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ORIGINAL ARTICLE

Archaeobotanical and palaeoenvironmental analyses from the easternmost Early Neolithic sites at Kamyane-Zavallia (Ukraine) and Nicolaevca V (Moldova)

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Abstract

Recent archaeological excavations at two Early Neolithic settlements at Kamyane-Zavallia (Ukraine) and Nicolaevca V (Moldova) have provided new plant assemblages. The sites belong to the Linearbandkeramik culture (LBK) and represent its easternmost settlements. In these regions, charred plant macro-remains are still very rarely sampled for and investigated, so these results may shed light on the plant-based economy of the first farmers of this area. Both sites are located in the area of loess soils, in the border zone between deciduous woodland, woodland steppe and steppe. A dominance of *Triticum monococcum* (einkorn) was evident at both sites, preserved both as grains and chaff (spikelet bases and glume base). Other cereals, including cf. *T. dicoccum* (emmer), cf. *T. timopheevii* and *Hordeum vulgare* (barley) were less frequent. Among wild herbaceous plants, ruderal and segetal communities were represented by species commonly found at LBK sites, including *Chenopodium album* type, *Fallopia convolvulus, Echinochloa crus-galli* and *Lapsana communis.* The majority of these plants are edible and it is also likely that they were used as food. At both sites, remains of awns of *Stipa* sp. (feather grass) were found, which indicate the existence of grasslands and/or open woodlands in the vicinity. The charcoal assemblages were dominated by a few taxa, such as *Fraxinus* sp., *Quercus* sp. and *Cornus* sp., suggesting that there were some wooded steppe and deciduous forests. Selected plant macro-remains were radiocarbon dated and the results show that they are from ca. 5200 – 5000 cal BC. From the same archaeobotanical samples, snails were analysed and the resulting malacofauna shows a dominance of open-country snails as well as those which might indicate local agricultural practices at both settlements.

Keywords Linearbandkeramik (LBK) · Early Neolithic · First agriculture · Archaeobotany · Charcoal · Snails · Ukraine · Moldova

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Introduction

The Transdanubian Linearbandkeramik Culture (LBK) reached the rivers Dnipro (Dnieper) and the Pivdennyi Buh (Southern Bug) as it spread eastward (Fig. 1a). In an increasingly continental climate and at the border of wooded steppe (Kirleis and Dreibrodt 2016), it became harder for the first farmers to continue their spread. Over the wide distribution area of the LBK, a comparatively high degree of homogeneity has been observed, to which mobility and contacts within this culture contributed. The selection of LBK settlement sites in landscapes reflects a known pattern of places with adequate precipitation and moderate temperatures followed by a conservative and successful preference for areas with loessic soils, lower elevations, low relief energy and perennial rivers and streams. On this eastern periphery of the LBK area there were only limited contacts with the comparatively rare settlements of the local communities with Mesolithic backgrounds of the Bug-Dniester, Volhynian and Kyiv-Cherkasy cultures.

A limited amount of research has been done on the economic foundations and environmental conditions of the LBK settlements in Ukraine and Moldova, leaving many open questions about the timing and routes of the spread of

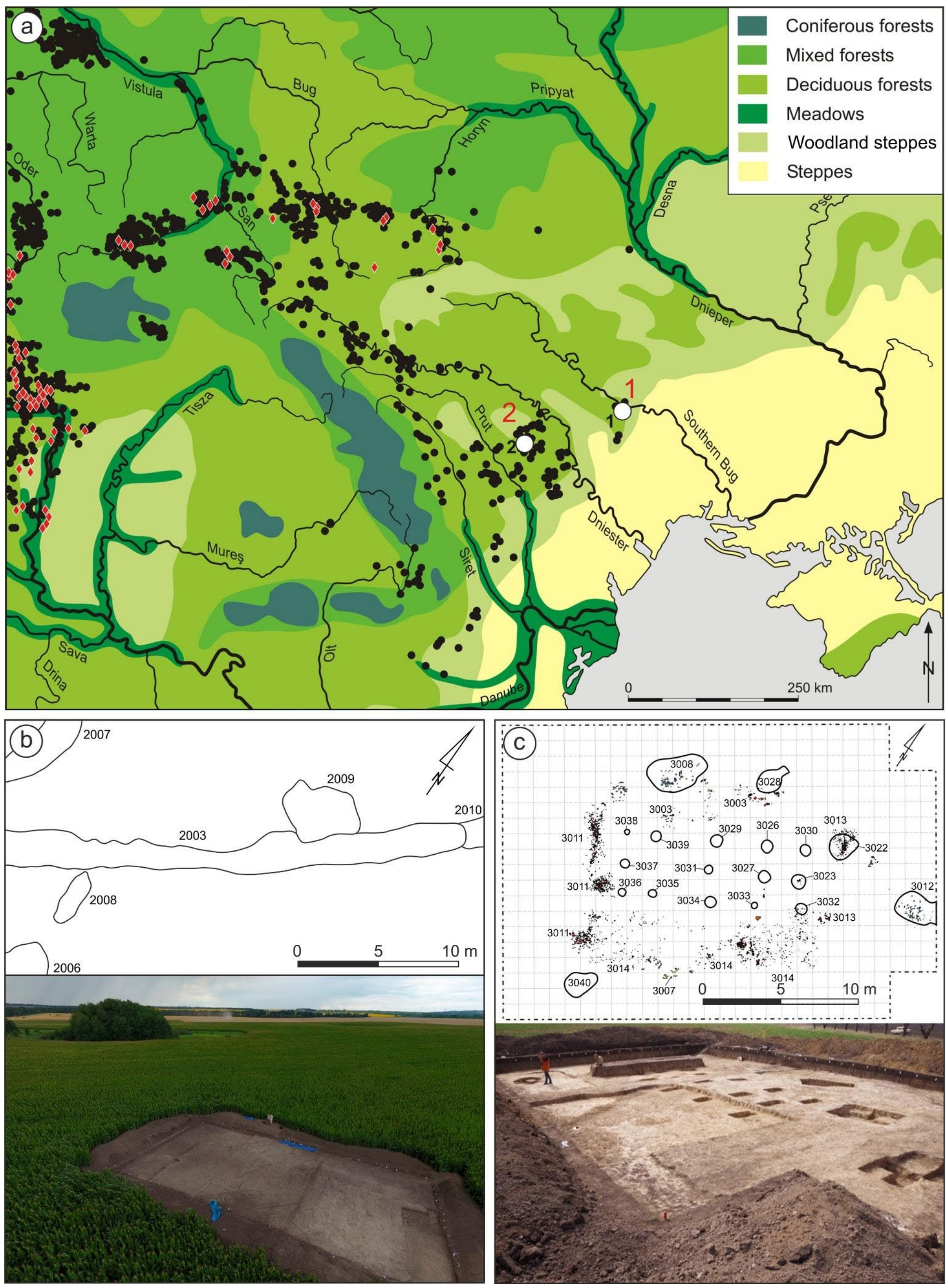

Fig. 1 **a**, Location of the archaeological sites, 1, Kamyane-Zavallia; 2, Nicolaevca V, the background shows the distribution of LBK sites; early phase, red dots; middle and late phases, black dots; and map of the natural potential vegetation. Base map: Map of the Natural Vegetation of Europe 1:2.500.000 by Bundesansanstalt für Naturschutz (after Saile 2020, p 220, Fig. 13; supplemented and with alterations); **b**, archaeological excavation at Kamyane-Zavallia. Drawing and photo by S. Radchenko; **c**, archaeological excavation at Nicolaevca. Drawing by S. Ţerna, photo by M. Dębiec

the first agricultural communities to these regions (Passek and Černyš 1963; Paškevič and Ohrìmenko 1990, 1992; Larina 1999; Kotova and Pashkevich 2003; Motuzaite-Matuzevičiūtė et al. 2009; Motuzaite-Matuzevičiūtė and Telizhenko 2016; Motuzaite-Matuzevičiūtė 2020; Salavert et al. 2021). The aim of this research is to increase information about the plants used by the early farmers in these two regions. It is especially crucial to discover the crops grown in the Bug and Dniester area, which are important for understanding the spread of farming to the woodland steppe belt and to find if the list of crops typical of the "Neolithic package" known from the more western LBK sites is the same in these easternmost areas. Therefore, the results obtained in our analyses of the material from the sites Kamyane-Zavallia and Nicolaevca certainly deserve attention.

Archaeological sites

Kamyane-Zavallia (48°10'51"N; 30°0'25"E; 100 m a.s.l.) is located on the western bank of the river Pivdennyi Buh (Southern Bug) in Ukraine (Fig. 1a/1). This LBK site was discovered in 2011 (Saile et al. 2016; Kiosak 2017) and since then, investigated in small-scale excavations. From the excavations in the years 2013–2014, the first archaeobotanical studies were done on one of the features (object 1) (Salavert et al. 2021). The excavations continued in 2019, providing information about several new features (Fig. 1b). The LBK settlement at Nicolaevca (site V, Moldova; 47°36'11"N; 28°02'59"E;135 m a.s.l.) is located in the Răut catchment on gentle slopes on both sides of a small depression west of a little unnamed brook that flows into the river Ciulucul de Mijloc in the catchment area of the river Ciulucul Mare (Fig. 1a/2). The site was discovered in the 1970s, and magnetic surveys in 2014 and 2019 revealed 19 longhouses (Saile et al. 2016; Saile 2020). An excavation was done in 2019 to evaluate the magnetic survey results of one building at this site. During the excavation, various features such as a long pit, postholes and settlement pits were found (Fig. 1c).

From both sites 13 new radiocarbon dates were obtained from identified charred plant remains (Table 1). These dates complete the chronology obtained previously from Kamyane (marked with * in Table 1) and they show that both sites represent the middle and late LBK, and are consistent with a period between ca. 5200 – 5000 cal BC.

The climate of the region is damp continental. In Zavallia, Ukraine, the average temperature in January is -4.5 and 20.2 °C in July. The average annual precipitation is about 550 mm (Salavert et al. 2021). In Nicolaevca, Moldova, the average temperature in January is -2.3 °C, while in July it reaches 22.7 °C. The average annual precipitation is about 603 mm (https://de.climate-data.org/). The sites are located in farm land with only patches of natural vegetation. According to the map of natural vegetation (Bohn et al. 2004, Fig. 1a), both sites are in the region where oak-hornbeam forests (Tilio-Carpinetum, subcontinental) grow and even reach their southern limits there. In the close vicinity, a woodland steppe zone is characteristic of the region, dominated by various oak species (*Quercus pubescens*, *Q. robur*, *Q. petraea*, *Q. pedunculiflora* and *Q. cerris*). They are accompanied by *Acer, Fraxinus* and *Carpinus*, as well as *Tilia* species in the tree layer. In the southern part of both sites, there is herb-rich steppe vegetation (Bohn et al. 2004).

Materials and methods

Archaeobotany

38 samples (total, 407 L) were collected from the Kamyane site, (Table 2) and 25 samples (226 L) from Nicolaevca (Table 3). The soil samples were floated using sieves of 0.5 and 1.2 mm mesh sizes. The plant remains, which were charred, were extracted from the flots and then identified using a stereo microscope with magnifications from 6× to 63×. The plant remains were identified by their seed and fruit morphology, including shape, size and character of the surface (Kulpa 1974; Cappers et al. 2006; Jacomet 2006), and by comparison with the reference collection of modern seeds and archaeobotanical remains of the W. Szafer Institute of Botany (IB PAS), Kraków. Charcoal fragments were identified with a reflected light microscope using magnifications from 100× to 500×, and compared with anatomical atlases such as Schweingruber (1990) and with specimens in the modern reference collection at IB PAS. Due to the lack of clear diagnostic features, the charcoal of trees and shrubs found in Europe is most often identified only to genus level. Also, a scanning electron microscope, available at the Laboratory of Scanning Electron Microscopy and Microanalysis of the Institute of Geological Sciences, Jagiellonian University, Kraków, was used in the present study. Only fragments > 2 mm in transverse section were analysed. The basis for counting is a charcoal fragment (Chabal 1997).

From Kamyane, a total of 312 charred plant remains of seeds, fruits and chaff were found. The density of charred plant remains was low for this site. Charcoal fragments (N = 516) were infrequent and scattered. These new materials confirm the general trend of the taphonomy of Early Neolithic sites that is not favourable to the preservation of plant macro-remains (Salavert et al. 2021).

A total of 123 charred plant remains of seeds, fruits and chaff were found from Nicolaevca. Plant material was very scarce there, while the density was always lower than one item/L of studied sediment. Charcoal fragments were small

Table 1 Results of radiocarbon dating of taxonomically identified charred plant remains from Kamyane-Zavallia and Nicolaevca (1–14*). 1–13, new results, *, previously published data (Kiosak 2017; Kiosak and Salavert 2018). Plant names follow Mirek et al. (2002) and for wheats Zohary et al. (2012)

No.	Site	Sample ID	Feature ID	Lab.code	Dated material	Age ^{14}C (BP)	Cal age, 2σ-range (BC)
1	KZ	22,357	2003	Poz-137,908	*T. monococcum*	6,260 ± 40	5316 – 5205 (72.7%) 5174 – 5069 (22.8%)
2	KZ	22,294	2003	Poz-137,825	*T. monococcum*	6,150 ± 50	5217 – 4945 (95.4%)
3	KZ	21,066	2006	Poz-137,560	*T. monococcum*	6,170 ± 50	5297 – 5260 (4.0%) 5221 – 4989 (91.4%)
4	KZ	21,810	2006	Poz-137,952	*Fallopia convolvulus*	6,140 ± 40	5213 – 4986 (93.4%) 4971 – 4954 (2.1%)
5	KZ	22,383	2008	Poz-137,826	*Triticum* sp.	6,240 ± 40	5309 – 5203 (52.7%) 5181 – 5061 (42.7%)
6	KZ	22,477	2008	Poz-137,827	*T. monococcum*	6,200 ± 40	5300 – 5254 (9.2%) 5223 – 5032 (86.2%)
7	KZ	22,350	2009	Poz-137,951	*Triticum* sp.	6,290 ± 50	5371 – 5206 (84.3%) 5171 – 5112 (7.5%) 5107 – 5072 (3.7%)
8	KZ	22,349	2009	Poz-137,828	*T. monococcum*	6,250 ± 40	5312 – 5204 (63.4%) 5176 – 5066 (32.1%)
9	NV	31,678	3008	Poz-137,959	Cerealia indet.	6,220 ± 40	5305 – 5240 (21.1%) 5230 – 5197 (11.4%) 5191 – 5046 (62.9%)
10	NV	31,418	3022	Poz-137,957	*Fallopia convolvulus*	6,180 ± 50	5298 – 5258 (5.8%) 5221 – 4996 (89.6%)
11	NV	31,573	3028	Poz-137,955	*T. monococcum*	6,175 ± 35	5215 – 5008 (95.4%)
12	NV	31,556	3028	Poz-137,958	*Chenopodium hybridum*	5,890 ± 70	4941 – 4585 (94.2%) 4569 – 4552 (1.3%)
13	NV	31,651	3040	Poz-137,954	*Fallopia convolvulus*	6,230 ± 40	5306 – 5201 (42.2%) 5185 – 5054 (53.3%)
14*	KZ	KZ2	1	Poz-67,554	*Fraxinus* (charcoal)	6,130 ± 40	5210 – 4952 (95.4%)
15*	KZ	KZ1	1	Poz-67,121	Animal bones	6,200 ± 40	5300 – 5254 (9.2%) 5223 – 5032 (86.2%)

(<4 mm) and scarce (N = 438). It was possible to identify 40–50 fragments only in four samples. The charcoal was in a good state of preservation, although most of it had a strongly vitrified anatomical structure.

Snail remains

Snail shells were found in the sediment samples and were identified using keys (Wiktor 2004; Welter-Schultes 2012; Horsák et al. 2013) and a reference collection (Tables 3 and 4). The identified taxa are grouped according to their ecological requirements (Ložek 1964; Alexandrowicz and Alexandrowicz 2011).

Results

Archaeobotany

Triticum monococcum (einkorn) was the main cereal found from both studied sites (Fig. 2/1a, b; 3/1a-c). From Kamyane, *T. dicoccum* (emmer) was present as only a few specimens identified as similar to that species (cf.) (Table 2). Also, one rachis internode of *Hordeum vulgare* (barley) was found (Fig. 2/5a, b). In general, cereal remains were distributed unevenly among the features as they were relatively numerous only in features 2003, 2008 and 2009. For Nicolaevca, chaff remains and caryopses of einkorn were found mostly from one feature, 3028, and also one glume base similar to New Glume Wheat (NGW) type (Fig. 3/4a-d). This has recently been confirmed to represent *T. timopheevii* (Czajkowska et al. 2020). A poor state of preservation does not allow its exact identification, but features of the keels together with the overall large size of the fork and the ribbed outer surface of the glume are all indicative of NGW (Filipović, personal communication). Fragments of large seeds of Fabaceae were found from Nicolaevca (Fig. 3/3a, b). The remains of wild plants were uncommon in both sites.

Four taxa were identified in the charcoal assemblage from Kamyane, mainly *Quercus* (oak), followed by *Fraxinus* (ash), while *Prunus* (sloe, etc.) was sporadic (Fig. 4b). In terms of ubiquity, *Quercus* and *Fraxinus* were very similar

Table 2 Results of the analysis of charred plant remains from the Kamyane-Zavallia site

Kamyane-Zavallia Feature ID	2003	2006	2007	2008	2009
Number of samples	17	5	1	6	3
Samples vol [litres]	171.8	55.2	12	80.3	34
Cultivated plants					
Triticum monococcum (caryopsis)		2		1	1
T. monococcum (spikelet base)	12	1		5	7
T. monococcum (glume base)	51	4		5	8
T. cf. *dicoccum* (spikelet base)	3				
T. cf. *dicoccum* (glume base)	2				
Triticum sp. (caryopsis)	1	1			
Triticum sp. (spikelet base)	6	2		6	1
Triticum sp. (glume base)	83		1	12	3
Hordeum vulgare (rachis)	1				
Cerealia indet.	3	4		7	3
Other plants					
Setaria viridis/verticillata (caryopsis)				2	1
Echinochloa crus-galli (caryopsis)	1				
Fallopia convolvulus (fruit)	1	1		2	1
Chenopodium album type (seed)	4			4	
cf. *Coronilla varia* (seed)	1				
Stipa sp. (awn)	9		1	11	1
Poaceae indet. (caryopsis)	1			1	1
Indeterminata	19	4	2	7	1

Table 3 Results of the analysis of charred plant remains from the Nicolaevca V site

Nicolaevca V, Feature ID	3008	3022	3028	3040
Number of samples	4	4	12	4
Samples volume [litres]	38.9	36	107.4	35.5
Cultivated plants				
Triticum monococcum (caryopsis)			5	1
Triticum monococcum (spikelet base)			2	
Triticum monococcum (glume base)			11	
Triticum sp. (caryopsis)	1			
Triticum sp. (spikelet base)			2	
Triticum sp. (glume base)		1	4	
cf. *Triticum timopheevii* "NGW" (glume base)			1	
Cerealia indet.		1	13	4
Other plants				
Bromus sp. (caryopsis)			1	
Chenopodium t. *album* (seed)			6	
Chenopodium hybridum (seed)	1	1	3	
cf. *Echinochloa crus-galli* (caryopsis)			1	
Fallopia convolvulus (fruit)		1	1	1
Fallopia dumetorum (fruit)	1			
Lapsana communis (fruit)				1
Fabaceae indet. – large (seed)		1	3	1
Stipa sp. (awn)	9	2	15	1
Poaceae indet. - large (caryopsis)			1	
Unidentified	6	2	17	2

as they appeared in almost all samples. For Nicolaevca, five taxa were identified, mainly *Fraxinus* and *Cornus* (cornel, dogwood), with fewer *Quercus* and *Ulmus* (elm), while *Acer* (maple) was sporadically found (Fig. 4b). The most ubiquitous taxon was *Fraxinus* which was present in 88% of the samples, while *Quercus* appeared in more samples than *Cornus*. For both sites, due to the small fragments of charcoal, usually up to 3–4 mm in transverse section, it was not possible to study ring curvature. However, three remains of twigs were found from Kamyane. Evidence of fungi in charcoal fragments from both sites was found.

Table 4 Snail faunas from Nicolaevca V and Kamyane-Zavallia

Ecological requirements	Taxon	SS	Nicolaevca V			Kamyane-Zavallia		
			N	%	Σ%	N	%	Σ%
Dry habitats, xerothermic (DM)	*Cochlicopa lubricella* (Porro)	Cl	8	4.4	26.8	36	2.4	13.7
	Truncatellina cylindrica (Fér.)	Tc				35	2.3	
	Chondrula tridens (Müll.)	Ct	1	0.5		88	6.0	
	Helicopsis striata (Müll.)	Hs	41	21.9		44	3.0	
Dry grasslands (DM)	*Vallonia costata* (Müll.)	Vc	55	29.4	29.4	363	24.5	38.2
	Vallonia excentrica (Streki)	Ve				203	13.7	
Moderately wet grasslands (MM)	*Vallonia pulchella* (Müll.)	Vp	63	33.7	33.7	684	46.0	46.0
Mesophilous (ME)	*Carychium tridentatum* (Risso)	Cr			0.5	10	0.7	0.7
	Euconulus fulvus (Müll.)	Ef	1	0.5				
Underground, in soil (UG)	*Mediterranea inopinata* (Uli.)	Mi	18	9.6	9.6	3	0.2	0.2
Loess (LO)	*Succinella oblonga* (Drap.)	So				6	0.4	0.7
	Clausilia dubia (Drap.)	Cd				2	0.1	
	Pupilla loessica (Ložek)	Pl				3	0.2	
Water (WT)	*Gyraulus crista* (L.)	Gc				1	0.1	0.5
	Segmentina nitida (Müll.)	Sn				5	0.3	
	Unio pictorum (L.)	Up				1	0.1	
			7			15		
			187	100	100	1,484	100	100

Snails

There was little taxonomic and ecological diversity in both sites. The assemblage from Kamyane was richer, with almost 1,500 specimens and 16 species, than the one from Nicolaevca with ca. 200 specimens and nine taxa (Table 4). The snail fauna is dominated by taxa characteristic of open habitats. Among them, a group of taxa of drier habitats can be distinguished, often found in warm and dry habitats with a calcareous substrate (DX group, Fig. 4c). They were more abundant from Nicolaevca (26.8%) than Kamyane (13.7%; Table 4). Snails typical of dry grassland biotopes (DM group) were present from both sites, 30% from Nicolaevca and almost 40% from Kamyane. The most important component of the snail fauna was *Vallonia pulchella* with 33.7% from Nicolaevca and 46% from Kamyane. It is a species inhabiting open grassland biotopes with medium dampness (MM group). Noteworthy is the presence of *Mediterranea inopinata*, a species which lives in the soil (UG group), with ca. 10% from Nicolaevca and single shells from Kamyane. Other ecological groups of mesophilous, loess and aquatic habitats are of marginal importance at less than 2% (Fig. 4c; Table 4).

Discussion

The plant material from both studied sites was scarce and relatively badly preserved. This is characteristic for the studied area, chronological period and the marginal zones of the LBK area (Matuzevičiūtė and Telizhenko 2016; Mueller-Bieniek et al. 2019; Salavert et al. 2021). For Kamyane, the assemblage is strongly dominated by wheat chaff remains (ca. 80% of all remains). The other three groups, including crop grains, feather grass awns and seeds of other possibly cultivated plants (Fabaceae), have similar values of 5–10% each (Fig. 4a). *Triticum monococcum* (einkorn) was the main identified cereal, while the growing of *Hordeum* (barley) is proved by the finding of one rachis internode, and it is likely that *T. dicoccum* (emmer) was also grown. These results complement previous results from Kamyane with 35 specimens from 116 L sediment, with badly preserved caryopses of the same taxa (Salavert et al. 2021). *Triticum monococccum* (einkorn) was mainly found from Nicolaevca, while cf. *T. timopheevii* (NGW) appeared sporadically. Crop grains, chaff remains and Fabaceae were represented evenly in the samples from this site (Fig. 4a). It is highly probable that the group of large Fabaceae seeds represents crops, but their exact identification was not possible due to the damage and a lack of diagnostic features. However, these finds most probably consist of *Pisum sativum* (peas) and *Lens culinaris* (lentils).

Despite the scarcity of plant remains from Nicolaevca and Kamyane, these taxa indicate local agricultural practices. In the snail assemblage, there were shells of *Mediterranea inopinata* from both sites, which is frequently associated with soils in agricultural areas (Füköh 1995; Balashov et al. 2013; Juřičková et al. 2013). As it lives in the soil, it could possibly be intrusive from more recent deposits.

There are only a few LBK sites with charred plant remains of crops from Ukraine and Moldova, such as Ratniv-2 and Nezvisko in the former, and Denchen-I and Floresht-I in the

Fig. 2 Charred remains of cultivated (1–3) and wild (4–6) plants from Kamyane-Zavallia. **1**, spikelet base of *Triticum monococcum* (einkorn); **2**, spikelet base of *Triticum* sp. (wheat), probably from the lowermost part of the ear; **3**, caryopsis (grain) of *Triticum monococcum* (einkorn); **4**, caryopsis of *Setaria viridis*/*verticillata* (green/bristly foxtail), **a**, ventral view with visible characteristic sculpture left by papillae of palea, **b**, dorsal view; **5** rachis fragment of *Hordeum vulgare* (barley); **6**, caryopsis of *Echinochloa crus-galli* (cockspur), **a**, ventral view with visible hilum, **b**, dorsal view; **7**, awn fragments of *Stipa* sp. (feather grass); scale bars, 0.5 mm (photos by K. Stachowicz)

latter (see the list of the sites in Table 9.1 and all cited literature in Motuzaite-Matuzevičiūtė 2020). They show the use of various species of wheat such as *Triticum monococcum* (einkorn), *T. spelta* (spelt), *T. dicoccum* (emmer), *T. aestivum* (bread) and *T. durum* (durum) wheats together with *Hordeum* (barley) and the pulses *Pisum sativum* (pea), *Vicia ervilia* (bitter vetch) and *Lens culinaris* (lentil). The remains of *T. timopheevii* (NGW) also appeared from Ratniv-2. This has recently been identified from several Early Neolithic sites in southeastern and eastern Europe, mostly in the Balkans, but also in the northern Black Sea area (Filipović et al. in press 2022). In southeastern and eastern Europe there is a higher number of LBK sites where cereals were identified from imprints in pottery (Monah 2007; Motuzaite-Matuzevičiūtė 2020, Table 9.1). However, we agree with the opinion of Motuzaite-Matuzevičiūtė (2020, p 315) that

Fig. 3 Charred remains of cultivated plants from Nicolaevca V. **1**, glume base of *Triticum monococcum* (einkorn); **2**, caryopsis of *Triticum* sp. (wheat), **a**, dorsal view, **b**, ventral view; **3**, Fabaceae indet., large (probably *Pisum* sp., pea); **4**, spikelet base of cf. NGW (*T. timopheevii*), **a**, ventral view, **b**, lateral view, **c**, top view, **d**, dorsal view; **5**, seed of *Chenopodium hybridum* (goosefoot); **6**, achene of *Lapsana communis* (nipplewort); **7**, awn fragments of *Stipa*. sp. (feather grass); scale bars, 1 mm (photos by K. Stachowicz)

due to the lack of details about the archaeological context (layer and potsherd origin) as well as difficulty of plant identification from imprints we should not take these data into account. This is especially true in the case of commonly found remains of *Panicum miliaceum* (broomcorn millet), as its Neolithic chronology still remains uncertain (Filipović et al. 2020). For example, one grain of *Panicum* from the Neolithic layer at Kamyane was dated and it proved to be later (Martin et al. 2021: cal AD 264–541; GifA19189a: 1,635 ± 45 BP). This suggests that millet remains can easily be intrusive at Neolithic sites. However, 11 specimens of cultivated and wild plants from Kamyane and Nicolaevca were directly radiocarbon dated and their Neolithic origin was confirmed (Table 1).

The cultivated plants at the two sites correspond to a typical LBK crop package with a limited crop diversity and the dominance of hulled wheat (Bogaard 2004; Kreuz 2007; Lityńska-Zając 2007). Even if the status of barley as either a crop or a weed is still unclear there, the find of one rachis internode at Kamyane confirms its presence in the eastern LBK plant economy (Motuzaite Matuzevičiūtė and Telizhenko 2016; Salavert et al. 2021). The relative importance of chaff remains in the LBK sites presented here is like that found in central European sites, including from rubbish contexts (Kreuz 2007), and in southeastern Early Neolithic sites (Kreuz and Marinova 2017), which probably confirms the comparability of our results within a broader regional context. Abundant chaff remains can indicate cereal processing on the site, perhaps at a domestic level, as supported by the significant amount of elongate dendritic phytoliths found from Kamyane (Salavert et al. 2021).

Among the wild herbaceous plants identified from Kamyane were *Chenopodium album* type, *Fallopia convolvulus*, *Setaria viridis/verticillata* (Fig. 2/4a, b) and *Echinochloa crus-galli* (Fig. 2/6a, b, Table 1). For Nicolaevca the spectrum of non-cereals was broader, as besides *C. album* type, *F. convolvulus*, cf. *E. crus-galli*, *Ch. hybridum* (Fig. 3/5) and *Bromus* sp. were also found (Table 3). These are weeds and ruderals, but they can also be a source of food, as confirmed by archaeobotanical and ethnographic studies (Helbæk 1959; Behre 2008; Mueller-Bieniek et al. 2019). However, their rather low number does not permit any conclusion about whether they may have been gathered. In addition, *Lapsana communis* (Fig. 3/6) and *Fallopia dumetorum*

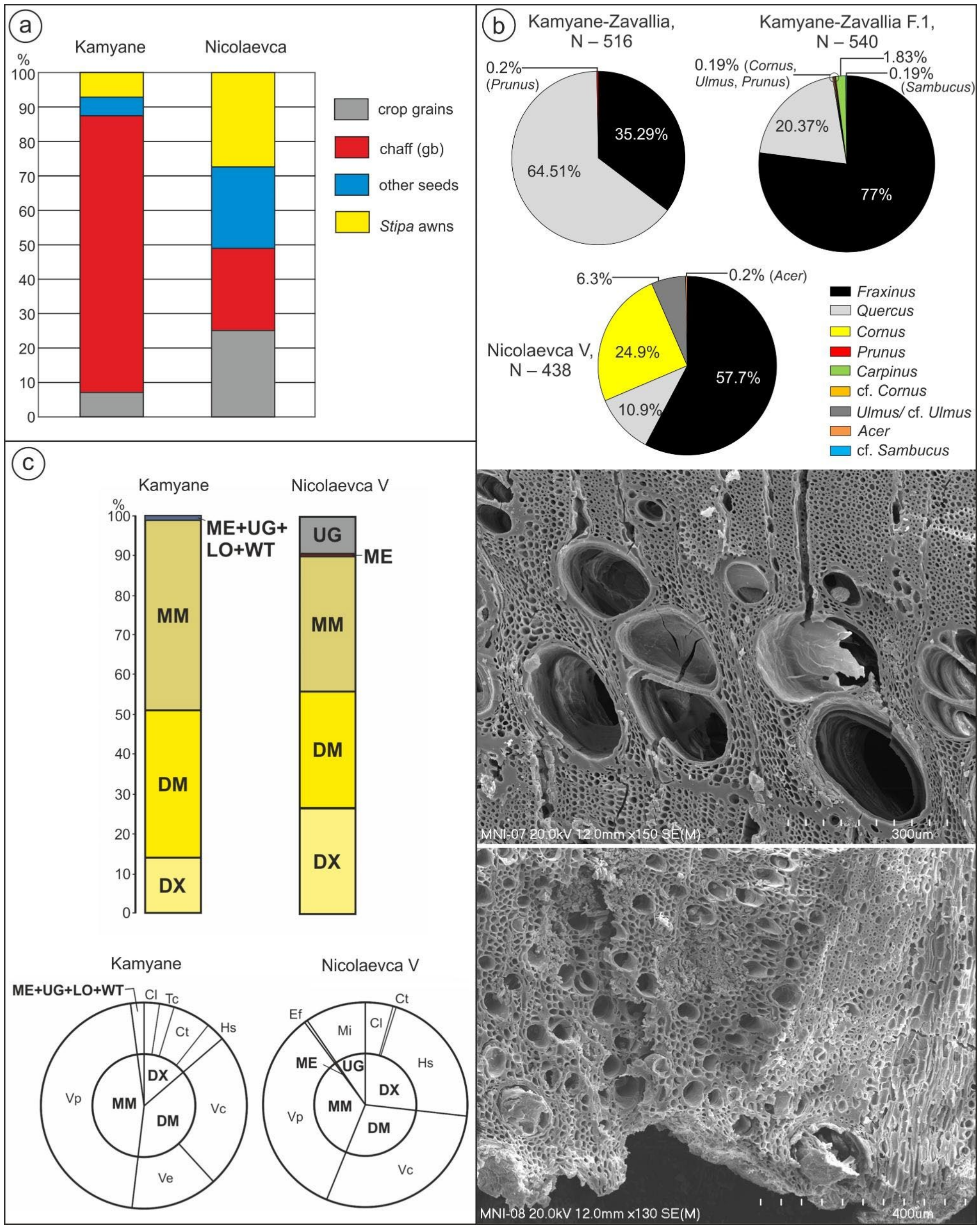

Fig. 4 **a**, Main groups of plant assemblages from Kamyane-Zavallia and Nicolaevca. For a comparison, total chaff was calculated as sum of glume bases and doubled number of spikelet forks; **b**, Results of the charcoal analysis presented as relative frequencies of the taxa from Kamyane-Zavallia (new and previous study, F.1) and Nicolaevca, taking into account only taxa identified up to genus level. Below, two examples of the main taxa in transverse section, *Fraxinus* sp. (upper part) and *Quercus* sp. (lower part); **c**, Ecological and taxonomic composition of mollusc assemblages from Nicolaevca V and Kamyane-Zavallia. Explanations of habitat codes in Table 4

were present (Table 3). The former can be a segetal plant (field weed), but also grows in woodland edges (Lityńska-Zając 2005), while the latter may indicate the use of plants brought from elsewhere, as it grows in mostly moist, nutrient-rich habitats with sandy and clay soils in riverside scrub and woodlands. Again, these species are often found among wild plants and mostly interpreted as weeds at the LBK sites in central Europe (Bogaard 2004; Bieniek 2007; Kreuz and Schäfer 2011; Motuzaite Matuzevičiūtė and Telizhenko 2016; Czekaj-Zastawny et al. 2020). It should be noted that grasses of the Paniceae tribe such as *Echinochloa crus-galli* and *Setaria viridis/verticillata* are of southeast Asian origin (Lityńska-Zając 2005; Lityńska-Zając and Wasylikowa 2005). They now grow as weeds of root crops or millet in Europe, but their cultivated varieties are grown in southern and southeastern Asia. Also, the presence of Paniceae grasses might be related to the method of cereal cultivation and could indicate different ways of field preparation as well as their probable use as food. Remains of two species of wild herbaceous plants from both studied sites were radiocarbon dated (Table 1), but none of these millet weeds were directly dated. Therefore, they could represent more recent intrusive material, especially in the context of such a recent date of *Panicum miliaceum* from Kamyane.

Awns of *Stipa* were identified from both sites (Tables 2 and 3; Figs. 2/7, 3/7). *Stipa* species are characteristic of steppes and steppe-like vegetation and grow there in Ukraine and Moldova. They can also appear in the herb layer in woodland steppe (Bohn et al. 2004). The archaeobotanical data from central and southeastern Europe shows the past presence of *Stipa*, indicating a steppe-like vegetation, dry grassland or open woodlands in the vicinity (Marinova et al. 2012/2013; Moskal-del Hoyo et al. 2017, 2018a, b) and its possible collection (Bieniek and Pokorný 2005). At Nicolaevca and Kamyane, *Stipa* probably represents natural vegetation with grasslands and/or open woodlands as suggested by the location of the sites on the border between deciduous woodland, woodland steppe and steppe. The snail analyses of both discussed sites confirm the presence of open grassland environments near the sites, including moderately wet grasslands and dry, even xerothermic environments (Fig. 4c; Table 4).

The charcoal assemblages from both Kamyane and Nicolaevca represent charcoal scatters which are found in pits associated with houses and termed “dispersed charcoal” or “long-term deposits” by Asouti and Austin (2005), and which may allow a reconstruction of the local ancient woodlands. The fragments were small and scarce, as is usually found with charcoal assemblages from other LBK sites on loessic areas (Moskal-del Hoyo 2021). The charcoal identified from both sites may have originated mainly from wood gathered for fuel. Nevertheless, certain taxa such as *Quercus* and *Fraxinus* might be over-represented because of their use as timber, or *Cornus* for wattle and daub constructions (Marinova and Thiébault 2008). In some cases, the abundance relationships in charcoal assemblages are not analogous to those from pollen data from cores near the archaeological sites (Salavert et al. 2018, p 726), but in others, both kinds of data are adequately comparable (Moskal-del Hoyo et al. 2018a). Moreover, the plant list is similar for both sites. In Nicolaevca, *Fraxinus* was the dominant followed by *Cornus*, while in Kamyane, *Quercus* predominated over *Fraxinus* (Fig. 4b). However, charcoal data from an earlier study of Kamyane showed the opposite, as *Fraxinus* was more frequent than *Quercus* there (Fig. 4b, F1). Taking into account the taxonomic composition of the charcoal samples, their local origin might be assumed. Usually, the most abundant taxa in the samples would be trees and shrubs that grew nearby. However, it should be emphasized that interpretation of the characteristics of woodland communities on the basis of only woody remains is usually limited, because identifications are usually possible only to genus level (Lityńska-Zając and Wasylikowa 2005).

The dominance of *Quercus* (oak) and *Fraxinus* (ash) may indicate that wood was gathered from local deciduous woodlands, which could have grown on the rich chernozem soils in loessic areas. Both sites are located in regions where, according to the natural vegetation (Bohn et al. 2004), deciduous oak woodland (present-day oak-hornbeam woods) might have appeared, alternating with wooded steppe. Such kinds of woods are open canopied and may overlap with areas of open grassland, which is also typical of the loess landscape in Moldova and Ukraine. In Nicolaevca, *Cornus* also appeared in a significant proportion, but it may represent two species that can grow in two different habitats. *Cornus sanguinea* (dogwood) can mainly be found in riverside habitats, while *C. mas* (cornel) grows in drier, well-lit habitats (Seneta and Dolatowski 2000). The remains of *Ulmus* (elm) were also found from Nicolaevca and Kamyane. The various species can be present both in damper and drier habitats so, for example, *U. minor* is often a component of the woodland steppe, while *U. laevis* is typical of riverside woodlands (Molnár 1996). In both habitats, various species of *Acer* can be found as well. Therefore, it is likely that the main taxa found as charcoal could have come from deciduous woods and wooded steppe, but could also have grown as azonal riverside vegetation in some damper areas, as both sites are located near rivers. At the Chalcolithic site of Durankulak, located in a woodland steppe environment, *Fraxinus* and *Ulmus* were also well represented in the charcoal assemblage, which probably indicates the use of the riverside woodlands near the site (Tonkov et al. 2014).

The charcoal assemblages from the eastern LBK (Alföld LBK) in neighbouring areas, such as the Alföld (Great Hungarian Plain) in Hungary (Moskal-del Hoyo et al. 2018b), and eastern Slovakia (Lityńska-Zając et al. 2008) were dominated by *Quercus*, *Cornus*, *Fraxinus* and *Ulmus*. *Quercus* and *Cornus* were clearly most abundant in Bulgaria (Marinova and Thiébault 2008; Marinova et al. 2012/2013). The two native species of *Cornus* could have grown near these sites, but it is worth mentioning that *C. mas* (cornel) was one of the most commonly found plants in eastern and south-eastern European Neolithic sites (Ivanova et al. 2018). In Hungary and Bulgaria, the presence of *C. mas* can be related to plant communities that were probably like the modern Sub-Mediterranean–Subcontinental thermophilous *Quercus cerris* (Turkey oak) and *Q. frainetto* (Hungarian oak) forests of southeast and east-central Europe (Bohn et al. 2004). Other taxa included *Prunus* and cf. *Sambucus* at Kamyane (Salavert et al. 2021). There were few records of taxa associated with woodland edges and scrub from sites in Ukraine, in contrast to LBK sites in central and western Europe, where such light-demanding taxa are often present (Kreuz 2008; Jansen and Nelle 2014; Salavert et al. 2014; Moskal-del Hoyo 2016). It is difficult to interpret these discrepancies as they can have various causes, such as a shorter duration of occupation or differences in the kinds of human impact on the vegetation. This difficulty of interpretation can also be related to the relatively low number of charcoal fragments found, which came from only a few archaeological features. This aspect of the work requires further study to provide more data.

Unfortunately, there are no well-dated pollen sequences close to Kamyane and Nicolaevca (Albert et al. 2020; Salavert et al. 2021). However, the pollen evidence from the region (southern Dobrudza; Bozhilova and Tonkov 1998) shows that the landscape could still have been rather open during the period around 5200 – 5000 BC (7,150-6,800 BP), but a study of the Dovjok swamp in southwestern Ukraine suggests that in the second half of the 6th millennium BC (zone 4; 6,260 ± 80 BP, ca. 5190 cal BC) there were woodlands similar to Quercetum mixtum (mixed oak woodlands) with *Corylus*, *Ulmus*, *Tilia*, *Quercus* and *Carpinus* (Kremenetski 1995). A few charcoal fragments of *Carpinus* also appeared from Kamyane (Salavert et al. 2021), which may confirm the presence of hornbeam in the region.

Conclusions

The results of the archaeobotanical analysis of two LBK sites in Ukraine and Moldova have provided new data that enrich the limited database of plants used by people at the eastern margins of this Early Neolithic culture area. The plant assemblages from Kamyane and Nicolaevca, although relatively small, come from representative samples with a good chronology, verified by a series of AMS dates on selected plant specimens. The cultivation of various cereals, such as einkorn and barley, was confirmed. It is likely that the inhabitants of these settlements grew emmer wheat, NGW and pulses, and various wild herbaceous plants have also been recorded, which mostly represent ruderal and segetal habitats. However, some of these plants may also have been consumed as food. The analysis of macroscopic plant remains has shown that the settlements were located in areas in which there were mosaics of open grasslands, wooded steppe and deciduous woods, including some riverside woodlands and scrub, habitats which could also have been used by early farmers for their food and wood supplies.

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