageth 1974; 4 – Gurova 2005; 6 – Steensberg 1943; 7 – Pfahlbauquartett 2004; 9 – Flinders Petrie 1891; 10-11 – Perini 1987; 12 – Mozsolics 1967; 13 – Chvojka et al. 2017; 14 – Angeli and Neuninger 1964). For the scale of individual objects, see the cited literature.

Such sickles are also depicted in frescoes with harvest scenes on the walls of tombs (Müller-Karpe 1974, Pl. 40.8, Pl. 47, Pl. 49.9, Pl. 60.3, Pl. 75.3, Pl. 78.3, Pl. 81.3, Pl. 96.5). In northern Italy, sickles similar to the Egyptian ones are known; these are referred to as sickles *a mandibola* (Fig. 3.10) and sickles of the Fiavé type (Fig. 3.11). They were in use until the Middle Bronze Age (Perini 1987, 395, Figs. 185-186, 1988, 59).

At the beginning of the Middle Bronze Age, the first bronze sickles joined the sickles with stone blades. Bronze tanged sickles are typical for southeastern Europe at this time. As the Dunaújváros-Kosziderpadlás II and Senomaty hoards show, the first sickles had a flat tang (Fig. 3: 12-13). The sickle from the former hoard is one of the few made for use with the left hand, and the sickle from the latter was made for use with the right hand (Mozsolics 1967, 135, Pl. 49: 10; Chvojka *et al.* 2017, Pl. 78: 17). At the beginning of the Late Bronze Age, bronze sickles with two to six vertical ribs on the tang (Fig. 3: 14) began to appear in the hoards *en masse*. We encounter them until the beginning of the Iron Age, and then they disappear. They are replaced by similarly shaped iron sickles with a flat tang. Whereas the number of tanged sickles from the Bronze Age reaches into the thousands, the number from the Early Iron Age is only a fraction of that. Whether this is due to the state of research or something else is a question that cannot be answered at the moment.

In Slovenia, the oldest flint pieces with gloss come from the Late Neolithic layers (5th millennium BCE) of the site of Moverna vas, in Bela krajina, located on a riverbank (Petru 1997, 89), and from the settlement of Dragomelj, near Ljubljana, located on a plain. At Dragomelj, up to 15% of the flint pieces show signs of having been used in harvesting (Petru 2005, 82, Fig. 4; Turk and Svetličič 2005; Turk and Turk 2019, Fig. 139). Of similar age are the three flint pieces with gloss from the settlement of Kamna gorica, near Ljubljana, also located on a plain (Petru pers. comm.).

From the Copper Age, we know of the flint pieces with gloss from the Trhlovca cave, near Divača (Petru 2004, 202), and from the pile-dwelling settlement of Hočevarica, in the Ljubljansko barje (Velušček 2004, 5, Fig. 34.1.34). Two flint pieces from the multi-period settlement of Col 1, situated on a plain near Podgračeno, in the Dolenjska region, are dated to the transition from the Neolithic to the Copper Age (Petru 2020, 104 no. 214, 105 no. 235). Due to the unclear stratigraphic situation, it is not known whether the flint piece with gloss from the Mala Triglavca cave, near Divača, dates to the Neolithic or to the Bronze Age (Petru 2004, 201).

Three completely preserved, left-handed metal sickles found in the Ljubljanica River belong to the Middle Bronze Age (Pavlin 2006, 79-76, Fig. 2.1a-3b). They can also be interpreted as gifts to the gods. No hoards are known from the Middle Bronze Age. In contrast, more than 60 hoards are known from the Late Bronze Age. Sickles, either entire or fragmented, are present in about three quarters of the hoards, and their combined number exceeds 300. Traces of hammering and sharpening prove that they were used primarily as harvesting tools. In addition to being found in hoards, they are found as individual finds both in and outside settlements (Teržan 1995). Particularly noteworthy is the Tribuna site, in Ljubljana. Among other things, at least three fragments of sickles were found there (Vojaković pers. comm.).

Summary and conclusions

Based on the available results from archaeological sites in Slovenia, the appearance of broomcorn millet and foxtail millet, together with oat, rye, lentil and faba bean, can be placed in the Late Bronze Age. In the Early Iron Age, the importance of millet increases, while the introduction of free-threshing wheat represents another agricultural innovation at this time. Just as emmer and einkorn are typical cereals of the Copper Age in the region, so millets are of the Late Bronze Age and, especially, of the Early Iron Age. Pulses were less common in the Copper Age and became more important also in the Late Bronze Age and Early Iron Age. Barley seems to have been equally important through all of these periods. Collected wild fruits and nuts were more important for the diet during the Copper Age than during the Late Bronze Age and Early Iron Age. However, the way in which archaeobotanical sampling/collecting, storing and sieving was done (if it was done at all) may have played an important role in the amount and type of results obtained, especially from excavations prior to 2007. Therefore, the identified remains only give a general impression of the staple crops used at the studied sites.

According to some recent reviews of the Bronze Age archaeobotanical finds from Europe (Stika and Heiss 2013; Filipović *et al*. 2020), broomcorn millet became a major (or even main) crop during the transition from the Middle to the Late Bronze Age. In Slovenia, the same phenomenon may be present, but the scarce archaeobotanical research, especially for the period between 2300-1200 BCE, cannot yet confirm the occurrence of millet before the 12th century BCE. The earliest finds of millet from neighbouring countries date from the Middle Bronze Age, namely to the 16th or 15th centuries BCE in Italy, Hungary, Croatia and to the 15th century BCE in Austria (Filipović *et al*. 2020). Both possible millet transition routes (via the Balkans or the Apennines or both; see Introduction) would thus allow for the possibility of an even earlier arrival of millet in Slovenia.

The crops introduced in the Late Bronze Age and later, in the Iron Age, were probably all used mainly for the preparation of porridge (see Fig. 2) and flat bread, and they are all quite resistant to unfavourable climatic conditions. For Slovenia, there is limited palaeoclimatic evidence for this period (Andrič *et al*. 2017, 2020). The pollen record from the marine core from the central Adriatic (Italy) shows a gradual, irreversible trend towards increasing aridity, less cool conditions and a reduction in precipitation before and during the Bronze Age (Mercuri *et al*. 2012), which could have been one of the reasons for the introduction of more drought-resistant crops in lowland (drier and warmer) regions in Slovenia.

Towards the end of the 14th century BCE, Europe experienced great changes in connection with the mass migrations of people. Central and eastern Slovenia were inhabited by people who belonged to the cultural sphere that stretched from western Hungary through Croatia to northern Bosnia. Large, Late Bronze Age settlements on the plains point to increased population density, which led to more intensive and efficient agricultural practices. At Late Bronze and Iron Age sites in Slovenia, cultivation of millets and free-threshing wheats increased, while that of hulled wheats decreased. Millets and free-threshing wheats are both more productive in comparison with hulled wheats. Although the cultivation of free-threshing wheat requires higher labour input (*i.e.* larger population), its processing is easier and faster. The greater presence of millets and free-threshing wheat may also be related to changes in culinary practices. Interesting research is going on at the moment involving analysis of ceramic forms in relation to food preparation, from various Slovenian archaeological sites dated to the Bronze Age and the Early Iron Age. Results to date reveal that some new forms of vessels (as well as changes in ceramic recipes) developed in the 12th-11th century BCE, which may be connected to changes or innovations in cooking techniques, perhaps linked with the appearance of millet. Later, in the Early Iron Age, these ceramic forms were used widely and regularly (Vinazza 2021).

Concerning the harvesting equipment in the studied region, bronze sickles with two to six vertical ribs on the tang began to appear at the beginning of the Late Bronze Age. We encounter them until the beginning of the Iron Age, and then they disappear. They are replaced by similarly shaped iron sickles with a flat tang.

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