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ORIGINAL ARTICLE

New research on crop diversity of the early farmers in southeastern Europe (ca. 6400 – 5700 BCE)

Amalia Sabanov[1] · Raül Soteras[2] · Irka Hajdas[3] · Goce Naumov[4] · Ferran Antolín[2,5]

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Abstract
Pelagonia is a mountain valley in North Macedonia that was densely occupied by early farming communities in the second half of the 7th and early 6th millennium BCE. Archaeobotanical analysis is being done on material from three sites there, Vrbjanska Čuka, Veluška Tumba and Vlaho. This paper presents the results of archaeobotanical analyses of remains from Pelagonia, which represent some of the oldest directly dated remains of cereals and pulses in Europe, and discusses the results on crop diversity among Early Neolithic communities within the region. The crop spectrum was broad, with five cereal species and several varieties, two pulses and potentially two oil crops. The diversity is slightly narrower than the one found in southwestern Asia, Greece and Bulgaria as *Cicer arietinum* (chickpea), *Lathyrus sativus* (grass pea) and *Vicia ervilia* (bitter vetch) were not present or very rare, and *Triticum aestivum/durum* (naked wheat) was only found in small amounts, probably because the early farmers were adapting their choices of crops to the different climatic conditions in Pelagonia. On the micro-regional level we have observed that the diversity and importance of certain crops may vary in relation to the 8.2 ka BP climate cooling event, as well as due to local environmental or cultural factors, showing the need for finer scale analyses beyond the level of site or phase.

Keywords North Macedonia · Cereals · Pulses · Papaver somniferum · Linum usitatissimum · Early neolithic · Neolithic expansion

Introduction

Farming practices developed in southwest Asia at the beginning of the Holocene as part of a broad spectrum economy. As a result, the start of farming is linked to a range of crops with various characteristics and often different growing requirements, including *Triticum monococcum* (einkorn), *T. dicoccum* (emmer), *T. aestivum/durum/turgidum* (naked wheat), *Hordeum distichon/vulgare* s.l. (barley), *Lens culinaris* (lentil), *Pisum sativum* (pea), *Cicer arietinum* (chickpea), *Vicia faba* (fava bean) and *Linum usitatissimum* (flax), among others (for example, Zohary et al. 2012). During the 7th and 6th millennia BCE, agriculture progressively spread from southwestern Asia into nearby regions. Its westward expansion brought farming first to Mediterranean areas with similar climatic conditions to those where it began, where almost the same crop spectrum was also cultivated (de Vareilles et al. 2020), and then progressively further northwards, starting in the Balkans. Authors have argued for a reduction of the crop spectrum as an adaptive strategy to the more continental climatic conditions there (Colledge et al. 2005; de Vareilles et al. 2022).

Archaeobotanical research on Early Neolithic sites in the Balkans has produced highly relevant data on crop choices by the early farmers (Valamoti and Kotsakis 2007; Valamoti 2017; Ivanova et al. 2018; de Vareilles et al. 2022).

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✉ Ferran Antolín
ferran.antolin@unibas.ch

1 Faculty of Philosophy, University of Belgrade, Čika-Ljubina 18-20, Beograd 11000, Republic of Serbia

2 Division of Natural Sciences, German Archaeological Institute (DAI), Im Dol 2-6, 14195 Berlin, Germany

3 Laboratory of Ion Beam Physics, ETH Zürich, HPK H27, Otto-Stern-Weg 5, Zürich CH-8093, Switzerland

4 Center for Prehistoric Research, Kiro Krstevski Platnik 11, Skopje 1000, North, Macedonia

5 IPNA/IPAS, University of Basel, Spalenring 145, Basel 4055, Switzerland

The crop spectrum in Bulgaria corresponds fully to the set of "founder crops" from southwest Asia (Marinova 2007, 2017; Marinova et al. 2016), while the sites in northern Greece lack some taxa such as *Cicer arietinum* (chickpea), but still keep many similarities (Valamoti and Kotsakis 2007; Kotzamani and Livarda 2018). An even more reduced set of crops is encountered in the Balkans, especially when it comes to pulses (Allen and Gjipali 2014; Filipović 2014; Beneš et al. 2018). Despite a growing amount of archaeobotanical research in southeastern Europe, the small number of systematically analysed sites still poses a considerable drawback for the understanding of the choices made by early farmers (de Vareilles et al. 2022), and the possibility of tracing decision-making processes at a local level has remained limited.

The focus of this paper is the valley of Pelagonia in North Macedonia from where significant evidence has been obtained for occupation and agriculture in the Early Neolithic and where new archaeobotanical research is being carried out on three sites, Vrbjanska Čuka, Veluška Tumba and Vlaho (Antolín et al. 2020; Naumov et al. 2023) which were occupied during the period 6400 – 5700 BCE.

Pelagonia and the investigated sites

Pelagonia is a geographical region encompassing a valley located in the central Balkan region, which stretches from North Macedonia to the Greek region of Macedonia, where the earliest Neolithic sites on the European continent are found (Karamitrou-Mentessidi et al. 2015; Kotzamani and Livarda 2018; Krauß et al. 2018). Numerous Early Neolithic tell sites are distributed throughout the valley (Naumov 2016), showing a continuous occupation and sedentary lifestyle in the initial phases of the Neolithic, starting as early as 6400 cal BCE according to the most recent radiocarbon dates (Naumov et al. 2023). Pelagonia consists of a large and fertile plain at around 650 m a.s.l. surrounded by mountains. The main river, Crna Reka, which had many tributaries in the past, filled this basin with fertile alluvial deposits (Trifunoski 1998, pp 11–12). Abundant underground water contributed to the favourable growing conditions and formed marshlands in the flatter parts of the valley (Barker 1975; Trifunoski 1998, pp 11–12).

The Early Neolithic tell sites of Vrbjanska Čuka near Prilep and Veluška Tumba near Bitola were first excavated in the 1970s and the new excavations, incorporating various techniques including archaeobotanical analysis started in 2016 and 2019, respectively (Naumov et al. 2020, 2021a). The third site mentioned in this paper, Vlaho near Živojno, was identified in the 20th century but was never excavated until the first test trench was opened in 2021 (Naumov et al. 2021b). Consequently, the data available from this site are more limited, but extremely valuable due to the earlier dates. Apart from the Neolithic occupation at all three sites, a much later Roman villa and several medieval pits and graves were found at Vrbjanska Čuka. All three sites had a very rich material culture typical of the Pelagonian Early Neolithic, including figurines, house models, tablet "altars", painted pottery, stone and bone tools and so on. Many buildings with robust daub walls were discovered, normally containing architectural features like pits, ovens, hearths, basins and platforms for the storage and processing of cereals and other foodstuffs (Naumov 2020, 2021a, b, 2023).

The first two sites are on the flatlands of the valley, Vrbjanska Čuka in the north and Veluška Tumba about 45 km away in south Pelagonia. Vlaho is on the slopes of the Nidže mountain on a natural plateau at about 780 m in the southern part of the valley close to Veluška Tumba (Fig. 1). The earliest radiocarbon dates from Vlaho at ca. 6400/6300 cal BCE are a few centuries earlier than for Vrbjanska Čuka and Veluška Tumba (ca. 6000 cal BCE) (Table 1; Naumov et al. 2021a, 2023). The occupation of this settlement seems to have ended approximately at the time when the other two were starting to be inhabited at about 6000 BCE, and they were inhabited for about 300–400 years, until ca. 5700/5600 BCE.

The climate in Pelagonia is considered continental, with a more Mediterranean type of precipitation in the south, with a higher average maximum temperatures around 11 °C and average precipitation around 650 mm, and a drier and cooler climate in the north averaging around 6 °C and 400–500 mm of precipitation (Trifunoski 1998, pp 10–11; Naumov 2016). These climatic differences between Vrbjanska Čuka in the north and Veluška Tumba and Vlaho in the south of Pelagonia probably also applied to the past. It is worth mentioning that the occupation at Vlaho coincided with the 8.2 ka BP climatic event, with generally cool and dry conditions (Weninger et al. 2009), but higher precipitation was recorded nearby as at the site of Nea Nikomedeia (Ghilardi et al. 2012).

The archaeobotanical research at these sites aims to fill a regional gap in the study of crop diversity among early farmers and to discuss potential evidence of agricultural decision-making at a local scale. Since Vlaho, located on a hill, was occupied several hundred years before the sites in the lowlands, we aim to investigate whether crop diversity was dependent on altitude and chronology, considering its coincidence with the 8.2 ka BP event. Also, since the material cultures at Vlaho and Veluška Tumba are more alike in comparison to that of Vrbjanska Čuka which is situated further north, we will discuss if cultural similarity possibly reflects preferences of crop choice as well.

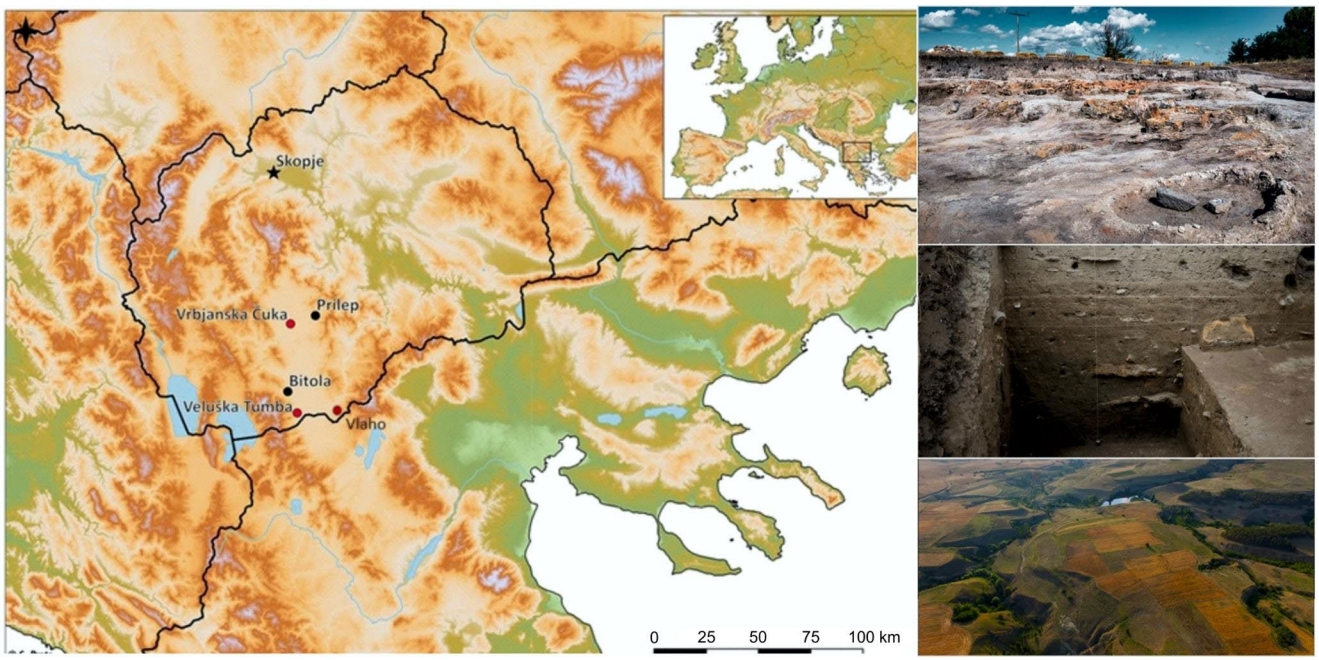

Fig. 1 Map of Pelagonia valley showing studied sites. Photos on right from top to bottom; Vrbjanska Čuka (photo, R. Soteras); Veluška Tumba (photo, R. Soteras); Vlaho (Naumov et al. 2021). Mapping with QGIS v. 3.16 from European Union, Copernicus Land Monitoring Service [2016], European Environment Agency (EEA)

Table 1 Radiocarbon dates from seed and fruit remains of cultivated plants for the three sites under investigation

Site	Layer	Sample	Lab.code	BP	cal BC (2σ)	Reference
Veluška Tumba	SU 83	*Hordeum vulgare* cf. var. *nudum*	ETH-122649	7,002 ± 28	5983 – 5798	This paper
Veluška Tumba	SU 137	*Pisum sativum*	ETH-122650	7,036 ± 28	5989 – 5842	This paper
Veluška Tumba	SU 140	*Triticum aestivum/durum*	ETH-122651	6,984 ± 28	5979 – 5773	This paper
Veluška Tumba	SU 154	*Lens culinaris*	ETH-122652	7,069 ± 28	6016 – 5888	This paper
Vrbjanska Čuka	Building 2	*Pisum sativum*	CNA-4703	7,030 ± 37	5995 – 5804	Naumov et al. 2021
Vrbjanska Čuka	Building 2	Cereal	BE-8236	6,995 ± 24	5980 – 5798	Naumov et al. 2021
Vrbjanska Čuka	Building 2	*Pisum sativum*	CNA-4705	6,976 ± 36	5978 – 5749	Naumov et al. 2021
Vrbjanska Čuka	Building 2	*Pisum sativum*	CNA-4706	6,824 ± 35	5771 – 5633	Naumov et al. 2021
Vlaho	Building 3	*Hordeum vulgare*	CNA-6151	7,460 ± 36	6410 – 6240	Naumov et al. 2023
Vlaho	Building 7	*Triticum* sp.	CNA-6150	7,151 ± 36	6072 – 5926	Naumov et al. 2023

Materials and methods

Preliminary results from the three sites have already been presented (Beneš et al. 2018; Antolín et al. 2020, 2021; Naumov et al. 2021a, b; Mazzucco et al. 2022; Sabanov et al. 2022), but this paper presents the first combined analysis of the largest number of samples (almost 200, representing ca. 800 L of sediment) from all three sites, including total numbers of finds and ubiquity calculations. The samples include those collected in 2019 to 2021 from Vrbjanska Čuka and Veluška Tumba, and in 2021 from Vlaho, plus several additional samples from 2022. The sampling was done in a semi-systematic manner where almost all stratigraphic units were sampled. Some units which did not seem to be useful (sterile layers) were not sampled because they would have provided insignificant data or were potentially contaminated by activities in later phases such as medieval pits, or disturbed by previous excavations. Large units like house floors were sometimes sampled several times in different zones, and every closed or more identifiable unit (pit, oven, hearth, canal, basin etc.) also provided a sample. The volume of each sample varied according to the size of the unit, normally ranging between 10 and 15 L. From Vrbjanska Čuka 73 samples (458 L of soil), from Veluška Tumba 106 samples (298 L) and from Vlaho 12 samples (57 L) were analysed. The types of contexts sampled at all three sites are of similar taphonomical nature, mainly secondary refuse deposits. No large deposits of stored remains in situ were recovered so far.

For separating the plant macroremains from the sample material the wash-over method was used (Kenward et al. 1980; Steiner et al. 2015), with a minimum sieve mesh size

of 0.35 mm (see also Antolín et al. 2021). The plant remains from all the fractions were sorted and if the 0.35 mm fraction was too large (> 12–15 ml), subsamples of 5–8 ml were taken using a riffle box, or the grid method during the excavations where no riffle box was available (Antolín et al. 2021). Then, to estimate the number of remains in the whole sample, the total number of remains of all taxa with three or more remains (following Jacomet et al. 1989; Antolín 2016) was multiplied by a factor defined by the volume of the subsample analysed (Jacomet et al. 1989, pp 50–51). Plant identification criteria followed Jacomet (2006). The data were added to the ArboDat database (Kreuz and Schäfer 2002) and the taxonomy follows the one used there. The quantification of the cereal grains was done according to Antolín and Buxó (2011), cereal chaff was counted following Hillman et al. (1996) and for the legumes, the whole seeds were counted as one and whole cotyledons were counted as half. Since this paper concentrates on crop diversity and discussion of other aspects of agriculture would exceed its capacity, only a selection of taxa are included here. Remains of *Vicia ervilia* and *V. sativa* were encountered only at Vrbjanska Čuka in very low numbers and since they grow naturally in the surroundings, they are not included in the analysis. *Papaver somniferum* (opium poppy), as a (most likely) non-native plant to the area (for instance, Salavert 2010), was considered as a cultivated plant. Other potentially cultivated plants such as *Chenopodium album* (white goosefoot) were not considered for this paper, since they could also grow naturally in the area and would require specific analyses to determine their status. Various parts of crop plants were recovered including above all chaff remains (rachis segments and glume bases, and also awn fragments, etc.), and grains or seeds. For the evaluation of the importance of the various taxa from sites within the Pelagonia region, both the proportions of each taxon within the site and their average densities from the whole site are considered (Table 2), since in this way the sites with very different sample numbers and volumes of sediment can be made comparable. No time phases within each site are considered at this stage of research and no analyses of remains from particular types of context have been done, since this would go beyond the goals of this paper. Comparisons are made at site level, as in other recent synthesis work (Ivanova et al. 2018; de Vareilles et al. 2022), since this is a first combined evaluation and it also makes it possible to compare the results from Pelagonia with those from nearby regions, where different methodologies were used.

Crop remains (barley, naked wheat, pea and lentil) from all three sites have been dated to ca. 6400 – 5800 cal BCE, which is in agreement with the pottery style associated with the contexts. Four new dates on remains of crops (two cereals and two pulses) from Veluška Tumba are published here which prove them to be as old as ca. 6000/5800 cal BCE, confirming that life at this settlement was contemporary with Vrbjanska Čuka, falling into the later phases of Early Neolithic (Table 1). The dates from Vlaho, particularly

Table 2 Crop remains from the three sites under investigation. Absolute numbers and the percentages of samples in which each taxon is present (ubiquity) are given for each site

	Vrbjanska Čuka		Veluška Tumba		Vlaho	
Number of samples	73		106		12	
Number of features	49		66		12	
Volume of sediment (L)	458		298		57	
	N	Freq.	N	Freq.	N	Freq.
Cereals						
Hordeum distichon / vulgare indet. grain	106	39	68	16	21	42
H. distichon / vulgare hulled / naked grain	120 (10)	36 (12)	286 (40)	12 (9)	9 (40)	17 (33)
H. distichon / vulgare chaff	193	9	279	19	22	67
Triticum aestivum / durum / turgidum grain / chaff	cf. 3 (1)	4 (1)	5 (12)	3 (7)	(3)	(25)
T. dicoccum grain / chaff	66 / 1,745	26 / 59	70 / 1,192	13 / 45	17 / 197	75 / 67
T. monococcum grain / chaff	304 / 7,997	43 / 88	108 / 1,770	24 / 48	86 / 634	92 / 83
T. timopheevii grain / chaff	4 / 1,022	4 / 46	4 / 197	2 / 28	2 / 46	17 / 58
Triticum sp. grain / chaff	108 / 6,470	23 / 51	59 / 1,202	20 / 42	32 / 184	25 / 67
Cerealia grain / chaff	1,088 / 356	68 / 24	923 / 1	43 / 5	731 / 2	83 / 33
Pulses						
Lens culinaris	123	26	231	25	19	42
Pisum sativum	438	47	28	14	24	67
Fabaceae (cultivated)	18	11	70	14	7	25
Oil plants						
Linum usitatissimum	cf. 1	1	1	1	0	0
Papaver somniferum	4	5	1	1	1	8
Total	20,174		6,547		2,077	

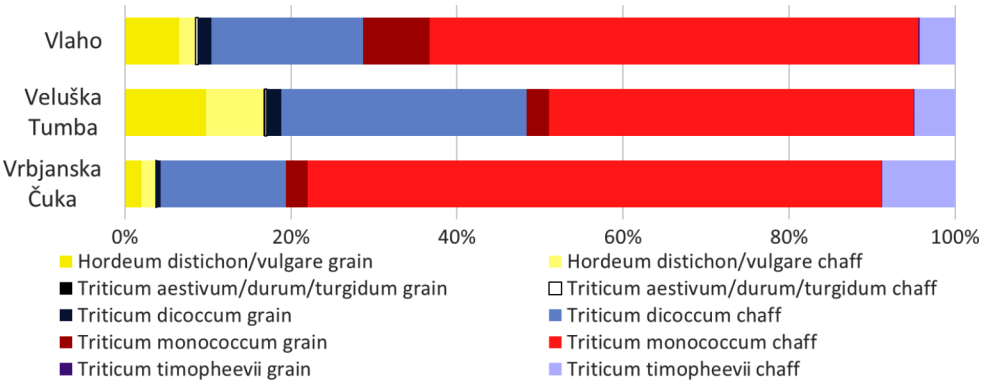

Fig. 2 Bar plot representing relative abundances of cereal remains at the investigated three sites

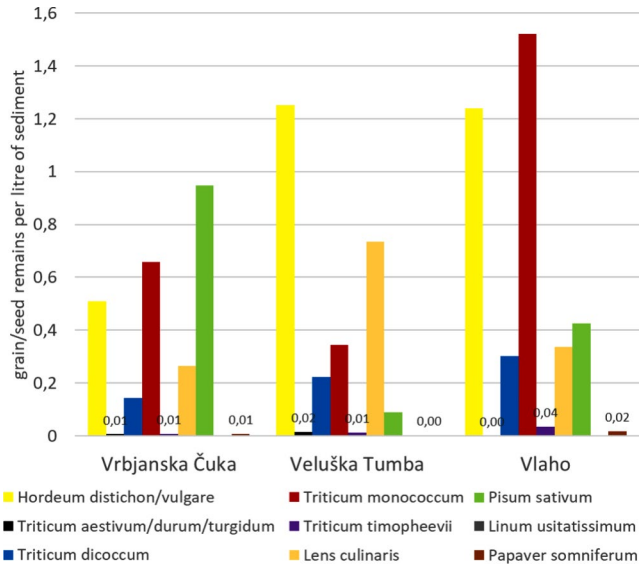

Fig. 3 Bar plot representing numbers of grain/seed remains/L sediment from the three sites

CNA-6151 (ca. 6400 – 6200 cal BC) are among the oldest on cereals in Europe, comparable to those from the Greek sites, Mavropigi with three wheat grains dated to ca. 6200 cal BCE and Revenia, with one barley grain dated to ca. 6350 cal BC, which are both located less than 100 km from Vlaho (Karamitrou-Mentessidi et al. 2015; Maniatis et al. 2015). The dated pea and lentil remains are certainly the oldest directly dated single finds of identified remains of legumes in Europe to date (Reingruber and Thissen 2018).

Published archaeobotanical data on crops from 11 Early Neolithic sites in the nearby regions, four in of Bulgaria (Marinova 2007, 2017; Marinova et al. 2016), one in North Macedonia (Renfrew 1976) and six in Greece (Valamoti and Kotsakis 2007; Kotzamani and Livarda 2018) were also synthesized to expand the comparisons between sites in the area. The absolute counts were converted into scores (Robinson 2003), which were used in QGIS v. 3.16 (QGIS Development Team 2021) to produce the pie charts representing the importance of different crops at each site.

Results

The total numbers of plant remains including both cultivated and wild plants from all three sites is high: 60,000 remains from Vrbjanska Čuka, 11,000 from Veluška Tumbaand and 3,000 from Vlaho. The average densities of plant remains (133 remains/L sediment from Vrbjanska Čuka, 55 from Vlaho and 37 from Veluška Tumba) show a good level of preservation. The vast majority of the remains from all three sites were charred, with only a few mineralized ones. For all three sites, remains of crops were very abundant. For Vrbjanska Čuka they make up 32% of the total number of plant remains recovered at the site, for Veluška Tumba 56%, while for Vlaho 70%. The crop taxa are represented by five species of cereals, *Triticum monococcum*, *T. dicoccum*, *T. timopheevii* s.l. (Timopheev's wheat, following Roushannafas et al. 2022, formerly known as 'new glume' wheat), *T. aestivum/durum/turgidum* and *Hordeum vulgare/distichon*, which were found from all three sites (Table 2; Figs. 2, 3 and 4). *Hordeum* was represented by at least two varieties, naked and hulled, and possibly two-rowed and multi-rowed varieties. Tetraploid naked wheat (*T.* cf. *durum/turgidum*) was probably most often found, although the presence of hexaploid *T.* cf. *aestivum* cannot be excluded according to the morphology of the preserved chaff remains.

Apart from cereals, pulses also made a considerable contribution with two species, *Lens culinaris* and *Pisum sativum* at all the sites in this study (Fig. 2). Seeds of oil crops were also recovered. *Papaver somniferum* (opium poppy), probably a wild form considering the small size of the seeds (which are generally badly preserved), was present in small quantities at all three sites and only one seed of *Linum usitatissimum* was discovered from Vrbjanska Čuka and one from Veluška Tumba. The flax seed from Vrbjanska Čuka was preserved by mineralization and its dating and identification are uncertain.

The proportions of the different cereals are somewhat similar at all three sites. Einkorn is always the dominant species making up more than 50% of the total number of cereal remains, and for Vrbjanska Čuka it is even more abundant

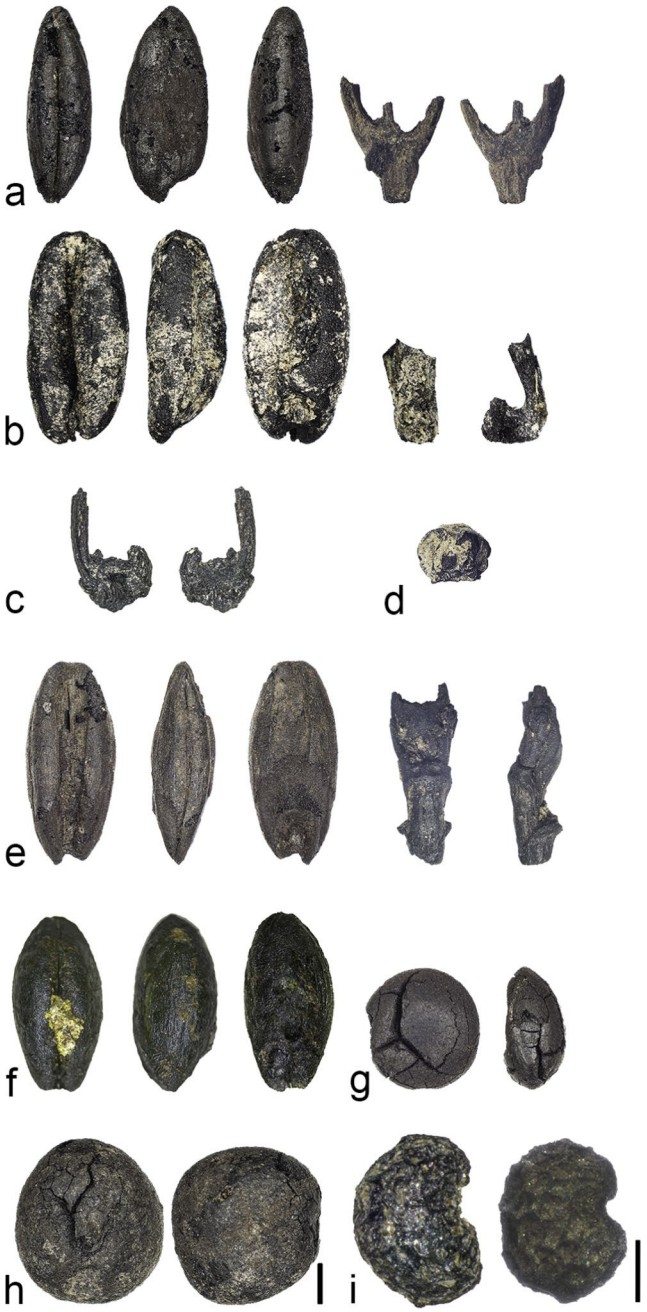

Fig. 4 Identified crop remains from Pelagonian Neolithic sites; **a**, *Triticum monococcum* (einkorn); **b**, *T. dicoccum* (emmer); **c**, *T. timophevii* (Timopheev's wheat); **d**, *T. aestivum/durum/turgidum* (naked wheat), node (top view); **e**, *Hordeum distichon* (2-row hulled barley); **f**, *Hordeum vulgare* var *nudum* (naked barley); **g**, *Lens culinaris* (lentil); **h**, *Pisum sativum* (pea); **i**, *Papaver sominferum* (opium poppy). scale, **a-h**, 1 mm; **i**, 0.25 mm; photos by R. Soteras and A. Sabanov

(> 70%) (Fig. 2). It is the most ubiquitous taxon at all sites as well, but for Veluška Tumba it was found in a similar number of samples to emmer, the next most abundant species, while barley and *Triticum timopheevii* were also recovered in significant quantities. *T. aestivum* (naked wheat) is more abundant from the sites in the south of the valley, with 17 remains from Veluška Tumba and three from Vlaho, where it was found in 25% of the samples. Only one rachis fragment from Vrbjanska Čuka is undoubtedly from naked wheat (1% of the samples), and three grains are identified with uncertainty (Table 2). Hulled and naked barley grains are always present. For the lowland sites, Vrbjanska Čuka and Veluška Tumba, hulled barley is significantly more abundant than naked, with ratios of 1:12 and 1:7 respectively. For Vlaho it is the opposite, with the hulled to naked barley grain ratio being 1:4.5. This pattern is represented in the ubiquity as well.

When chaff identifications are excluded, it is evident that pulses are almost as abundant as cereals, and einkorn is not as dominant in the record (Fig. 3). The pulses from Vrbjanska Čuka contribute to almost 50% of the crops, while for Veluška Tumba they make up 30% and for Vlaho 20%. Peas are extremely abundant from Vrbjanska Čuka, and lentils make a smaller contribution, while for Veluška Tumba it is the opposite, with lentils being much more abundant there than peas. For Vlaho they are both present in similar quantities and contribute significantly, but peas are more ubiquitous than lentils. The cereal grains show a similar picture at all three sites, with einkorn and barley contributing the most.

Discussion

The numerous crop remains from the three new sites in Pelagonia presented here are very valuable for the understanding of the main trends in early farming in southeastern Europe between 6400 and 5700 BCE. The consistency of the results obtained at the three sites and the differences between the sites suggest that the datasets could be representative of general local trends in the area. Nevertheless, some of the differences observed, such as the different proportions of pulses to grain from the sites, might be the result of the preliminary state of research on Vlaho, but other possibilities are discussed below. Pulses and oil plants are most likely to be under-represented in the archaeobotanical record of dry sites (Wilson 1984). In all investigated sites, cereals and most specifically glume wheats, and particularly their chaff remains, dominate the assemblages, and would therefore represent chaff-rich sites as proposed from investigations of several Late Neolithic sites in nearby regions (Valamoti 2005). This abundance of chaff might be due to well-known taphonomic factors, such as activities related to crop cleaning (Hillman 1981; Jones et al. 1986), storage practices (Jones et al. 1986) and charring processes (Boardman and Jones 1990), which may over-represent some crops such as glume wheats compared with others, such as free-threshing cereals. Therefore, the presence or abundance of

the different cereals can be better compared by the results from grain finds in this case. In order to go deeper into micro-regional trends and finer details of the crop spectra, expansion of the excavated areas at Veluška Tumba and Vlaho would be needed in the near future. The small sampled area to date cannot be considered representative for each occupation phase. Analyses at a higher resolution, with the support of more radiocarbon dates, would allow study at the level of individual context and within time phases and have the potential to reveal short-term agricultural decision making in the area. This paper therefore concentrates on the general patterns of the whole sites.

The most important cereal crops at all the studied sites, based on the abundance of grain remains, were einkorn and barley, followed by emmer. Apart from these, *T. timopheevii* was also present in significant but smaller amounts, and is mostly represented by chaff. In comparison with these, free-threshing wheat is either under-represented or did not have a big role in the economy. For the surrounding sites with published archaeobotanical data, glume wheats are dominant as well, represented by einkorn and emmer for all, but with *T. timopheevii* only from two sites in Greece, Paliambela and Phyllotsairi, because it has only been identified in recent archaeobotanical research (Jones et al. 2000). Barley is very commonly present in large quantities, while naked wheat was found from two nearby sites in Greece, Giannista B and Paliambela, and two other sites to the west of Pelagonia, Amzabegovo and Kovačevo (Fig. 5).

For Vlaho, where occupation starts at the earliest date, the total amount of naked wheat and barley is higher than from the other two sites (Table 1). The ratio of naked to hulled barley changes greatly in the later phases of Early Neolithic in lowland Pelagonia, which might be explained by several possibilities. Hulled barley is superior to naked when it comes to beer brewing and is more commonly used as animal fodder, while naked barley is more commonly used as a foodstuff for humans (Lister and Jones 2013; Zohary and Hopf 2000). This might indicate that barley was principally grown for human consumption in the earliest phases of settlement at Pelagonia, while later it was grown as a fodder crop or was used for brewing beer, although there is no evidence for brewing in the region to date. Nonetheless, as other authors have observed (Bouby et al. 2020) naked wheat and barley are less hardy in a harsh climate and more prone to diseases than hulled varieties, which might point to the abandonment of crops which may have been poorly suited to the local environmental conditions, after several hundred years of settlement in this area. The occupation of Vlaho coincides with the time of a potentially arid climatic phase, the 8.2 ka event (Weninger et al. 2009). It is possible that naked cereals grew better under drier conditions as in a similar case study (Steiner et al. 2022), than in a damper environment after 6000 BC, but this should be further investigated in the future. Naked wheat seems to show a higher importance for the nearby site of Amzabegovo, which lies within the Mediterranean climate area (Fig. 5).

Peas and lentils were by far the most important pulse crops at the Pelagonian sites, and possibly also at the Early Neolithic sites in the surrounding regions (Marinova 2007, 2017; Allen and Gjipali 2014; Marinova et al. 2016; Kotzamani and Livarda 2018). Lentils are always present from the sites in Greece, while pea is more common from Bulgaria, but it is only as important as in Pelagonia at two sites, Bâlgarčevo and Mursalevo. Seven sites show, sometimes in large amounts, the presence of *Vicia ervilia* (bitter vetch) and five sites have (grass) peas in the genus *Lathyrus* (Fig. 5). Additionally, *Cicer arietinum* (chickpea) was present at several Early Neolithic sites in Bulgaria (Marinova 2007) but absent in other areas. Since weedy races of bitter vetch commonly infest fields of crops in southwest Asia and Greece (Zohary and Hopf 2000, p 116), and presumably in Pelagonia as well, it is most probable that the very few fragments from Vrbjanska Čuka came into the assemblage through their accidental collection during the harvest. Regarding *Lathyrus sativus* (grass pea), which is potentially an Aegean addition to the Neolithic crop spectrum (Zohary and Hopf 2000; Valamoti and Kotsakis 2007), it was not of economic importance during the Early Neolithic in Pelagonia and was restricted to the sites with a Mediterranean climate (Fig. 5).

This narrowing of the crop spectrum from southern to northern Pelagonia is possibly a response to the environmental constraints as proposed for the regions further north in the central Balkan region where the climatic conditions are similar to Pelagonia (de Vareilles et al. 2022). Various environmental factors could have influenced this decision. For example, Ivanova et al. (2018) see this reduction as a response to a lower risk of summer droughts in the temperate climate, and our data, especially for pulses, agree with this proposal. They state how in the semi-arid Mediterranean environment where drought is a major risk, crops were sown in autumn to use winter moisture and flower early in spring in order to develop full grains before the summer drought. In an environment where the main risk is cold winters, as in parts of Pelagonia, sowing could also have been done in spring (Mazzucco et al. 2022), to postpone the germination and flowering time, and avoid the coldest months as well as late frosts. Thus a narrower crop spectrum can be expected.

Among the oil plants, flax and opium poppy were recorded, but they are represented by very few remains. While poppy had not yet been identified, *Linum usitatissimum* (flax) is rare but present at Early Neolithic sites in the surroundings and southeastern Europe in general

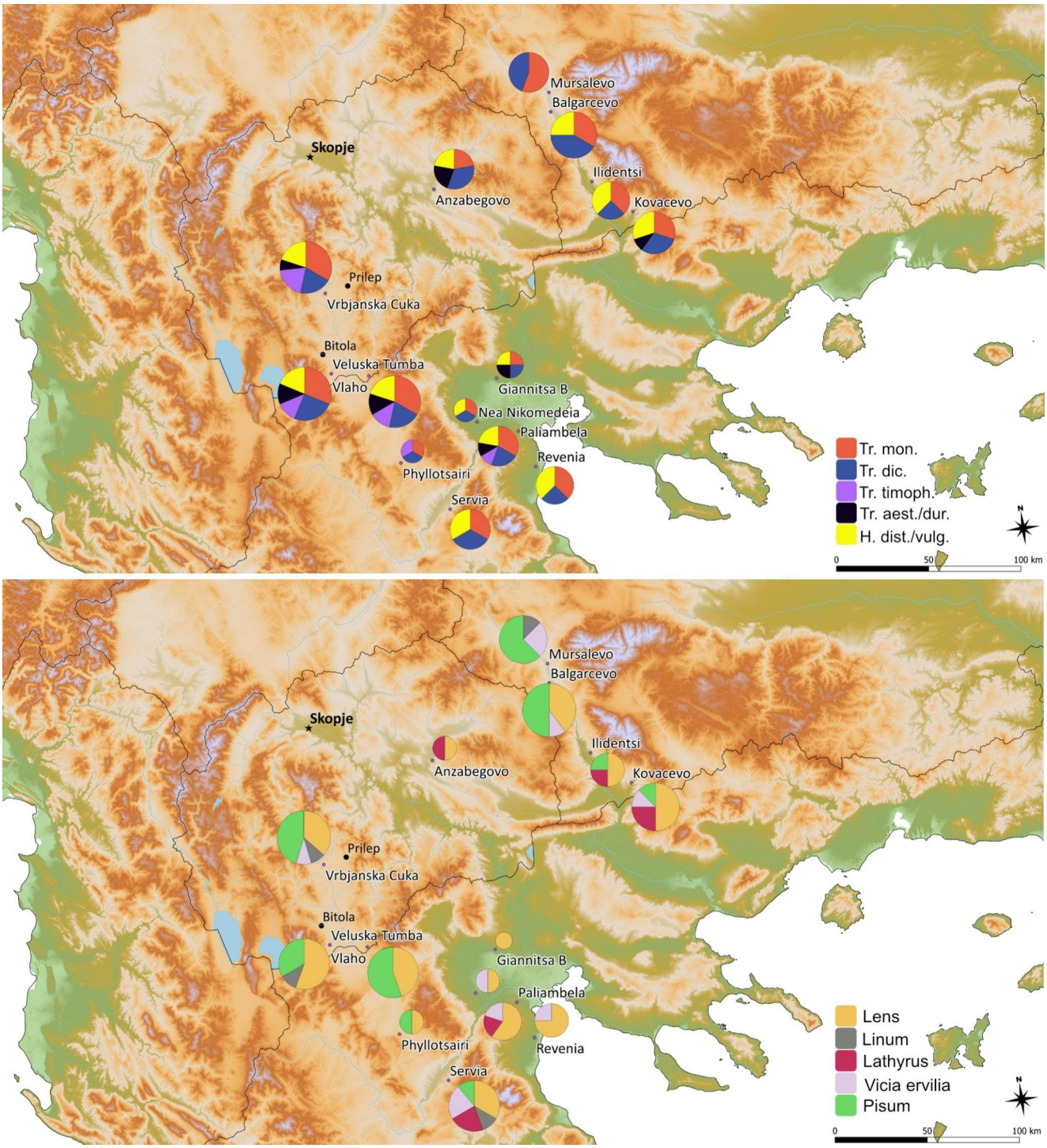

Fig. 5 Main crops, cereals (top) and pulses/flax (bottom), from sites dated between 6400 and 5700 BC from Pelagonia and the nearby regions, presented as pie charts based on scores (see end of the Methods section). Mapping used QGIS v. 3.16 from European Union, Copernicus Land Monitoring Service [2016], European Environment Agency (EEA)

(Fig. 5; Marinova 2007; Valamoti 2011). Flax seeds have not been found from Vlaho, which could be a consequence of the small number of processed samples. Climatically, flax would be an appropriate crop for temperate regions (Zohary and Hopf 2000, p 127), yet it is also present at the sites of Servia (Greece) and Mursalevo (Bulgaria), as well as at the pile-dwelling site of Ploča-Mićov Grad in the lake Ohrid, dated to ca. 4600 BC (Holguin et al. in press). The few seeds of *Papaver somniferum* (opium poppy) recovered from Pelagonia could be among the earliest known in Europe

(Salavert et al. 2020) and a rare find in the Balkan Peninsula. For this reason, they should be treated with caution until more finds are obtained and absolute dates are available. Large amounts of waterlogged opium poppy seeds have recently been found from Ploča-Mićov Grad (Holguin et al. in press). The fact that they were recovered from the three Pelagonian sites reinforces evidence that they are not intrusive material. Perhaps the use of the wash-over sieving technique, particularly suited for the recovery of very fragile plant remains (even in a waterlogged state) and a fairly small mesh size of 0.35 mm favoured their recovery. It is well known that even for sites with excellent waterlogged preservation conditions, oil plants are usually found in extremely high numbers in an uncharred state, yet only represented by a few charred seeds if not completely absent (Jacomet et al. 1989). We think our results indicate that the importance of oil plants in the region might need to be revised in the future as more data and associated radiocarbon dates are obtained.

The observed patterns within the Pelagonia region may be due to climatic or cultural factors. The absence of several pulses and the rarity of naked wheat remains already suggests an early adaptation of the original founder crop spectrum to the region of Pelagonia, as was proposed for the nearby regions of Greek Macedonia (Valamoti and Kotsakis 2007; Valamoti 2017). Further details can be discussed in the light of the new data presented above. Vrbjanska Čuka shows a narrower crop spectrum, since einkorn predominates with more than 70% of all the crop remains. Naked wheat seems to be slightly better represented from both Vlaho and Veluška Tumba, since for Vrbjanska Čuka only one find is identified with certainty, even though this is the best investigated of all three sites. It is possible that this difference in representation of naked wheat reflects cultural choices that are also demonstrated in the material culture, which is less like those of Vlaho and Veluška Tumba (Valamoti 2017; Naumov et al. 2020, 2021a, b). It is nevertheless also possible that as people moved northwards through the valley, einkorn became more important and some other crops such as naked wheat less so, as a response to the more continental environmental conditions. It is known that einkorn has lower yields than other cereals, but can endure harsher conditions and poorer soil quality. It requires plenty of moisture which would have been more than available in Pelagonia (Zohary and Hopf 2000; Haldorsen et al. 2011; Weiss and Zohary 2011). More *Pisum sativum* (pea) remains were recovered than any other crop when the numbers of grain/seed remains from Vrbjanska Čuka are considered, and for the two northernmost sites shown on Fig. 5 it is also present in large amounts, which is also significant in comparison to the sites in the surrounding regions, as peas are often completely absent from nearby sites in Greece. There was more *Lens culinaris* (lentil) from Veluška Tumba, located more to the south, than elsewhere. This might again point to a gradual adaption to environmental conditions as people moved northwards through the valley, for pea is better suited to a wetter environment than lentil (Weiss and Zohary 2011; Lucas and Fuller 2020). The narrowing of the crop spectrum as a response to the environmental conditions in more northern parts makes sense (Ivanova et al. 2018), since summer drought is less of a risk in temperate regions, especially in Pelagonia with its high water availability. As observed, not only north/south differences seem to have influenced crop diversity, but also climatic and environmental changes over time, and cultural choices. In the detailed results from Pelagonia we could observe slight differences between sites, although they seemed to be generally quite similar to each other when compared with other sites in nearby regions. Future work with more precise dating would be necessary to better understand the crop diversity observed.

Conclusions

The earliest sedentary communities that inhabited the Pelagonia valley depended upon their crops for their everyday diet and economy from the very start of the Neolithic in the region. This is evidenced by the presence of a considerable number of remains of domesticated plant species which were undoubtedly used as crops. Some of these remains represent the oldest directly dated cereals and pulses on the European continent so far. The crop choice was versatile with five cereal species (and several varieties), two pulses and potentially two oil crops. It was less diverse than the one found from some nearby sites in Greece and Bulgaria as vetches and chickpea are absent, but more than on sites in southern Serbia, suggesting that Pelagonia was potentially on one of the routes by which Neolithic cultures spread towards the north. In addition, the presence of opium poppy may connect it to the regions of the Adriatic Sea and, more broadly, the Mediterranean Neolithic groups.

We observed changes in the crop spectrum within the study area, as farmers spread further north into areas with a more continental climate. At the southernmost site of Vlaho, inhabitants chose more crops with naked grains than in the later phases and possibly relied less on pulses, which might point to different adaptations to the climate and the landscape there in the later periods of settlement in the area. The inhabitants of the village at Vrbjanska Čuka, situated more to the north of the valley, grew a narrower crop spectrum, mainly einkorn, hulled barley and pea. Since Pelagonia has a rather continental climate and high water availability, it is plausible that this narrowing of the crop spectrum indicates readjustments to the new climatic setting. Further studies

in the region might also help to observe whether a western Mediterranean influence can be established in the potential cultivation of opium poppy in the area, or if it could have been growing naturally in the region.

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