Acta Palaeobotanica 65(2), 231–248, 2025
https://doi.org/10.35535/acpa-2025-0010

e-ISSN 2082-0259
ISSN 0001-6594

Rubbish or kindling? Plant remains from two Neolithic sites in the Chełmno Land, Poland, with special focus on the *Arrhenatherum elatius* ssp. *bulbosum* find

DOMINIKA KOFEL[1*], KAMIL ADAMCZAK[1] and DOROTA BIENIAS[1]

[1]Institute of Archaeology, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland;
e-mails: domkof@umk.pl, ORCID: 0000-0003-3104-2898; adamczak@umk.pl, ORCID: 0000-0002-8847-5670;
dosiab@umk.pl, ORCID: 0009-0001-3662-5657

Received 1 April 2025; accepted for publication 30 September 2025

ABSTRACT. This article presents the results of carpological and anthracological analyses of charred plant remains collected as soil and charred wood samples from two Funnel Beaker culture sites located in Kałdus and Browina, in the Kuyavian–Pomeranian Voivodeship, Poland. Most samples contained occasional plant remains, including, among others, barley (*Hordeum vulgare*) grain, emmer wheat (*Triticum dicoccum*) grain, hulled wheat (*T. monococcum/dicoccum/spelta*) chaff, seeds and fruits of wild taxa, and charred wood of oak (*Quercus* sp.) and Scots pine (*Pinus sylvestris*). Based on these findings, along with the first Neolithic discovery of tuber oat-grass (*Arrhenatherum elatius* ssp. *bulbosum*), we interpret these as a pragmatic use of plant fragments for kindling rather than understanding it as rubbish. We suggest that *Arrhenatherum elatius* ssp. *bulbosum*, along with inedible parts of plants, seeds and fruits of wild plants, and wood fragments, were used in the storage pits to start small fires for drying, lining fires, and/or fumigating the interior of the pit.

KEYWORDS: Funnel Beaker culture, archaeobotanical analyses, plant macroremains, Polish Plain, Chełmno Land

INTRODUCTION

Chełmno Land is one of the regions in Poland where farmers first settled during the second half of the 6th millennium BC, likely due to its fertile soils and a rich inland water network. The material culture of the Neolithic period in Chełmno Land is relatively well-studied (see more: Czerniak, 1994; Kukawka, 1997; Kukawka et al., 2002). However, we still lack good knowledge of the plant economy of these early farming communities.

The most comprehensive archaeobotanical studies of early farming communities have examined material from southern Poland (e.g. Mueller-Bieniek et al., 2019; Lityńska-Zając and Czekaj-Zastawny, 2021; Kapcia et al., 2024), whereas research on Neolithic agriculture in the central and northern parts of Poland remains relatively limited. The most detailed work was conducted in the 2000s and 2010s at nine sites of the Linear Pottery culture and Brześć-Kujawski culture located on the Kuyavian Plain (Bieniek, 2002, 2007; Mueller-Bieniek, 2016; Mueller-Bieniek et al., 2016), and in 2023, new studies on the cemetery of the Funnel Beaker culture (FBC) at Gaj, site 1, were published (Mueller-Bieniek, 2023). The date ranges of the aforementioned cultural horizons are provided in Table 1.

Archaeobotanical research on the Neolithic sites in Chełmno Land has begun only recently,

* Corresponding author

Publisher: W. Szafer Institute of Botany, Polish Academy of Sciences

Table 1. Archaeological units (cultures) of the Neolithic in the Lower and Middle Vistula zone and their chronological frameworks (based on: Czebreszuk, 2001; Grygiel, 2008; Kukawka, 2010; Czerniak, 2017; Szmyt, 2017)

ARCHAEOLOGICAL UNIT	TIME FRAME (BC)
Linear Band Pottery culture	5400/5200–4900/4800
Late Linear Band Potter culture (= Stoked Pottery culture)	4800/4700–4600/4500
Brześć Kujawski culture	4600/4500–4100/4000
Funnel Beaker culture	4200/4000–3100/2800
Globular Amphorae culture	3600/3500–2600/2400
Corded Ware culture	2900/2800–2400/2200

and so far, only a few results have been published. These include the contents of soil samples from two FBC features in Browina, site 4 (Bienias and Kofel, 2021), and plant remains preserved as imprints in FBC pottery sherds and daub fragments from Małe Czyste, site 20 (Kofel, 2020) and Kałdus, sites 1–4 (Kofel and Adamczak, 2024). The results, although limited, have shed light on Neolithic farming and introduced us to the agricultural practices of Chełmno Land.

GENERAL INFORMATION ON THE SITES AND ARCHAEOLOGICAL CONTEXTS

Samples were collected from FBC features at two archaeological sites: Kałdus, site 4 and Browina, site 4. Both sites are located in the Kuyavian–Pomeranian Voivodeship on the Chełmno Plateau: Kałdus in the western part of the plateau (18°22′E; 53°19′N) on the edge of the Lower Vistula Valley (Fig. 1), and Browina in the central part (18°22′E; 53°19′N) (Fig. 2).

Kałdus, site 4

Archaeological research in Kałdus began in the second half of the 19th century (see Chudziak, 2003). Approximately 15 ha were divided into four separate sites: Kałdus sites 1–4. The initial project, which focused on the layers of the early medieval period, was started in 1996 (Chudziak, 2003: 14–17), and in 2015, research on the prehistoric layers of site 4 began. To date, only ~15% (2.3 ha) of the whole sites complex has been excavated, revealing three main

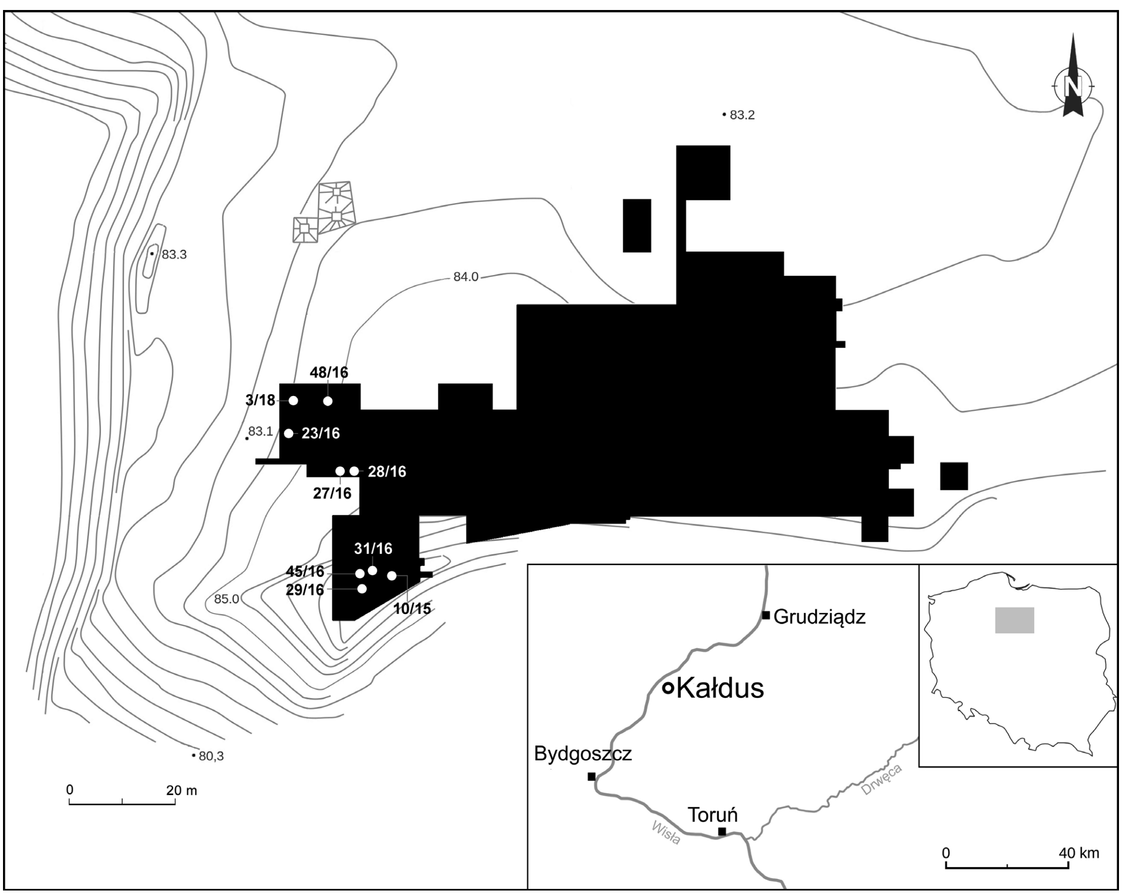

Figure 1. Kałdus site 4. Topographic map of the site showing the location of archaeological trench and selected FBC features

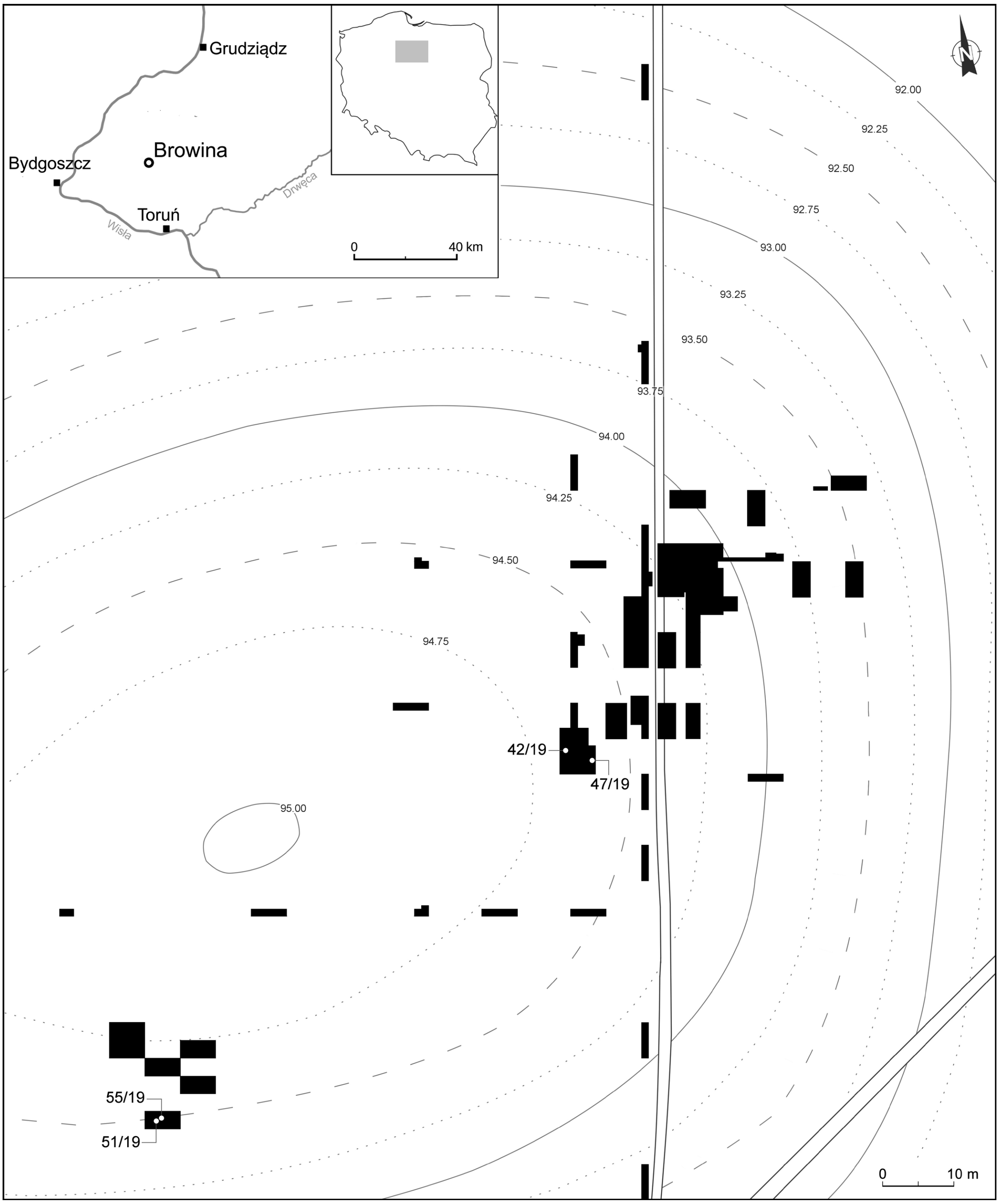

Figure 2. Browina site 4. Topographic map of the site showing the location of archaeological trenches and selected FBC features

chronological horizons: the Neolithic, the Iron Age, and the Early Middle Ages (Chudziak, 2003). Research in Kałdus is ongoing.

Several FBC features have been uncovered, including settlement structures, utility pits, and ritual features (Kowalski et al., 2020; Adamczak et al., 2021). Based on radiocarbon dating and Bayesian chronological modelling, it is estimated that FBC communities inhabited the site over a relatively short period between 3520 and 3320 cal BC (Adamczak et al., 2024: 8). During this timeframe, an area of ~15 hectares was in use. Other FBC settlements in the Polish Lowlands generally range from a few hectares to about one hectare. Thus, Kałdus stands out for its considerable size. Additionally, numerous artefacts made from non-local raw materials such as metal, exotic flint and amber have been found at the site. The finds have led to the interpretation of Kałdus as a ritual and political supra-regional centre from the second half of the 4th millennium BC.

Samples from nine archaeological contexts at Kałdus site 4 are included here: feature

10/2015, pit 23/2016, pit 27/2016, pit 28/2016, pit 29/2016, pit 31/2016, pit 45/2016, feature 48/2016 and feature 3/2018.

These features were at various stages of preservation, likely due to their placement within the site. Most of the features are located on the dune or at its base (Fig. 1), areas that were not affected by agricultural activities in the past. Consequently, the depth of these features ranges from 55 to 90 cm. The later Iron Age inhabitants damaged some of the features on the dune, such as feature 10/2015, which was measured to be 35 cm deep.

Agricultural activities dating back to Prehistory have led to a flattening of the area north of the dune. These practices have caused damage and a reduction in the depth of Neolithic features. In this part of the site, the maximum depth of the FBC features is 30 cm (pit 23/2016, feature 48/2016 and feature 3/2018).

Although no traces of storage vessels or possible stored resources have been found in the dune features (pit 27/2016, pit 28/2016, pit 29/2016, pit 31/2016 and pit 45/2016), based on their size and capacity, they have been identified as storage pits. Their fills are multilayered, indicating that the filling process was probably a gradual accumulation over time.

Due to its structure and content, one of the dune's most interesting contexts is feature 10/2015. The fill contained abundant charred matter, pottery sherds, and bone and daub fragments. At the base of 10/2015, there were two strongly fired stones which crumbled under pressure (Fig. 3). The pit likely served a specialised practical function related to roasting organic material or heat treatment (cooking?). Similarly, pit 23/2016 (Fig. 4), located north of the dune, also contained two stones at the bottom, but in this case, without evidence of firing. The feature was relatively large but shallow (up to 23 cm deep) and contained bones, pottery sherds, daub and flint. This suggests that at least one of its functions was related to cooking or processing. However, the possibility of pit 23/2016 being used as a rubbish pit should not be dismissed.

Feature 48/2016 was merged with two other features (35/2016 and 47/2016), forming a complex of ritual features (Fig. 5). The 35/47/48 feature complex comprises a complete vessel with comb-made ornaments and a half-shaft-hole axe with a button butt (Fig. 6). The soil sample was collected from feature 48/2016.

Finally, feature 3/2018 is a shallow feature (depth up to 30 cm) containing several dozen FBC pottery sherds. Its exact function has not been identified.

Browina, site 4

Three excavation seasons (2014, 2015 and 2019) have been carried out at site 4 in Browina (Adamczak, 2021). The site, estimated to cover ~2 ha, is located at the highest topographic point near the town of Chełmża. To date, approximately 500 m^2 of the site have been explored, revealing intensive occupation from the Neolithic to the Iron Age. In total, eleven FBC features (pits and postholes) have

Figure 3. Kałdus site 4. Cross-section of feature 10/2015 with two strongly burnt stones and black fill (photo by Ł. Kowalski)

Figure 4. Kałdus site 4. Cross-section of pit 23/2016 (photo by K. Adamczak)

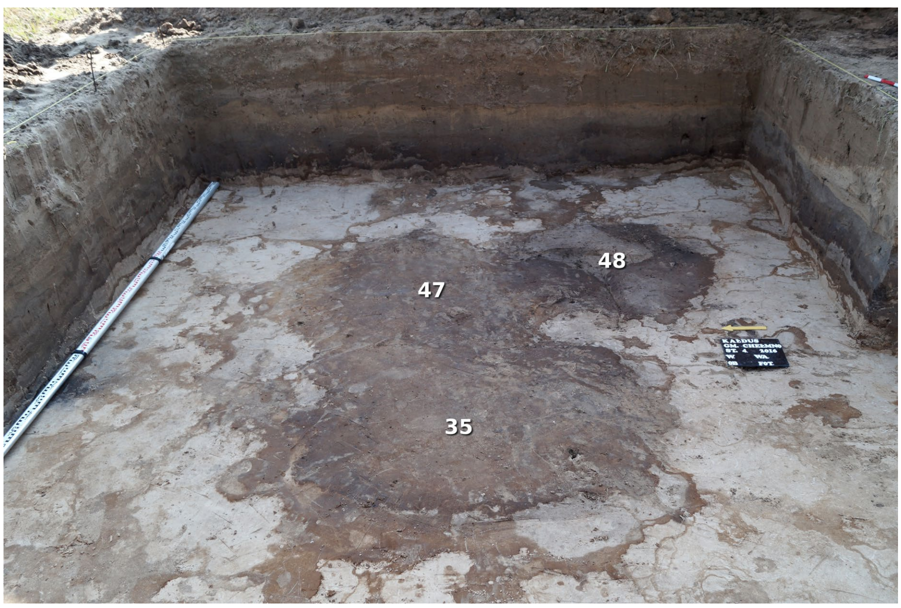

Figure 5. Kałdus site 4. Plane view of the top of merged features 35/47/48/2016 (photo by K. Adamczak)

been uncovered. Relative and absolute dating provide a date range spanning from 3640 to 3510 cal BC for the FBC settlement in Browina (Adamczak, 2021: 145). Archaeobotanical analyses of two features (pit 16/2014 and pit 17/2014) have already been published (Bienias and Kofel, 2021). Here we present the results from five pits: 42/2019, 45/2019, 47/2019, 51/2019 and 55/2019, all of which are only preserved in their lowest parts (up to 20 cm deep) and each containing a single fill layer. It has not been possible to determine their primary functions based on the shape and size of the pits and artefacts found within them. The fills consisted of pottery sherds and occasional flint fragments. Pits 42/2019, 45/2019 and 47/2019 are located in the central part of the site, near storage pit 17/2014 (Adamczak, 2021; Bienias and Kofel, 2021), whereas pits 51/2019 and 55/2019 are located in the southern part of the site, several metres away from the other FBC features (Fig. 2). Nonetheless, similarities in pottery ornaments found in pits 42/2019, 45/2019, 47/2019, 51/2019 and 55/2019 indicate that these two areas of the site were used synchronously.

Figure 6. Kałdus site 4. A comb-band ornamented vessel and a defragmented stone battle axe from feature 35/2016 (photo by W. Ochotny)

MATERIALS AND METHODS

Samples were taken during active archaeological excavations conducted in 2015, 2016, 2018 and 2019. Plant macroremains were preserved as charred and extracted from soil and charred wood samples. Details of the processed samples, complete species lists and the abundance of plant remains recovered from each sample are provided in Table 2.

In total, 38 samples (31 from Kałdus and 7 from Browina), ranging from 0.4 to 8 litres, were processed by flotation, using meshes of 0.25 mm and 1.00 mm to trap the float and the residue, respectively. All residues were dried and sorted to retain any ecofacts present. Floats and sorted botanical materials from the residues were examined under a binocular microscope at magnifications up to ×15. Charred plant remains were sorted, identified and counted. In the case of anthracology, 24 samples from Kałdus and 7 samples from Browina were suitable for further study. Most of the charred wood pieces derived from soil samples, and only seven samples from Kałdus were collected directly in the field from charred wood accumulations visible to the naked eye. Charred wood fragments were relatively small, ranging from < 0.5 cm (in soil samples) to 2.5 cm (in charred wood samples), whereas the maximum diameter of twig fragments was 1.5 cm. However, shrinkage during charring might have occurred (Gale and Cutler, 2000: 11). An anthracological observation was conducted using a stereomicroscope (Leica M205C) at magnifications up to 160x to examine the diagnostic features visible in three anatomical sections. The abundance of organic remains was estimated using the following scale: 'x' – occasional (up to 10 items), 'xx' – medium (11 to 50), 'xxx' – abundant (51 to 250), 'xxxx' – highly abundant (over 250). All plant macroremains, including charcoal identifications, were checked against botanical literature (e.g. Greguss, 1959; Kulpa, 1974; Schweingruber, 1990; Cappers et al., 2006; Jacomet, 2006) and compared with the modern reference collection of the Department of Environmental Archaeology and Human Paleoecology, Nicolaus Copernicus University in Toruń. Nomenclature follows Mirek et al. (2020).

RESULTS

KAŁDUS SITE 4

One soil sample collected from feature 10/2015 contained only seeds and fruit of wild taxa, including, among others: common self-heal (*Prunella vulgaris*), greater yellow-rattle (*Rhinanthus serotinus*), field pennycress (*Thlaspi arvense*), German knotweed (*Scleranthus annuus*), bedstraw (*Galium* sp.), clover (*Trifolium* sp.) and vetch (*Vicia* sp.). The seeds and fruit are smaller (undeveloped?) than the average size. Occasional charred wood fragments larger than 4 mm are identified as Scots pine (*Pinus sylvestris*) and intermediate deciduous trees. The sample also contains moderate amounts of *Cenococcum geophilum* fungus sclerotia.

Nineteen samples were collected during the 2016 season: five from pit 23/2016, four from pit 27/2016, two from pit 28/2016, four from pit 29/2016, three from pit 31/2016 and one from feature 48/2016. Overall, the samples collected in the 2016 season are relatively small and sparse.

Assemblages from pit 23/2016 contain occasional crop grains, including barley (*Hordeum vulgare*), emmer wheat (*Triticum dicoccum*), undetermined wheat (*Triticum* sp.), and indeterminate cereals and/or wild grass (*Cerealia* / Poaceae indet.). Hulled wheat (*T. monococcum* / *dicoccum* / *spelta*) glume bases and occasional grains of rye brome (*Bromus secalinus*), indeterminate brome grass (*Bromus* sp.), and indeterminate wild grass (Poaceae indet.) were also identified. Additionally, there was a fragment of common hazelnut (*Corylus avellana*) husk, occasional sclerotia of *C. geophilum* fungus, and charred amorphous remains, which might represent charred food leftovers, fruit pulp, bread crumbs, and/or badly damaged charcoal. Some charred wood fragments are slag-like, and occasional indeterminate twigs, as well as oak (*Quercus* sp.) fragments were also noted.

Extremely small and sparse materials were observed in samples analysed from pits 27/2016 and 28/2016 (Fig. 7). Most of the plant macroremains, including, among others, *T. monococcum* / *dicoccum* / *spelta* glume bases, grains of *Cerealia* / Poaceae indet., sclerotia of *C. geophilum* fungus, and fragments of charred amorphous remains, can be identified in the uppermost layers of the features and probably represent later deposition. Twigs and charred wood of *Pinus sylvestris* are noted at the bottom of the features.

Samples analysed from pit 29/2016 contain occasional glume bases and spikelet forks of *T. monococcum* / *dicoccum* / *spelta*, as well as grains of *Cerealia* indet. Interestingly, the wild plant assemblage, though mainly represented by single finds, was relatively rich, comprising *Bromus* sp., fat-hen (*Chenopodium album*), knotweed (*Polygonum* sp.), curly dock (*Rumex crispus*), green foxtail (*Setaria viridis*), vetch similar to smooth vetch (*Vicia* cf. *tetrasperma*), and *Vicia* sp., along with sclerotia of *C. geophilum* fungus, and fragments of

Figure 7. Kałdus site 4. Cross-section of storage pits 27/2016 and 28/2016 (photo by Ł. Kowalski)

charred amorphous remains. Additionally, the charred wood samples from pit 29/2016 contained various taxa, including birch (*Betula* sp.), elm (*Ulmus* sp.), ash (*Fraxinus excelsior*), *Quercus* sp., *Pinus sylvestris*, along with indeterminate slag-like material and twigs.

Most plant remains in pit 31/2016 originate from a depth of 20–40 cm. The remains include grains of *Hordeum vulgare*, *Cerealia*/Poaceae indet., *T. monococcum/dicoccum/spelta* glume bases, and *Cerealia* indet. rachis. Wild plants are represented by seeds and fruit of *Chenopodium album*, a seed similar to common toadflax (cf. *Linaria vulgaris*), *Setaria viridis*, and *Vicia* cf. *tetrasperma*. Medium amounts of *C. geophilum* fungus sclerotia and occasional fragments of charred amorphous remains were also present. The samples from pit 31/2016 contained the most abundant charred wood material (313 fragments), of which over 96% can be identified as *Pinus sylvestris*.

The richest and most intriguing sample was found at the base of pit 45/2016. The assemblage contained a moderate amount of einkorn wheat (*T. monococcum*) and chaff from *T. monococcum/dicoccum/spelta* chaff, along with fruits and seeds of wild plants, including *Bromus* sp., *Setaria viridis*, and *Vicia* sp. These samples also contained fragments of *Cerealia*/ Poaceae indet. straw, pieces of indeterminate stalks, sclerotia of *C. geophilum*, fragments of tuber oat-grass (*Arrhenatherum elatius* ssp. *bulbosum*) bulb, *Corylus avellana* husk, and charred amorphous remains. The wood fragments are heavily charred, consisting of indeterminate twigs and numerous pieces smaller than 4 mm. From the charred wood fragments larger than 4 mm, it was possible to identify alder (*Alnus* sp.), *Fraxinus excelsior*, *Quercus* sp., *Ulmus* sp. and *Pinus sylvestris*.

A small and sparse assemblage is noted in the sample taken from feature 48/2016. The materials consist of *T. monococcum/dicoccum/spelta* glume bases, grains *Cerealia* indet., one seed from the legume family (Fabaceae indet.), occasional sclerotia of *C. geophilum* fungus, single fragments of charred amorphous remains, and occasional charred wood.

One sample taken from feature 3/2018 consists of occasional glume bases and spikelet forks of *T. monococcum/dicoccum/spelta*, moderate amounts of highly fragmented *Cerealia* indet. grains, and occasional seeds and fruits of *Bromus* sp., black-bindweed (*Fallopia convolvulus*), probably elder (cf. *Sambucus* sp.), along with one fragment of *Corylus avellana* husk. There are also occasional charred amorphous remains and strongly charred indeterminate wood fragments.

BROWINA, SITE 4

Generally, all samples collected from features in Browina appeared remarkably similar. In one sample from pit 42/2019 (Fig. 8), moderate amounts of *T. dicoccum* and *T. monococcum/dicoccum/spelta* chaff were found, along with single finds of *Bromus* sp., a fruit similar to common knotgrass (cf. *Polygonum aviculare*), three fragments of charred *Quercus* sp., sclerotia of *C. geophilum* fungus and moderate fragments of charred amorphous remains.

Samples from pits 45/2019 and 47/2019 consist of *T. monococcum / dicoccum / spelta* chaff and occasional *Cerealia*/Poaceae indet. grains, one seed of *Chenopodium album,* single pieces of charred *Quercus* sp., and fragments of *C. geophilum* fungus sclerotia, along with charred amorphous remains.

Figure 8. Browina site 4. Cross-section of pit 42/2019 (photo by K. Adamczak)

Three samples from pit 51/2019 were analysed. The materials consist of occasional *Cerealia* indet. and *Cerealia* / Poaceae indet. grains, *T. dicoccum*, *T. monococcum*, and *T. monococcum* / *dicoccum* / *spelta* chaff, as well as grains of *Bromus* sp. and timothy-grass (*Phleum pratense*). Additionally, traces of charred wood of *Pinus sylvestris* can be identified, along with fragments of *C. geophilum* fungus and charred amorphous remains.

In pit 55/2019, *T. monococcum*, and *T. monococcum* / *dicoccum* / *spelta* chaff, fragmented *Cerealia*/Poaceae indet. grains and a *Cerealia*/ Poaceae indet. straw have been identified. The remains of cultivars are associated with *Bromus* sp., charred wood of *Pinus sylvestris*, and of deciduous trees, fragments of *C. geophilum* fungus sclerotia and a piece of charred amorphous material.

DISCUSSION

Archaeobotanical analyses often help answer questions about the function of features, plant taphonomy, agricultural practices and forest management. However, in some cases, the charred plant assemblages at archaeological sites raise more questions than answers, as is the case here, because these remains indicate rubbish/waste in contexts that were centrally used for storage. The discussion has been divided into three parts: one for each site and one for the first Neolithic find of *Arrhenatherum elatius* ssp. *bulbosum* tuber in Poland.

KAŁDUS SITE 4

Based on the size, shape, two heavily charred stones at the bottom, and a homogenous fill of charred matter, it was assumed that feature 10/2015 from Kałdus was related to cooking or roasting. Imprints and charred plant remains extracted from 33 daub fragments and 18 pottery sherds collected from the fill were analysed indicating the presence of cultivars during clay preparation (Kofel and Adamczak, 2024). The imprints included *T. monococcum* / *dicoccum* / *spelta* chaff and *Cerealia*/Poaceae indet. grains and rachis, while charred remains consisted of *Hordeum vulgare* grain and the epidermis of *Cerealia* / Poaceae indet. (Kofel and Adamczak, 2024: 135–136). However, no cultivars were detected in the soil sample from the 10/2015 fill. Of course, there is no direct link between pottery and daub temper and the fill of the feature where they were found. Imprints and plant remains in the ceramic matrix most likely represent by-products of crop processing used during ceramic production (e.g. Mueller-Bieniek, 2016: 753; Bienias and Kofel, 2021), whereas soil samples represent the actual fill of the feature. If we assumed that feature 10/2015 was linked to cooking or roasting, then how can we explain the absence of any domesticated plants in the assemblage? The lack of cultivars in archaeobotanical remains suggests that feature 10/2015 was not used for food-related activities. In storage, rubbish and other pits associated with crop processing or food preparation, remains of cultivated plants – either as grains, seeds, or chaff, are typically found (e.g. Filipović et al., 2018, 2019; Kapcia and Nowak, 2024).

Yet, no charred remains or meal leftovers were present in this assemblage. Additionally, the seeds and fruits identified in the 10/2015 sample are smaller than average, suggesting the plants were collected before full maturation possibly while still flowering and before harvest. Additionally, species such as *Prunella vulgaris*, *Rhinanthus serotinus*, *Thlaspi arvense*, and *Scleranthus annuus* have different habitat preferences (Table 2). It is possible that some of these plants represent contamination – growing around the pit and accidentally entering – an occurrence documented at other FBC sites (e.g. Out et al., 2025: 190). However, we cannot rule out the possibility that the plants were intentionally brought to the site.

Our current knowledge does not allow us to determinethe function of feature 10/2015. Notably, the upper part of feature 10/2015 was destroyed by Iron Age inhabitants. Although the base of feature 10/2015 was untouched, with no visible signs of disturbance, a bioturbation of (charred) materials from the upper (Iron Age) layers could be possible. Unfortunately, the Iron Age layers were not sampled, therefore, we lack comparative materials and do not know what was in the fill. All of this suggest a pit with functions that cannot be fully understood at present.

Two stones without evidence of firing were also observed at the base of pit 23/2016. However, unlike the remains from feature 10/2015, those from pit 23/2016, although small and sparse, contain cultivated plants, crop weeds, and other edible plants. Additionally, the anthracological analyses show traces of high temperature and the use of twigs, possibly as kindling. All of this opens a twofold discussion about whether pit 23/2016 was used as rubbish or cooking and/or roasting place. The identified plant assemblage could represent either spoiled parts of a meal that accidentally ended up in the cooking fire or ash swept from elsewhere and thrown into the rubbish pit. Therefore, although pit 23/2016 has a similar assemblage to the storage pits (discussed in detail below), its depth (30 cm) suggests a function related to cooking and/or roasting or waste disposal.

Meanwhile, the shallow feature 3/2018 was most likely used for cooking, as the assemblage contains moderate amounts of highly fragmented *Cerealia* indet. grains along with a cf. *Sambucus* sp. seed and *Corylus avellana* husk, which could represent remains of porridge or gruel dropped accidentally or deliberately into the fire. Finds of porridge-like and/or gruel-like deposits are well-documented from Neolithic sites in Poland (e.g. Lityńska, 1990) and northern Europe (e.g. Out et al., 2025).

No further conclusions could be drawn about the function of feature 48/2016, as the archaeobotanical materials are too sparse.

Charred chaff, occasional segetal and ruderal plants and charred amorphous remains are found in the samples collected from storage pits 27/2016, 28/2019, 29/2016, 31/2016 and 45/2016. Finds of charred inedible parts of plants, seeds and fruits of wild plants, along with occasional charred wood fragments, might represent crop-processing by-products (e.g. Hillman, 1981; Fuller et al., 2014), which were used as fuel and later discarded as ash into the rubbish pit. However, archaeological data do not support the idea of using these features for rubbish but clearly indicate storage use of pits 27/2016, 28/2016, 29/2016, 31/2016 and 45/2016. Therefore, another interpretation of the archaeobotanical materials was sought. It has been previously suggested (e.g. Bienias and Kofel, 2021: 156) that assemblages comprising crop-processing by-products might represent remains of kindling. Small fires could have been lit to dry, burn the lining, and/or fumigate the interior of the pit (Podkowińska, 1961; Pasqualone, 2025). This might also apply to our samples from pits: 27/2016, 28/2016, 29/2016, 31/2016 and 45/2016.

Crops in Neolithic Kałdus were most likely stored in containers rather than directly on the bottom of the pit. Finds of pottery sherds and charred wood fragments could represent, at least partly, the remains of some sort of containers. If we assume that ceramic vessels were used for storage, then fires could occasionally be lit during storage (set in the spaces between the vessels) to dry crops and reduce humidity. However, if other organic types of storage containers were used, the fires were more likely set in periods between depositions of stored goods.

Storage pits must have had some sort of cover/roofing protecting them from the outside world. Such covers could have been made using twigs, straw, clay, and covered with soil (Podkowińska, 1961: 31; Pasqualone, 2025). Small fires could have been set just before sealing/closing to reduce oxygen levels in the pit. Creating a low-oxygen environment could

Table 2. Results of archaeobotanical analyses from FBC sites in Kałdus and Browina, the Kuyavian–Pomeranian Voivodeship (* – charred; gr – grain; sf – spikelet fork; gb – glume base; ra – rachis; st – straw; s – soil sample; ch – charred wood sample)

TOWN	KAŁDUS SITE 4															
SEASON	2015	2016														
FEATURE	10	23					27								28	
GIVEN INVENTORY NUMBER	KA4/2015/1	KA4/2016/33	KA4/2016/36	KA4/2016/43	KA4/2016/44	KA4/2016/52	KA4/2016/67	KA4/15/16w	KA4/2016/68	KA4/2016/83	KA4/13/16w	KA4/2016/57	KA4/14/16w	KA4/16/16w	KA4/2016/65	KA4/2016/64
TYPE OF SAMPLE	s	s	s	s	s	s	s	ch	s	s	ch	s	ch	ch	s	s
ARBITRARY LAYER	III/IV	.	.	.	.	.	.	II	.	II	III	III	IV	IV	.	.
HORIZON	.	.	10–20	.	.	.	0–10	10–50	35–50	40–50	50–70	60–70	70–90	70–90	20–40	40–60
CULTIVATED PLANTS																
Hordeum vulgare gr	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Triticum dicoccum gr	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Triticum sp. gr	.	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.
T. monococcum / dicoccum / spelta gb	.	1	1	.	.	.	1	.	.	.	.	.	.	.	2	.
Cerealia indet. gr	.	1	.	.	2	2	3	.	.	.	.	.	.	.	.	.
Cerealia / Poaceae indet. gr	.	1	.	.	.	.	.	.	.	1	.	.	.	.	1	.
SEGETAL AND RUDERAL PLANTS																
Bromus secalinus	.	1	1	.	.	.	.	.	.	.	.		.	.	.	.
Rhinanthus serotinus	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scleranthus annuus	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thlaspi arvense	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
GRASSLAND, MEADOW AND PASTURE																
Prunella vulgaris	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
OTHER																
Bromus sp.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.
Galium sp.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium sp.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vicia sp.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fabaceae indet.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Poaceae indet.	4	1	.	.	.	.	2	.	.	.	.	.	.	.	.	1
Indeterminate	5	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
TREES AND SHRUBS																
Corylus avellana husk (frag.)	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CHARRED WOOD (frag.)																
< 4 mm	xx	x	.	x	.	.	x	.	.	xx	.	.	.	.	xx	.
Betula sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Quercus sp.	.	.	.	3	4	.	.	.	1	.	.	.	.	.	.	2
Pinus sylvestris	4	.	.	.	.	1	.	46	1	13	4	67	13	43	23	1
deciduous	18	.	.	.	.	3	.	.	.	7	.	2	.	.	.	5
diffuse-porous	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
indetermined	.	.	.	.	.	7	.	.	1	.	.	.	.	.	.	.
UNGROUPED																
Cenococcum geophilum	xx	x	x	.	.	.	.	.	.	x	.	.	.	.	.	.
charred amorphous remains	.	x	.	.	.	.	x	.	x	x	.	.	.	.	x	.
VOLUME [l]	7.00	0.50	0.40	0.50	8.00	5.00	1.00		1.00	2.00		2.00			1.00	1.00
Sorted [%]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 2. Continued

TOWN	KAŁDUS SITE 4														
SEASON	2016														2018
FEATURE	29					31					45			48	3
GIVEN INVENTORY NUMBER	KA4/22/16w	KA4/2016/54	KA4/2016/56	KA4/2016/62	KA4/2016/72	KA4/29/16w	KA4/2016/80	KA4/2016/76	KA4/28/16w	KA4/2016/79	KA4/2016/69	KA4/2016/71	KA4/2016/73	KA4/2016/70	KA4/2018/2
TYPE OF SAMPLE	ch	s	s	s	s	ch	s	s	ch	s	s	s	s	s	s
ARBITRARY LAYER	.	X	.	X	.	.	.	.	IV	.	.	.	.	.	.
HORIZON	.	.	.	.	40–50	0–10	0–10	20–40	30–40	.	.	.	.	.	5–10
CULTIVATED PLANTS															
Hordeum vulgare gr	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
Triticum monococcum sf	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.
Triticum monococcum gb	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.
T. monococcum / dicoccum / spelta gb	.	4	.	.	.	.	.	7	.	.	.	32	.	2	7
T. monococcum / dicoccum / spelta sf	.	1	.	.	.	.	.	1	.	.	.	3	.	.	1
Cerealia indet. gr	.	.	1	.	1	.	.	.	.	.	.	.	.	2	40fr.
Cerealia indet. ra	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Cerealia / Poaceae indet. gr	.	.	.	.	.	.	.	4fr.	.	1	.	.	.	.	.
Cerealia / Poaceae indet. st (frag.)	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.
SEGETAL AND RUDERAL PLANTS															
Chenopodium album	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.
Chenopodium sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Fallopia convolvulus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
cf. *Linaria vulgaris*	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Polygonum sp.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Rumex crispus	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.
Setaria viridis	.	.	.	.	1	.	.	1	.	.	.	1	.	.	.
Vicia cf. *tetrasperma*	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.
GRASSLAND, MEADOW AND PASTURE															
Arrhenatherum elatius ssp. *bulbosum*	.	.	.	.	.	.	.	.	.	.	.	11fr.	.	.	.
OTHER															
Bromus sp.	.	1	.	.	1	.	.	.	.	.	.	2fr.	.	.	1
Carex sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
cf. *Sambucus* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Vicia sp.	.	.	1	.	.	.	.	.	.	.	.	4fr.	.	.	.
Asteraceae indet.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Fabaceae indet.	.	.	.	.	2	.	.	.	.	1	.	.	.	1	.
Poaceae indet.	.	2	.	.	3	.	.	2	.	.	1	3	.	.	.
Polygonaceae indet.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Indeterminate	.	.	1	.	3	.	.	1	.	1	3	10fr.	.	1	3
TREES AND SHRUBS															
Corylus avellana husk (frag.)	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1
CHARRED WOOD (frag.)															
<4 mm	.	xxx	.	x	xxxx	.	.	xx	.	xxxx	.	xxx	.	xxx	x
Alnus sp.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
Betula sp.	.	4	2	2	.	.	.	.	.	.	.	.	.	.	.
Fraxinus excelsior	.	.	1	.	.	.	.	1	.	.	.	2	.	.	.
Quercus sp.	.	4	.	.	7	.	.	1	.	3	.	8	.	.	.
Ulmus sp.	23	2	2	.	.	.	.	.	.	.	.	.	.	.	.
Pinus sylvestris	.	28	.	.	81	137	.	3	107	54	.	133	.	2	.
coniferous	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
deciduous	.	17	12	.	.	.	.	.	.	.	.	16	.	.	15
diffuse-porous	.	.	.	.	.	.	.	7	.	.	.	5	.	9	.
twig indet. (frag.)	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
indetermined	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
UNGROUPED															
Cenococcum geophilum	.	xx	.	.	xx	.	.	xx	.	xx	.	31	.	x	.
charred amorphous remains	.	x	.	x	xx	.	.	x	.	.	.	34	x	x	x
VOLUME [l]		4.00	4.00	2.50	4.00		2.00	5.00		4.00	3.00	4.00	3.00	3.00	2.40
Sorted [%]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 2. Continued

TOWN	BROWINA SITE 4						
SEASON	2019						
FEATURE	42	45	47	51 E	51	51	55 N
GIVEN INVENTORY NUMBER	G-26/19	G-19/19	G-8/19	G-18/19	G-20/19	G-21/19	G-17/19
TYPE OF SAMPLE	s	s	s	s	s	s	s
ARBITRARY LAYER	.	.	.	.	I	II	II
CULTIVATED PLANTS							
Triticum monococcum sf	.	.	.	.	.	.	3
Triticum monococcum gb	.	.	.	4	.	.	.
Triticum dicoccum gb	4	.	.	2	.	.	.
T. monococcum / dicoccum / spelta gb	10	25	6	6	15	8	19
T. monococcum / dicoccum / spelta sf	.	1	1	.	.	.	.
Cerealia indet. gr	.	.	.	.	2	1	.
Cerealia / Poaceae indet. gr	.	2fr.	6	7	.	1	13fr.
Cerealia / Poaceae indet. st (frag.)	.	.	.	.	.	.	1
SEGETAL AND RUDERAL PLANTS							
Chenopodium album	.	3	.	.	.	.	.
cf. *Polygonum aviculare*	1	.	.	.	.	.	.
GRASSLAND, MEADOW AND PASTURE							
Phleum pratense	.	.	.	.	.	1	.
OTHER							
Bromus sp.	1	.	.	1	.	.	3fr.
Indeterminate	1	5	1	1	3	1	3fr.
CHARRED WOOD (frag.)							
Quercus sp.	3	1	1	.	.	.	.
Pinus sylvestris	.	.	.	8	4	8	12
deciduous	.	.	.	.	.	.	4
UNGROUPED							
Cenococcum geophilum	1	1	3	1	.	1	3
charred amorphous remains	12fr.	9	1	1	.	.	1fr.
bones (frag.)	.	2*	.	.	x	.	x*
VOLUME [l]	0.50	1.20	2.50	1.00	1.00	1.00	1.00
Sorted [%]	100	100	100	100	100	100	100

block the development of some microorganisms and, along with low moisture and temperature, could help prevent spoilage and preserve crops for longer (Jiménez-Jáimez and Suárez-Padilla, 2020). Some of the charred wood fragments found in pits: 27/2016, 28/2016, 29/2016, 31/2016 and 45/2016 could represent the remains of the roofing/cover of the pit.

No evidence of sudden or violent incidents has been observed in the archaeological contexts from Kałdus. We can infer that at some point in time, the inhabitants decided to leave and took all their belongings with them, consequently, we do not find archaeobotanical proof of supplies.

Chaff is more hygroscopic than grain and tends to keep moisture away from the grain mass. Therefore, it was often used as an admixture in the plaster used for the interior lining of the pit (Pasqualone, 2025). This could be one explanation for the chaff imprints found in daub fragments from FBC sites (Bienias and Kofel, 2021; Kofel and Adamczak, 2024), but it does not clarify the presence of charred chaff in the analysed samples.

The anthracological results from Kałdus also reveal that various woodland habitats were explored. The location of the site on the plateau close to the Vistula River Valley, along the boundary of two different landscape units, is reflected in the taxonomic composition of the analysed charred wood. Forests growing at the foot of the plateau and in the lower part of the Vistula River Valley could have been composed of *Fraxinus excelsior* and *Ulmus* sp., whereas according to the map of potential vegetation, Chełmno Land is mostly covered by *Ficario-Ulmetum* riparian forest (Cyzman and Kamiński, 2004: 115). On the plateau and its slopes, the main type of forest could be the subcontinental hornbeam-oak *Tilio cordatae-Carpinetum betuli*, formed mostly by *Quercus* sp. and small-leaved lime (*Tilia cordata*). Additionally, the boundary zone between the plateau and dunes (Luc and Szmańda, 2004: 35) could have formed a continental *Querco roboris-Pinetum* forest dominated by *Pinus sylvestris*, silver birch (*Betula pendula*) and pedunculate oak (*Quercus robur*) (Cyzman and Kamiński, 2004: 116). The anthracological studies are consistent with general palynological studies of the second phase of FBC (3500–2900 cal BC) at Chełmno Land, where the share of *Pinus sylvestris* is 25–30% and that of *Quercus* sp. is 10–15% (Noryśkiewicz, 2013: 115–118). Unfortunately, more specific data cannot be provided at present, since no traces of Neolithic deposits have been detected in cores from lakes near Kałdus, i.e. Starogrodzkie Lake (Noryśkiewicz, 2004: 170), Uść Lake, and Chełmno/Rybaki (Noryśkiewicz, 2013: 113, fig. 38).

BROWINA SITE 4

Crop processing by-products are the only finds in the samples from Browina. Here again, the discussion of whether the by-products represent rubbish or something else arises. Pits from Browina are problematic because only their lower parts are preserved. Nonetheless, the overall shape and archaeological content suggest that the FBC features from Browina were storage pits. Therefore, we suggest that the assemblages of chaff, wild plants and fragments of charred wood again represent the remains of kindling for small fires. The items were burned to dry out the interior of the pit or crops, to reduce humidity or remove pests. Traces of small fires lit in the pits, sometimes creating multi-layered fills, are known from other FBC sites (e.g. Podkowińska, 1961) and therefore could be considered a rather common practice.

The anthracological results from Browina correspond with the analyses of two features excavated in 2014 (Bienias and Kofel, 2021). All taxa identified in samples from 2019 are also found in samples from previous seasons. Among the taxa identified in the 2014 samples, *Quercus* sp. is the most frequent in feature 17/2014 (located near pits 42/2019 and 47/2019), whereas *Pinus sylvestris* fragments are the most common in feature 16/2014 (Bienias and Kofel, 2021: 153). Similarly to Kałdus, the analysis of the macroremains agrees with general palynological studies, with *Pinus sylvestris* accounting for 30–35% and *Quercus* sp. for 10–15% (Noryśkiewicz, 2013). The closest core is from Grodzieńskie Lake (Filbrandt-Czaja, 2009), ~8 km from Browina. During the Neolithic, the pollen diagram shows a decrease in *Ulmus* sp., *Tilia* sp. and *Quercus* sp., along with a high share of *Corylus avellana*. In the soil samples from Browina, the remains of common hazelnut cannot be observed, whereas in Kałdus, occasional *Corylus avellana* husks are identified. Whether it is a matter of preference, accessibility, or sampling remains a topic for further discussion.

Arrhenatherum elatius ssp. *bulbosum*

Fragments of *A. elatius* ssp. *bulbosum* (Fig. 9) are found among other species in the assemblage from pit 45/2016 (Kałdus). All fragments presumably represent a single find as only one tip and base part, with visible longitudinal marks on the epidermis, were identified.

Oat grass (*Arrhenatherum elatius*) can be divided into two subspecies or varieties: false oat grass (*A. elatius elatius*) and *A. elatius* ssp. *bulbosum*. Only *A. elatius* ssp. *bulbosum* develops bulbs (Roehrs et al., 2013) and constidered a ruderal weed, particularly in cereal fields, where the non-bulbous forms are not present (Effenberger et al., 2019). The bulbs usually form underground, but may also grow above ground (Bond et al., 2007). *Arrhenatherum elatius* ssp. *bulbosum* is often found in archaeological

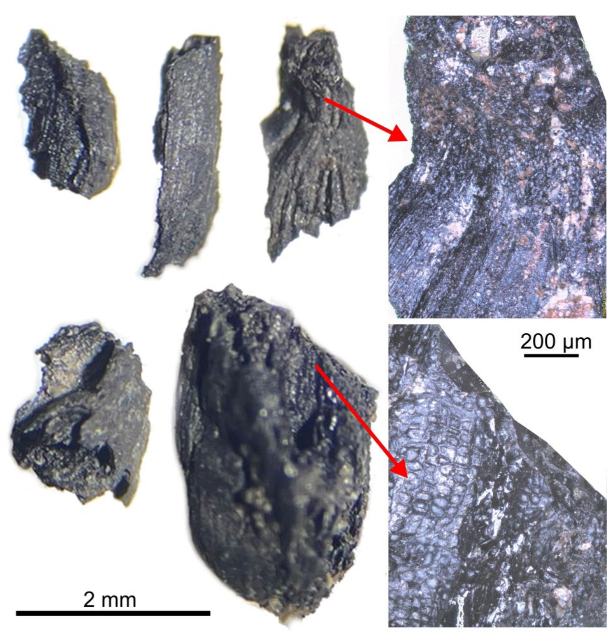

Figure 9. Fragmented bulb of tuber oat-grass (*Arrhenatherum elatius* ssp. *bulbosum*) found in Kałdus site 4

contexts, both at settlements and cemeteries, with the oldest finds dating to the Neolithic. Most European finds of *Arrhenatherum* tubers are recorded in the British Isles and Scandinavia, with only a few in Belgium, the Netherlands, Switzerland, Finland and Poland (Roehrs et al., 2013). However, *A. elatius* ssp. *bulbosum* is sensitive to hard frost and may be more suited to wetter climatic regions with mild winters (Bond et al., 2007; Effenberger et al., 2019), which might explain its lesser occurrence in the North European Plain.

It has been suggested that tuber oat grass was cultivated, harvested and consumed (Engelmark, 1984; Robinson, 1994; Kirleis and Klooß, 2014). However, recent experimental studies (Effenberger et al., 2019) of growing, collecting and charring *A. elatius* ssp. *bulbosum* have shown that bulbs were most likely not consumed due to bitterness, a fibrous and woody structure, along with the time-consuming extraction of small amounts of starchy material from the bulbs. Moreover, the experiments conducted by Effenberger et al. (2019) have shown that to obtain the characteristic groove pattern, *A. elatius* ssp. *bulbosum* must have been collected when the bulbs were dried, i.e. not earlier than late summer/autumn. This refutes the idea of bulb consumption because if the tubers had been eaten, they would have been collected at the peak of development in early summer. Therefore, it has been suggested that the dried bulbs were a readily available material for kindling used both in the settlements, as well as in cremation pyres (Effenberger et al., 2019: 8). A ritual significance of tuber oat grass may be supported by their frequent deposition in burial contexts (e.g. Jensen et al., 2010; Campbell and Robinson, 2007; Jacomet and Brombacher, 2009). However, in Kałdus, the tuber was found in a storage pit, suggesting that a cultic aspect is unlikely; it is rather interpreted as kindling.

To date, *A. elatius* ssp. *bulbosum* has only been identified at one site in Poland (Mueller-Bieniek, 2012), which is the Roman influences period (Iron Age) site 1 in Paprotki Kolonia located in NE Poland. In 2014, Wacnik et al. (2014: 456) suggested that the bulbs found at the site of Paprotki Kolonia, presumably belong to timothy-grass (*Phleum pratense*) and not to *A. elatius* ssp. *bulbosum*. They stated that *Arrhenatherum* tubers should be "excluded on the basis of its present distribution in Europe and the present lack of the bulbous form of *A. elatius* in Poland" (Wacnik et al., 2014: 456). Nevertheless, a couple of years later, Effenberger et al. (2019) discussed in detail the reasons for the locally limited decline of tuber oat-grass from the pre-Roman Iron Age onward. They suggested that the introduction of new ploughing methods, a shift towards winter crop cultivation, and colder winters might have resulted in the local demise of *A. elatius* ssp. *bulbosum* (Effenberger et al., 2019: 9). This could be an explanation for the absence of tuber oat-grass in recent Polish flora. Overall, this makes the specimen from Kałdus the first Neolithic find of *A. elatius* ssp. *bulbosum* in Poland.

GENERAL DISCUSSION

In features 10/2015, 23/2016, 27/2016, 29/2016, 31/2016, 45/2016 and 48/2016 from Kałdus, as well as in all features from Browina, sclerotia of the fungus *C. geophilum* have been observed. *C. geophilum* is a soil fungus that develops at depths of 0–10 cm, and typically occurs in the vicinity of deciduous and coniferous trees (Kataržytė, 2009: 61–62), as well as in peats, agricultural land (Jensen, 1974), and land disturbed and/or exposed to fire (Shay and Kapinga, 1997), which might explain its presence in archaeological assemblages (Hall et al., 2003). Moreover, *C. geophilum* might also develop in strictly anthropogenic environments on wooden elements, such as pit wooden reinforcement and/or lining (Wierzbicki, 1999: 226). Unfortunately, at the current stage of research, it does not seem possible to determine whether the sclerotia found in the analysed samples represent wooden lining, the use of wood as fuel, or in construction elements, contamination, or a combination of all these factors.

The subsistence strategies of the FBC people were of a mixed type, including farming, husbandry, hunting and gathering (Wiślański, 1969, 1979: 212–219; Jankowska, 1990: 270–286; Nowak, 2009: 391–450). The taxonomic variety of post-consumption animal bones found at the FBC settlements and in graves in Poland helps reconstruct parts of the prehistoric diet (e.g. Jankowska, 1990; Nowak, 2009; Waszczuk, 2011), and our knowledge of forest management is constantly growing as a result of anthracological analyses (e.g. Stępniak, 2006, 2007a, b; Bienias, 2011; Stępniak et al., 2014; Stępniak and Szmyt, 2015). The same can be said for information regarding species and the scale of use of domesticated and wild plant in the FBC milieu (Lityńska-Zając, 2005: 264–267; Nowak, 2009: 392–394; Nowak et al., 2020; Mueller-Bieniek, 2023).

CONCLUSION

Archaeobotanical studies help not only to understand and establish the agricultural context of archaeological sites, but also, quite often, open new possibilities for interpretation and expand our knowledge of plant-related activities. In the case of charred plant assemblages from Kałdus and Browina, we did not find macroremains that could be directly associated with storage features. Instead, we found rubbish in the form of charred by-products of crop processing. By combining archaeological contexts with archaeobotanical data, we came to the conclusion that inedible parts of plants, seeds and fruits of wild plants, and wood fragments were used in the storage pits to set small fires to dry or burn the lining, and/or fumigate the interior of the pit. The first Neolithic find of an *Arrhenatherum* tuber seems to confirm this kindling hypothesis.

We did not find archaeobotanical proof of supplies, but we did find evidence of practices undertaken to keep crops dry and protected from pests, rodents, and humidity. Further studies, including plant microremains, as well as site micromorphology, will help draw a broader picture of the FBC settlers.

ACKNOWLEDGMENT

We thank Dr Laerke Recht for her remarks and English corrections. We thank two anonymous reviewers for their comments and suggestions, which improved the manuscript.

ADDITIONAL INFORMATION

CONFLICT OF INTEREST. The authors have declared that no competing interests exist.

ETHICAL STATEMENT. No ethical statement was reported.

FUNDING. This article was made possible through funding awarded to the main author for the project "Different background, same diet? Agriculture of the first farmers in the territory of the lower and middle Vistula: cultural and chronological dynamics in the light of archaeobotanical analyses" (NCN 2023/48/C/HS3/00173).

REFERENCES

Adamczak, K., 2021. Browina (stan. 4), pow. toruński. Pozostałości osadnictwa kultury pucharów lejkowatych. In: Gackowski, J., Adamczak, K., Bokiniec, E., Weinkauf, M., Markiewicz, M., Bienias, D. (eds), XXI Sesja Pomorzoznawcza. Tom 1: od epoki kamienia do okresu wędrówek ludów. Wydawnictwo UMK, Toruń, pp. 131–147.

Adamczak, K., Kowalski, Ł., Urbanová, P., Douka, K., Brown, S., Kowalski, A.P., Kukawka, S., Wilczyński, J., Szczepańska, G., Zawilski, P., 2021. New Evidence for Deer Valorisation by the TRB Farmers from Poland using ZooMS and micro-CT Scanning. Journal of Archaeological Science: Reports 40(B), 103230. https://doi.org/10.1016/jasrep.2021.103230

Adamczak, K., Kozicka, M., Kowalski, Ł., Kofel, D., Chudziak, W., Błędowski, P., Bojarski, J., Kaźmierczak, R., Weinkauf, M., 2024. Radiocarbon dataset for the TRB central-place at Kałdus, Poland. Data in Brief 55, 110707. https://doi.org/10.1016/j.dib.2024.110707

Bienias, D., 2011. Wyniki analiz antrakologicznych materiałów ze stanowisk Jastrzębiec 4 i Renice 5–6. In: Rzepecki, S. (ed.), Studia i materiały do najdawniejszymi dziejami Równiny Gorzowskiej. Osady i cmentarzyska kultury pucharów lejkowatych na stanowiskach Jastrzębiec 4 i Renice 6. Wydawnictwo Poznańskie, Poznań, pp. 125–134.

Bienias, D., Kofel, D., 2021. Użytkowanie roślin przez mieszkańców osady kultury pucharów lejkowatych na stanowisku 4 w Browinie, pow. toruński. Wyniki badań archeobotanicznych wypełnisk obiektów 16 i 17. In: Gackowski, J., Adamczak, K., Bokiniec, E., Weinkauf, M., Markiewicz, M., Bienias, D. (eds), XXI Sesja Pomorzoznawcza. Tom 1: od epoki kamienia do okresu wędrówek ludów. Wydawnictwo UMK, Toruń, pp. 149–159.

Bieniek, A., 2002. Archaeobotanical analysis of some Early Neolithic settlements in the Kujawy region, central Poland, with potential plant gathering activities emphasised. Vegetation History and Archaeobotany 11(1), 33–40. https://doi.org/10.1007/s003340200004

Bieniek, A., 2007. Neolithic plant husbandry in the Kujawy region of central Poland. In: Colledge, S., Conolly, J. (eds), The origins and spread of domestic plants in southwest Asia and Europe. Routledge, London, pp. 372–342.

Bond, W., Davies, G., Turner, R., 2007. The biology and non-chemical control of onion couch (*Arrhenatherum elatius* ssp. *bulbosum* P.Beauv. ex J&C. Presl Var. bulbosum (Willd.) St-Amans). Available from: https://scispace.com/papers/the-biology-and-non-chemical-control-of-onion-couch-1h0ibrv083?references_page=2. Accessed July 2025.

Campbell, G., Robinson, M., 2007. Environment and land use in the Valley Bottom. In: Harding, J., Healy, F. (eds), The Raunds Area Project. A Neolithic and Bronze Age Landscape in Northamptonshire: Vol. 1. English Heritage, Swindon, pp. 18–34. https://doi.org/10.2307/j.ctvxbpj94.13

Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2006. Digitale zadenatlas van Nederland. Groningen. Barkhuis.

Chudziak, W., 2003. Wczesnośredniowieczna przestrzeń sakralna in Culmine na Pomorzu Nadwiślańskim. Mons Sancti Laurentii 1. Toruń. Wydawnictwo UMK.

Cyzman, W., Kamiński, D., 2004. Rzeczywista i potencjalna roślinność w Kałdusie i w jego otoczeniu. In: Chudziak, W. (ed.), Wczesnośredniowieczny zespół osadniczy w Kałdusie. Studia przyrodniczo-archeologiczne. Mons Sancti Laurentii. Tom 2. Wydawnictwo UMK, Toruń, pp. 113–127.

Czebreszuk, J., 2001. Schyłek neolitu i początki epoki brązu w strefie południowo-zachodniobałtyckiej (III i początki II tys. przed Chr.). Alternatywny model kultury. Poznań. Wydawnictwo UAM.

Czerniak, L., 1994. Neolit i wczesna epoka brązu na ziemi chełmińskiej. Grudziądz. Muzeum w Grudziądzu, IAE UMK w Toruniu.

Czerniak, L., 2017. Zanim powstała kultura brzesko-kujawska. Przykład stanowisk 2, 3, 6 i 7 w Ludwinowie, gm. Włocławek. In: Marciniak-Kajzer, A., Andrzejewski, A., Golański, A., Rzepecki, S., Wąs, M. (eds), Nie tylko krzemienie – Not only flint. Studia ofiarowane prof. Lucynie Domańskiej w 45-lecie pracy naukowo-dydaktycznej i w 70. rocznicę urodzin. Wydawnictwo UŁ, Łódź, pp. 199–236.

Effenberger, H., Nickol, M., Kirleis, W., 2019. *Arrhenatherum elatius* ssp. *bulbosum* revisited-A practical approach to decode past plant-related activities. Environmental Archaeology 26(1), 64–74. https://doi.org/10.1080/14614103.2019.1673574

Engelmark, R., 1984. Two useful plants from Iron Age graves in central Sweden. In: Baudou, E. (ed.), Papers in Northern Archaeology. Archaeology and Environment 2. Umeå University, Umeå, pp. 87–92.

Filipović, D., Obradović, Đ., Tripković, B., 2018. Plant storage in Neolithic southeast Europe: synthesis of the archaeological and archaeobotanical evidence from Serbia. Vegetation History and Archaeobotany 27, 31–44. https://doi.org/10.1007/s00334-017-0638-7

Filipović, D., Mewis, F., Saalow, L., Schmidt, J.-P., Kirleis, W., 2019. Waste disposal in the Bronze Age: plants in pits at Wismar-Wendorf, Northern Germany. In: Dal Corso, M., Kirleis, W., Kneisel, J., Taylor, N., Wieckowska-Lüth, M., Zanon, M. (eds), How's Life? Living conditions in the 2nd and 1st Millennia BCE. Scales of Transformation in Prehistoric and Archaic Societies 04. Sidestone Press, Leiden, pp. 103–130.

Filbrandt-Czaja, A., 2009. Historia działalności człowieka w rejonie Jeziora Grodzieńskiego koło Chełmży w świetle analizy pyłkowej. In: Gackowski, J. (ed.), Archeologia epoki brązu i żelaza. Studia i materiały. T. 1. PWN, Warszawa, pp. 211–229.

Fuller, D.Q., Stevens, C.J., McClatchie, M., 2014. Routine activities, tertiary refuse and labor organization: social inference from everyday archaeobotany. In: Madella, M., Lancelotti, C., Savard, M. (eds), Ancient plants and people. Contemporary trends in archaeobotany. University of Arizona Press, Tucson, pp. 174–217.

Gale, R., Cutler, D., 2000. Plants in archaeology. Otley. Westbury Academic and Scientific Publishing.

Greguss, P., 1959. Holzanatomie der europäischen Laubhölzer und Sträucher. Budapest. Akadémiai Kiadó.

Grygiel, R., 2008. Neolit i początki epoki brązu w rejonie Brześcia Kujawskiego i Osłonek. T. 2, Środkowy neolit, grupa brzesko-kujawska kultury lendzielskiej. Łódź. Wydawnictwo FBA, MAiE w Łodzi.

Hall, A., Kenward, H., Carrott, J., 2003. Evaluation of biological remains from a watching brief at the Guardian Glass site, Goole, East Riding of Yorkshire (site code: GGG2002). Palaeoecology Research Services 2003/14, 2–4.

Hillman, G., 1981. Reconstructing crop husbandry practices from charred remains of crops. In: Mercer, R. (ed.), Farming practice in British prehistory. Edinburgh University Press, Edinburgh, pp. 123–162.

Jacomet, S., 2006. Identification of cereal remains from archaeological sites. Basel. Archaeobotany Lab, IPAS.

Jacomet, S., Brombacher, C., 2009. Geschichte der Flora in der Regio Basiliensis seit 7500 Jahren: Ergebnisse von Untersuchungen pflanzlicher Makroreste aus archäologischen Ausgrabungen. Mitteilungen der Naturforschenden Gesellschaften beider Basel 11, 27–106.

Jankowska, D., 1990. Społeczności strefy południowo-zachodniobałtyckiej w dobie neolityzacji. Poznań. Wydawnictwo UAM.

Jensen, H.A., 1974. *Cenococcum geophilum* Fr. in arable soil in Denmark. Friesia 10(5), 300–314.

Jensen, P.M., Andreasen, M.H., Mikkelsen, P.H., 2010. Bulbous oat grass – a magic plant in prehistoric Jutland and Funen. In: Bakels, C., Fennema, K., Out, W.E., Vermeeren, C. (eds), Of plants and snails. A collection of papers presented to Wim Kuijper in gratitude for forty years of teaching and identifying. Sidestone Press, Leiden, pp. 103–114.

Jiménez-Jáimez, V., Suárez-Padilla, J., 2020. Understanding pit sites: storage, surplus and social complexity in Prehistoric Western Europe. Journal of Archaeological Method and Theory 27, 799–835. https://doi.org/10.1007/s10816-019-09429-7

Kapcia, M.D., Nowak, M., 2024. Plant remains from the Linear Pottery Culture settlement at sites Modlniczka 3 and 4, Kraków district. New sources for understanding agriculture in the Early Neolithic in southern Poland. Acta Palaeobotanica 64(2), 422–431. https://doi.org/10.35535/acpa-2024-0017

Kapcia, M., Korczyńska-Cappenberg, M., Lityńska-Zając, M., Wacnik, A., Głód, A., Moskal-del Hoyo, M., 2024. Plant cultivation and diversity at the Early Neolithic settlement in Biskupice in Poland. Scientific Reports 14, 20393. https://doi.org/10.1038/s41598-024-70546-9

Katarżytė, M., 2009 (unpubl.). Lietuvos požeminių grybų įvairovė, paplitimas ir saitai su smulkiaisiais žinduoliais (summary: Hypogeous fungi of Lithuania: diversity, distribution and links with small mammals). Archives Vilnius University Ph.D. thesis typescript, Vilnius.

Kirleis, W., Klooß, S., 2014. More than simply fallback food? Social context of plant use in the northern German Neolithic. In: Chevalier, A., Marinova, E., Peña-Chocarro, L. (eds), An offprint of Plants and People: choices and diversity through time. Oxbow Books, Oxford and Philadelphia, pp. 428–466.

Kofel, D., 2020. Makroskopowe szczątki roślinne. In: Bokiniec, E. (ed.), Małe Czyste, gmina Stolno, województwo kujawsko-pomorskie, stanowisko 20. Wielokulturowe stanowisko sepulkralne na ziemi chełmińskiej. Wydawnictwo UMK, Toruń, pp. 307–317.

Kofel, D., Adamczak, K., 2024. Plant Use by the Funnel Beaker Farmers in Poland. New Archaeobotanical Data from Pottery Sherds and Daub Imprints. Acta Universitatis Lodziensis. Folia Archaeologica 39, 127–142. https://doi.org/10.18778/0208-6034.39.06

Kowalski, Ł., Weckwerth, P., Chabowski, M., Adamczak, K., Jodłowski, P., Szczepańska, G., Chajduk, E., Polkowska-Motrenko, H., Kozicka, M., Kukawka, S., 2020. Towards ritualisation: insights into bone-tempered pottery from the TRB settlement in Kałdus (Poland, 3500–3350 BC). Ceramics International 46(3), 3099–3112. https://doi.org/10.1016/j.ceramint.2019.10.012

Kukawka, S., 1997. Na rubieży środkowoeuropejskiego świata wczesnorolniczego. Społeczności ziemi chełmińskiej w IV tysiącleciu p.n.e. Toruń. Wydawnictwo UMK.

Kukawka, S., 2010. Subneolit północno-wschodnioeuropejski na Niżu Polskim. Toruń. Wydawnictwo UMK.

Kukawka, S., Małecka-Kukawka, J., Wawrzykowska, B., 2002. Wczesny i środkowy neolit na ziemi chełmińskiej. In: Wawrzykowska, B. (ed.), Archeologia toruńska. Historia i teraźniejszość. Muzeum Okręgowe w Toruniu, Toruń, pp. 91–107.

Kulpa, W., 1974. Nasionoznawstwo chwastów. Warszawa. PWRiL.

Lityńska, M., 1990. Zboża i chwasty z neolitycznego stanowiska Iwanowice-Klin, woj. Kraków. Sprawozdania Archeologiczne 42, 105–108.

Lityńska-Zając, M., 2005. Chwasty w uprawach roślinnych w pradziejach i wczesnym średniowieczu. Kraków. IAE PAN.

Lityńska-Zając, M., Czekaj-Zastawny, A., 2021. Utilisation of plant materials in houses of the Linear Pottery Culture. A case study of Brzezie. Journal of Archaeological Science: Reports 35, 102710. https://doi.org/10.1016/j.jasrep.2020.102710

Luc, M., Szmańda, J.B., 2004. Krajobraz chełmińskiego mezoregionu osadniczego. In: Chudziak, W. (ed.), Wczesnośredniowieczny zespół osadniczy w Kałdusie. Studia przyrodniczo-archeologiczne. Mons Sancti Laurentii. Tom 2. Wydawnictwo UMK, Toruń, pp. 31–42.

Mirek, Z., Piękoś-Mirkowa, H., Zając, A., Zając, M., 2020. Vascular Plants of Poland. An annotated checklist. Kraków. IB PAN.

Mueller-Bieniek, A., 2012. Bulwki rajgrasu wyniosłego (*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl subsp. *bulbosum*) na stanowiskach archeologicznych. Etnobiologia Polska 2, 23–26.

Mueller-Bieniek, A., 2016. Badania materiałów roślinnych związanych z kulturą pucharów lejkowatych w rejonie Brześcia Kujawskiego i Osłonek. In: Grygiel, R. (ed.), Neolit i początki epoki brązu w rejonie Brześcia Kujawskiego i Osłonek. T III. Środkowy i późny neolit. Kultura pucharów lejkowatych. Wydawnictwo FBA, Łódź, pp. 753–764.

Mueller-Bieniek, A., 2023. Makroszczątki roślinne z neolitycznego stanowiska 1 w Gaju na Pojezierzu Kujawskim. In: Papiernik, P., Brzejszczak, R., Wicha, J. (eds), Źródła archeologiczne w rejonie Parku Kulturowego Wietrzychowice. Tom II. Cmentarzysko kultury pucharów lejkowatych w Gaju, stanowisko 1.Wydawnictwo FBA, Łódź, pp. 365–378.

Mueller-Bieniek, A., Kittel, P., Muzolf, B., Cywa, K., Muzolf, P., 2016. Plant macroremains from an early Neolithic site in eastern Kuyavia, central Poland. Acta Palaeobotanica 56(1), 79–89. https://doi.org/10.1515/acpa-2016-0006

Mueller-Bieniek, A., Nowak, M., Styring, A., Lityńska-Zając, M., Moskal-del Hoyo, M., Sojka, A., Paszko, B., Tunia, K., Bogaard, A,. 2019. Spatial and temporal patterns in Neolithic and Bronze Age agriculture in Poland based on the stable carbon and nitrogen isotopic composition of cereal grains. Journal of Archaeological Science: Reports 27, 101993. https://doi.org/10.1016/j.jasrep.2019.101993

Noryśkiewicz, B., 2004. Badania palinologiczne osadów limnicznych Jezior Starogrodzkich. In: Chudziak, W. (ed.), Wczesnośredniowieczny zespół osadniczy w Kałdusie. Studia przyrodniczo-archeologiczne. Mons Sancti Laurentii. Tom 2. Wydawnictwo UMK, Toruń, pp. 165–173.

Noryśkiewicz, A., 2013. Historia roślinności i osadnictwa ziemi chełmińskiej w późnym holocenie. Toruń. Wydawnictwo UMK.

Nowak, M., 2009. Drugi etap neolityzacji ziem polskich. Kraków. Księgarnia Akademicka.

Nowak, M., Lityńska-Zając, M., Moskal-del Hoyo, M., Mueller-Bieniek, A., Kapcia, M., Kotynia, K., 2020. Plants of the Funnel Beaker Culture in Poland. Sprawozdania Archeologiczne 72(1), 87–114. https://doi.org/10.23858/SA/72.2020.1.005

Out, W.A., García-Granero, J.J., Andreasen, M.H., Patús, C.N., Kirleis, W., Barfod, G.H., Andersen, N.H., 2025. Plant use at Funnel Beaker sites: combined macro- and microremains analysis at the Early Neolithic site of Frydenlund, Denmark (ca. 3600 BCE). Vegetation History and Archaeobotany 34, 177–203. https://doi.org/10.1007/s00334-024-01020-9

Pasqualone, A., 2025. Addressing shortages with storage: from old grain pits to new solutions for underground storage systems. Agriculture 15(3), 289. https://doi.org/10.3390/agriculture15030289

Podkowińska, Z., 1961. Spichrze ziemne w osadzie kultury pucharów lejkowatych na Gawrońcu-Pałydze w Ćmielwie, pow. Opatów. Archeologia Polski 6, 21–63.

Robinson, D., 1994. Plants and Vikings: everyday life in Viking Age Denmark. Botanical Journal of Scotland 46(4), 542–551. https://doi.org/10.1080/13594869409441761

Roehrs, H., Klooss, S., Kirleis, W., 2013. Evaluating prehistoric finds of *Arrhenatherum elatius* var. *bulbosum* in north-western and central Europe with an emphasis on the first Neolithic finds in Northern Germany. Archaeological and Anthropological Sciences 5, 1–15. https://doi.org/10.1007/s12520-012-0109-0

Schweingruber, F.H., 1990. Mikroskopische Holzanatomie. Birmensdorf, Herausgeber Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft.

Shay, C.T., Kapinga, M.R.M., 1997. *Cenococcum geophilum* sclerotia from an archaeological site in western Canada. North American Archaeologist 18(4), 363–370. https://doi.org/10.2190/1A9U-LCN5-LT3G-JXC6

Stępniak, T., 2006. Identyfikacja taksonomiczna węgli drzewnych z obiektów wziemnych. Podstawy oceny funkcjonalnej. In: Kośko, A., Szmyt, M. (eds), Opatowice – Wzgórze Prokopiaka. Tom I. Wydawnictwo Poznańskie, Poznań, pp. 265–268.

Stępniak, T., 2007a. Identyfikacja taksonomiczna węgli drzewnych. In: Kośko, A., Szmyt, M. (eds), Opatowice – Wzgórze Prokopiaka. Tom II. Wydawnictwo Poznańskie, Poznań, pp. 249–255.

Stępniak, T., 2007b. Identyfikacja taksonomiczna węgli drzewnych. In: Kośko, A., Szmyt, M. (eds), Opatowice – Wzgórze Prokopiaka. Tom III. Wydawnictwo Poznańskie, Poznań, pp. 371–374.

Stępniak, T., Szmyt, M., 2015. Identyfikacja taksonomiczna węgli drzewnych. In: Kośko, A., Szmyt, M. (eds), Opatowice – Wzgórze Prokopiaka. Tom V. Wydawnictwo Poznańskie, Poznań, pp. 453–461.

Stępniak, T., Kośko, A., Szmyt, M., 2014. Identyfikacja taksonomiczna węgli drzewnych. In: Kośko, A., Szmyt, M. (eds), Opatowice – Wzgórze Prokopiaka. Tom IV. Wydawnictwo Poznańskie, Poznań, pp. 453–470.

Szmyt, M., 2017. Collective graves, flint axes, and cows. The people of Globular Amphora culture on the Vistula and Odra. In: Włodarczak, P. (ed.), The Past Societies. Polish lands from the first evidence of human presence to the Early Middle Ages 2: 5500-2000 BC. IAE PAN, Warszawa, pp. 212–273.

Wacnik, A., Kupryjanowicz, M., Mueller-Bieniek, A., Karczewski, M., Cywa, K., 2014. The environmental and cultural contexts of the late Iron Age and medieval settlement in the Mazurian Lake District, NE Poland: combined palaeobotanical and archaeological data. Vegetation History and Archaeobotany 23, 439–459. https://doi.org/10.1007/s00334-014-0458-y

Waszczuk, K., 2011. Analiza materiałów faunistycznych ze stanowisk Jastrzębiec 4 i Renice 6. In: Rzepecki, S. (ed.), Studia i materiały do najdawniejszymi dziejami Równiny Gorzowskiej. Osady i cmentarzyska kultury pucharów lejkowatych na stanowiskach Jastrzębiec 4 i Renice 6. Wydawnictwo Poznańskie, Poznań, pp. 103–111.

Wierzbicki, J., 1999. Łupawski mikroregion osadniczy ludności kultury pucharów lejkowatych. Poznań. Wydawnictwo UAM.

Wiślański, T. 1969. Podstawy gospodarcze plemion neolitycznych w Polsce północno-zachodniej. Wrocław. Zakład Narodowy im. Ossolińskich.

Wiślański, T., 1979. Kształtowanie się miejscowych kultur rolniczo-hodowanych. Plemiona kultury pucharów lejkowatych. In: Hensel, W., Wiślański, T. (eds), Prahistoria ziem polskich. Tom 2, Neolit. Zakład Narodowy im. Ossolińskich, Wrocław, pp. 165–260.