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Plant macro-remains preserved in slag-pit furnaces from the Iron-Age settlement in the Mazovian Centre of Metallurgy

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A R T I C L E I N F O

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A B S T R A C T

Iron production appeared in the Barbarian World in the Early pre-Roman Iron Age (5th–3rd c. BC), but in the study area, in Central Poland, the exact timing has not been well recognised yet due to the absence of distinctive artefacts in the archaeological record that are directly connected to metal production. The main purpose of this study was to investigate features archaeobotanically and analyse charred plant macro-remains from slag-pits. Among them, cultivated plants were almost absent, while plants growing in grasslands, meadows, and ruderal places dominated the assemblage. Most numerous were grasses producing small grains, though brome grass was also present. Members of the Polygonaceae family and fat-hen were significant while other small and rather delicate seeds and fruits were scarce. We noticed a similarity between our assemblage and the data coming from Iron-Age Jutland in present-day Denmark, but the latter differs in the composition of plant remains, which usually is dominated by crops and field weeds. In the case of the site at Zaborów, we can presume a similar use of herbal plants in smelting technology, but the local environment was probably different from that in Jutland. In Zaborów, open landscape dominated, covered by grasslands and ruderal plants, while the presence of crop fields was not confirmed yet. Preliminary radiocarbon data obtained from eight seed samples indicate that in the studied area, metal production started at least one century earlier than was previously assumed, probably introduced by settlers of the Jastorf culture originating from the Jutland Peninsula.

1. Introduction

The so-called Mazovian Centre of Metallurgy (Mazowieckie Centrum Metalurgiczne) was the second-largest iron production centre operating in the pre-Roman and Roman periods (approximately from the 1st century BCE to the 3rd century CE) in Barbarian Europe (Pleiner, 2000, pp. 45–47; Woyda, 2005, 2002; Woźniak, 2022). The scale of production was enormous. Based on the results of excavations and magnetic research, it is estimated that 120 000 to 150 000 iron smelts existed in the area (Woyda, 2005, p. 134, 2002, p. 123), commonly single-use slag-pit furnaces (Bielenin, 1973; Pleiner, 2000, pp. 149–163), whose remains are usually well preserved in archaeological sites. These features rarely contain artefacts that would establish their relative chronology. They are usually dated typologically by association with other archaeological features in their vicinity.

In Poland, studies on botanical materials from archaeological features related to iron production are generally rare and limited to charcoal analyses (Bielenin, 1992, pp. 158–161; Lehnhardt et al., 2019, tbl. 5; Lityńska-Zając, 1997, pp. 233–236; Orzechowski, 2013, pp. 53–55, 2007, p. 180; Pazdur, 1990). The single investigation that was dedicated to other plant remains only provided information about phytoliths, while no carpological remains were noted (Lehnhardt et al., 2019). The primary goal of our research was to obtain data that could support a reconstruction of technological aspects of iron production and a description of the local environment. Charcoal was an indispensable element of smelting, as it served as fuel, and the use of different iron ores may have required the selection of different fuels (Orzechowski, 2013, p. 53, 2007, p. 184); such an assumption, however, was never clearly confirmed by direct data. Until now, charcoal was a main source of material for radiocarbon dating, and thus was of crucial importance for the study of the chronology of barbarian iron production.

Research at iron production sites in other parts of Barbarian Europe proved that charcoal fragments, though dominant, are not the only plant remains that could be found in the slag-pit furnaces. Fossilised wood,

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straw and seeds (mostly desiccated and charred) were found in slag-pits in Denmark and north-eastern Germany (Brumlich, 2020, tbl. 1, 2018, tbls. 34–37; Henriksen, 2003; Jöns, 1997, pp. 126–129; Mikkelsen, 2003, 1997; Mikkelsen and Nørbach, 2003; Voss, 1989, p. 154). In Iron-Age Denmark (ca. 2nd-7th centuries AD), bunches of straw were most probably used as infill in the lowermost parts of the furnace, to make sure that the mixture of fuel and ore moved down into the slag-pit slowly enough to receive sufficiently high temperatures (Jöns, 1997, pp. 129–130; Mikkelsen, 2003, pp. 88–89, 1997). The straw, often with its bottom parts and roots, was usually accompanied by crop grains as well as numerous and variable seeds of weeds and other plants. Such assemblages are a very good source of information about Iron-Age fields, crop cultivation, and local environmental conditions (Henriksen, 2003; Mikkelsen, 2003).

Until recently, archaeobotanical research had not been conducted in sites of the Mazovian Centre of Metallurgy at all. During excavations in Zaborów in 2022, a first attempt was made to obtain archaeobotanical material from Mazovian iron-smelting furnaces that was better suitable for radiocarbon dating than charcoal (i.e. without the “old wood” effect). The project’s objective was to investigate the chronology of smelting activities in the Mazovian Centre of Metallurgy, which, due to limited radiocarbon data (Janiszewski, 2018), remains unclear (Maciałowicz, 2016, p. 84; Orzechowski, 2013, pp. 211–224).

The aim of this paper is to present the first carpological data derived from Iron-Age slag-pit furnaces located in the Mazovian Centre of Metallurgy in central Poland with their cultural and environmental interpretation.

1.1. The study area

The microregion of Zaborów (Leszno commune, Warsaw West county, Mazovian Voivodeship), a few kilometres west of Warsaw, is an Iron-Age settlement cluster of the Jastorf and Przeworsk cultures that consists of a cemetery and at least three settlements with evidence of intensive iron production. It is located on the boundary of the Łowicko-Błońska Plain and the Warsaw Basin, two physiographic mesoregions in the Central Mazovian Lowlands macroregion (Fig. 1). The former of these landscapes is a denudation plain, a relatively flat area traversed by a network of medium-sized and small rivers from the lower Bzura basin. It is characterised by high-quality soils, including black soils. For this reason, the area is used intensively for agriculture and is almost completely free of forests now (Sosnowska and Szumacher, 2021). Without human influence, according to the map of potential natural vegetation (Matuszkiewicz et al., 1995), the area would be currently covered by lime-oak-hornbeam forests (*Tilio-Carpinetum*). The region’s natural resources include rich deposits of boulder clay, which was even mined industrially until recently, as well as bog iron ore. The latter was rediscovered here only in the 1970 s during geological investigations to reconstruct the availability of raw material for protohistoric iron smelting. The Warsaw Basin is a wide glacial valley of the Vistula River, situated between the middle section of the present river and the Łowicko-Błońska Plain, and consists of a floodplain and a flood terrace. The floodplain is covered by fertile alluvial soils and used to be frequently flooded by the river until the construction of the Vistula embankment (mid-20th century). The flood terrace consists of elongated sand dunes running in an east–west direction and is covered by wet meadows and marshes that are unsuitable for settlement. The area neighbouring the study site would have been covered by oak-pine mixed forest (*Querco-Pinetum*) and in low-lying places by alder fen forest (*Carici elongatae-Alnetum*) (Matuszkiewicz et al., 1995). Until the 18th century CE, this region was covered by an extensive primeval forest, which was later intensively cleared for timber (Sosnowska, 2021). After World War II, this agriculturally unattractive area was largely reforested and converted into the Kampinos National Park.

The site Zaborów V/22 (52°16′09.5″ N, 20°40′26.2″ E), located partly on the Łowicko-Błońska Plain, dominated by clays, and partly in the Warsaw Basin, dominated by sands and aeolian gravels (Szumański and Kwapisz, 2005), covers an area of about 12 ha (Fig. 2). It has been studied since 2022 by a team of researchers from the Faculty of Archaeology, University of Warsaw, and from the Museum of Ancient Mazovian Metallurgy in Pruszków. Excavations were preceded by non-invasive methods, such as surface prospection with drones and metal detectors as well as magnetics. Most of the research area is covered by pastures and meadows (grasslands) now. Following the surveys, seven excavation trenches were selected with a total area of 270 m^2. Apart from several concentrations of slag-pit furnaces (Fig. 3), other features,

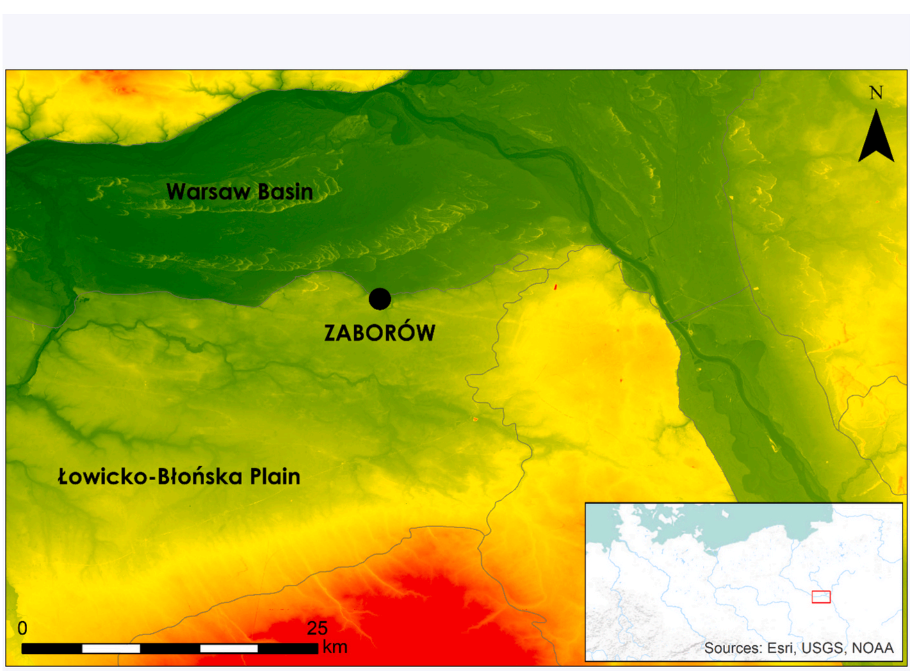

Fig. 1. Location of the Iron-Age settlement microregion in Zaborów (Warsaw West District, Mazovian Voivodeship) against the background of Poland’s physico-geographical divisions. The microregion is situated on the border of the Warsaw Basin and the Łowicko-Błońska Plain.

Fig. 2. View of the archaeological excavations at the Zaborów V/22 settlement. In the background, the forest belonging to the Kampinos National Park and Warsaw's skyscrapers (top right corner of the photo).are visible.

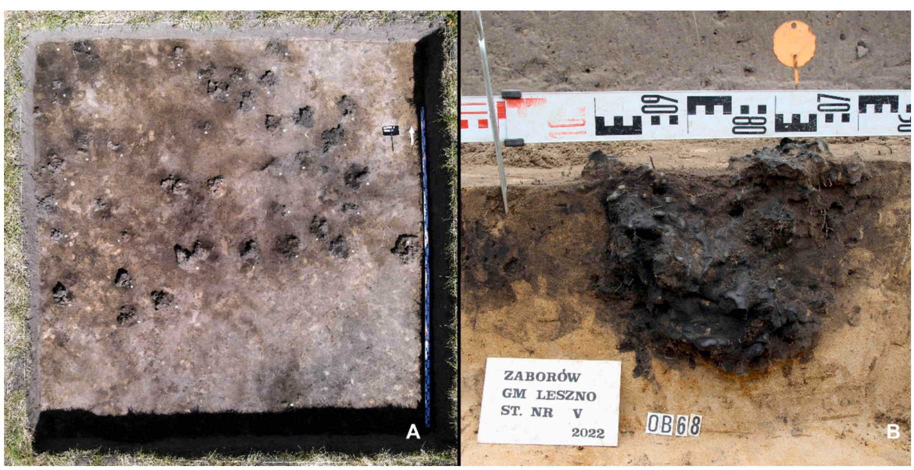

Fig. 3. Archaeological excavation at Zaborów site V/22 with a concentration of slag-pit furnaces (A); and a cross-section of a sample slag-pit furnace showing slag deposits and intensely black soil saturated with charcoal (B).

such as a lime kiln, were discovered. A thick cultural layer was also explored, in which numerous potsherds, animal remains, and metal objects (parts of clothing, tools) were preserved. They allow to distinguish two main horizons of settlement development: the older correlated with the Jastorf culture (ca. 3rd century BCE), and the younger linked to the Przeworsk culture (1st century BCE – 2nd/3rd century CE) (Cieśliński et al., 2025; Cieśliński et al., in press; on both culture groups in general, cf. Andrzejowski, 2010; Dąbrowska and Mączyńska, 2003; Grygiel, 2015, 2013; Kontny, 2016; Maciałowicz, 2016, pp. 76–87).

2. Material and methods

Most of the sediment samples were collected from archaeological features directly connected with metallurgy (42 samples from 30 slag-pits and 4 samples from features associated with smelting). Additionally, four samples were taken from a cultural layer of the settlement, and

Table 1
General characteristics of the studied material from Zaborów V/22 (detailed information in Supplementary data).

	Number of features	Number of samples	Number of samples with seeds	Volume [litr]	Number of all seeds	Number of uncharred seeds
Slag pits and features connected with metallurgy	34	46	33	36,6	285	23
Layer	–	5	5	11	48	25
Control	–	1	0	1	0	0

one control sample was collected from the soil substrate, in which no traces of past human activity were visible (Table 1). In total, 48 L of sediment were water-sieved using a gentle flotation method and a column of sieves, of which the smallest mesh size was 0.25 mm. Heavy fraction was sieved with a net of 2 mm mesh size. Both fractions were dried and then sorted under a low power microscope (magnification 6–40 x). In the samples from the features not directly connected with metallurgy, a limited number of charred macro-remains were found. They were omitted in further analyses and discussion. The control sample contained no botanical remains at all. All carpological remains were identified, but only charred remains were interpreted as contemporaneous with the archaeological context, because a possibility that uncharred ones could be a result of bioturbation and younger contamination of the archaeological layers is relatively high in that well-drained sediments (for example Mueller-Bieniek et al 2020, p. 69-70; Campbell et al 2011). Charred carpological remains were found in 30 samples from slag-pits. In this paper, all seeds and fruits are simplified as 'seeds'. Final identification and documentation was done with the help of the digital microscope Keyence VH-Z100R and relevant literature (Bojnanský and Fargašová, 2007; Cappers et al., 2006; Gluza, 1977; Katz et al., 1965; Kulpa, 1974). Plant names follow *Flowering plants and Pteridophytes of Poland. A checklist* (Mirek et al., 2002), and their qualification to ecological groups is given (Ellenberg et al., 1991; Lityńska-Zając, 2005; Mueller-Bieniek and Woch, 2012; Zarzycki et al., 2002).

The data were processed with the help of ArboDatMulti (Kreuz and Schäfer, 2002; Pokorná et al., 2011). In the case of fragments, a minimal number of reconstructed complete items is given (Table 2).

3. Results

Most of the remains were not identified, or their identification was not certain because of common fragmentation, erosion and mineralisation (Table 2, and detailed documentation given in Supplementary data). Cultivated plants are very rare, and they include singular remains of millet (*Panicum miliaceum*) as well as possibly barley (cf. *Hordeum vulgare*) and pea (cf. *Pisum/Vicia*). Seeds of wild herbaceous plants dominate the assemblage: most numerous among them are finger millet (*Digitaria* sp.) and fat-hen (*Chenopodium album* type), the latter also present as uncharred seeds, excluded from the interpretation. Members of the Polygonaceae family are also relatively numerous, including common knotgrass (*Polygonum aviculare*). Apart from finger millet, other grasses are also well visible, from them grains of brome grass (*Bromus* sp.) are noteworthy. Their grains usually were fragmented, and their exact identification on species level was not possible. Very small seeds are preserved in the material as well, some of them relatively numerously, such as nettle (*Urtica dioica*), rushes (*Juncus* sp.), broadleaf plantain (*Plantago major*), and oregano (cf. *Origanum vulgare*). The very small but characteristic seeds of St John's wort (*Hypericum perforatum*) and red sorrel (*Rumex acetosella*) are worth mentioning, even if only sporadic. *Polygonum aviculare*, *Digitaria* sp., *Chenopodium album* type and *Bromus* sp. are also relatively frequent in the whole material. In most of the samples, sclerotia of *Cenococcum geophilum* fungus were found (Table 2, Fig. 4).

Seeds of cultivated plants are very rare, while grasslands and ruderal/weedy plants dominate the assemblage (Fig. 5:A). Usually, wild taxa represent plants that are adapted to anthropogenic habitats, fast growing, frequently resistant to trampling (i.e. *Digitaria* sp., *Polygonum aviculare*, *Plantago major*). However, the heterogeneity of the material is visible in the presence of plants that prefer untrampled habitats, like nettle (*Urtica dioica*), St John's wort (*Hypericum* sp.), and oregano (cf. *Origanum vulgare*). Plants growing in wet soils and on the edge of water are also present in the material (mainly rushes, *Juncus* sp., most of the taxa can grow in humid patches of meadows and pastures), while plants preferring shady locations and forests are generally absent. The assemblage is dominated by seeds from the families Poaceae (grasses), Polygonaceae (knotgrasses and sorrel), and Chenopodiaceae (fat-hen)

Table 2
List of taxa from Zaborów site V/22, number of specimens, their presence and frequency. All specimens are charred with exception of 6 lowermost lines of the table. Total number of samples N = 46, 30 samples with preserved charred remains (non-empty). The classification into separate ecological groups is not strict, as some plants of some aggregate taxa (like *Plantago major*, *Polygonum aviculare*, *Rumex acetosella*) can grow also in ruderal places, gardens, and fields.

Botanical name	Number of specimens	Presence in samples	Frequency (% of non-empty samples)
Crops			
cf. *Hordeum vulgare*	1	1	3
Panicum miliaceum (and cf.)	2	2	7
cf. *Pisum/Vicia*	1	1	3
Weeds and Ruderal vegetation			
Chenopodium album type	16	7	23
Digitaria sp. (and cf.)	20	8	27
Echinochloa crus-galli	2	1	3
Fallopia convolvulus (and cf.)	2	2	7
Polygonum lapathifolium	2	2	7
Urtica dioica	9	3	10
Grassland vegetation			
Bromus sp.	14	6	20
Hypericum perforatum	1	1	3
cf. *Origanum vulgare*	6	3	10
Plantago major (and cf.)	6	4	13
Poaceae indet. (culm node)	1	1	3
Poaceae (small grained) (and cf.)	20	8	27
Polygonum aviculare (and cf.)	18	14	47
Rumex acetosella	3	2	7
cf. *Trifolium* sp.	2	2	7
Varia			
Carex sp.	1	1	3
Cerealia/Poaceae (rachis fragment)	1	1	3
Cerealia/Poaceae (large grained)	1	1	3
cf. *Cyperus flavescens*	1	1	3
cf. *Fagopyrum*	1	1	3
Juncus sp.	10	2	7
cf. Lamiaceae indet.	3	2	7
Luzula sp. (and cf.)	4	2	7
cf. *Mentha* sp.	1	1	3
cf. Panicoideae	1	1	3
Polygonaceae indet.	3	3	10
Polygonum cf. *persicaria*	5	4	13
Polygonum sp.	3	2	7
Potentilla sp.	1	1	3
cf. *Ranunculus* sp.	1	1	3
Silene sp.	1	1	3
Indeterminata	98	22	73
	262	30	100
Uncharred (possibly recent)			
Poaceae indet.	1	1	3
cf. Poaceae indet.	2	1	3
Chenopodium album type	17	12	40
Stellaria media	1	1	3
Alnus glutinosa	1	1	3
Malvaceae indet.	1	1	3
Cenococcum (sclerotia)	x	29	97

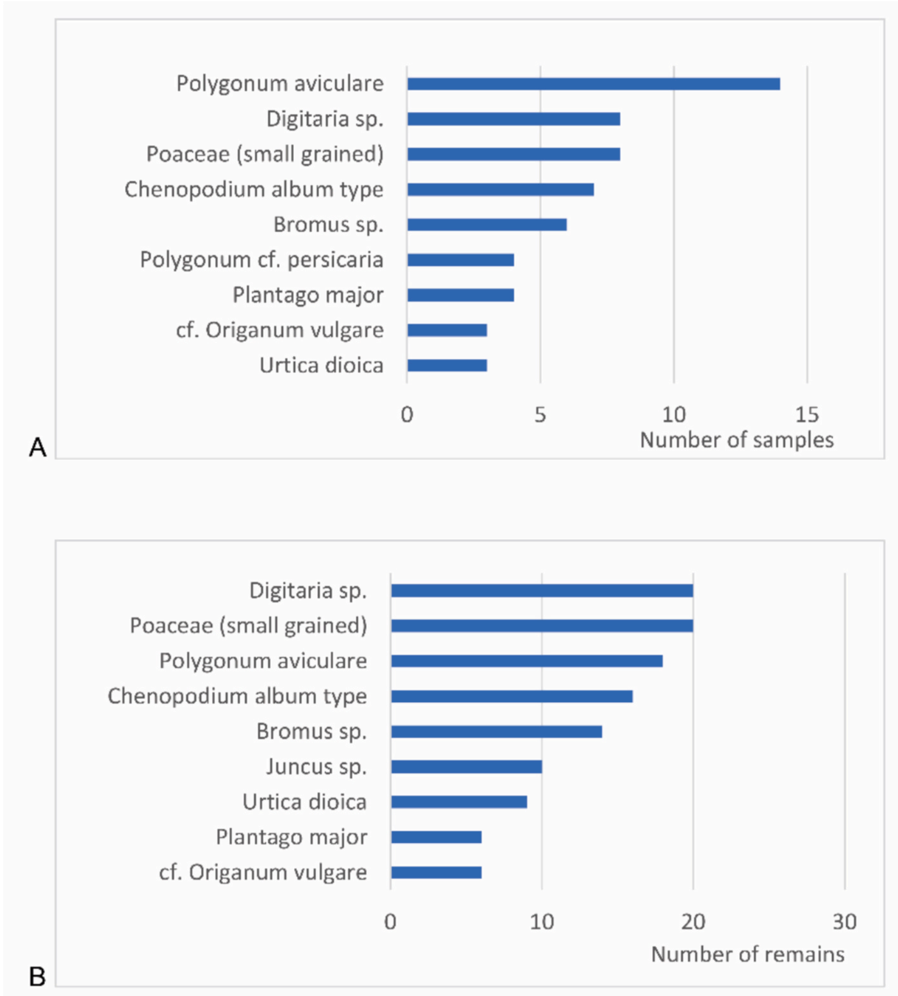

Fig. 4. Zaborów V/22, selected characteristics of the archaeobotanical data: A – the most frequent taxa, X-axis shows number of samples with the seeds of the taxon; B – the most numerous taxa, X-axis shows total number of the seeds of the taxa.

(Fig. 5:B). These taxa usually are well represented in charred archaeobotanical assemblages due to their relatively coarse structure.

4. Discussion

When comparing the data from Zaborów, in the Mazovian Centre of Metallurgy in central Poland, with similar sites and features elsewhere, the uniqueness of the presented results is apparent. In part, this picture is a consequence of the poor state of archaeobotanical research of metallurgical structures, with an exception of Danish studies.

Carpological macro-remains (and straw) were found in slag-pit furnaces from several Danish Iron-Age sites in Jutland, dated to ca. 100–700 CE (Henriksen, 2003; Mikkelsen, 2003, 1997; Mikkelsen and Nørbach, 2003). The very good preservation of charred macro-remains in Danish slag-pits can be explained by oxygen depletion and relatively low temperatures during the smelting process in the lower layers of the pit. These conditions were observed and confirmed during experiments, when the temperature in the pit grew very slowly and did not reach more than 200 °C in the first 9 h and no more than 320 °C during the whole experiment. The freshly uprooted plants, with their grains and seeds, were dried first and then charred, only in selected areas of the pit and always without "popping" (Mikkelsen, 1997, pp. 65–66). The archaeobotanical assemblages from Jutland usually were dominated by crops, mostly rye and barley, and accompanied by remains of other plants, including crop weeds. The plant remains, their stems and ears, were usually visible to the naked eye during the archaeological exploration of the features. It was deduced that they were collected by past craftsmen in bunches directly from the fields, usually with crop roots still attached, and in some cases also stems of weeds. The assemblages generally reflected one field in one season and thus served as an excellent opportunity to study the agricultural methods of ancient farmers (Henriksen, 2003; Mikkelsen, 2003).

In contrast, at the site of Zaborów, plant remains were rare and found scattered in the sediment infill of the slag-pits. Seeds and fruits were not visible to the naked eye, straw and crop remains were generally lacking or very scarce (Table 2). However, it is important to note that at the site of Zaborów the density of plant remains was higher in slag-pits than in features not associated with smelting (Table 1, and Supplementary data), which could be due to limited disturbances in the features left by one-time metal production events. Additionally, uncharred and thus most probably recent plant remains were very rare in slag-pits. Similar observations were described in the Danish studies and explained by the nature of zone of slag-pits cluster as place used only once and then avoided by the settlers (Mikkelsen, 1997, p. 64). In the case of Zaborów, the difference between slag-pits and domestic features is only a preliminary observation, as the number of samples taken from the latters is very limited.

The very small number of crop remains from slag-pits in Zaborów is linked to an absence of typical field crop weeds, which in Danish assemblages usually are very well represented. In the iron smelting sites in

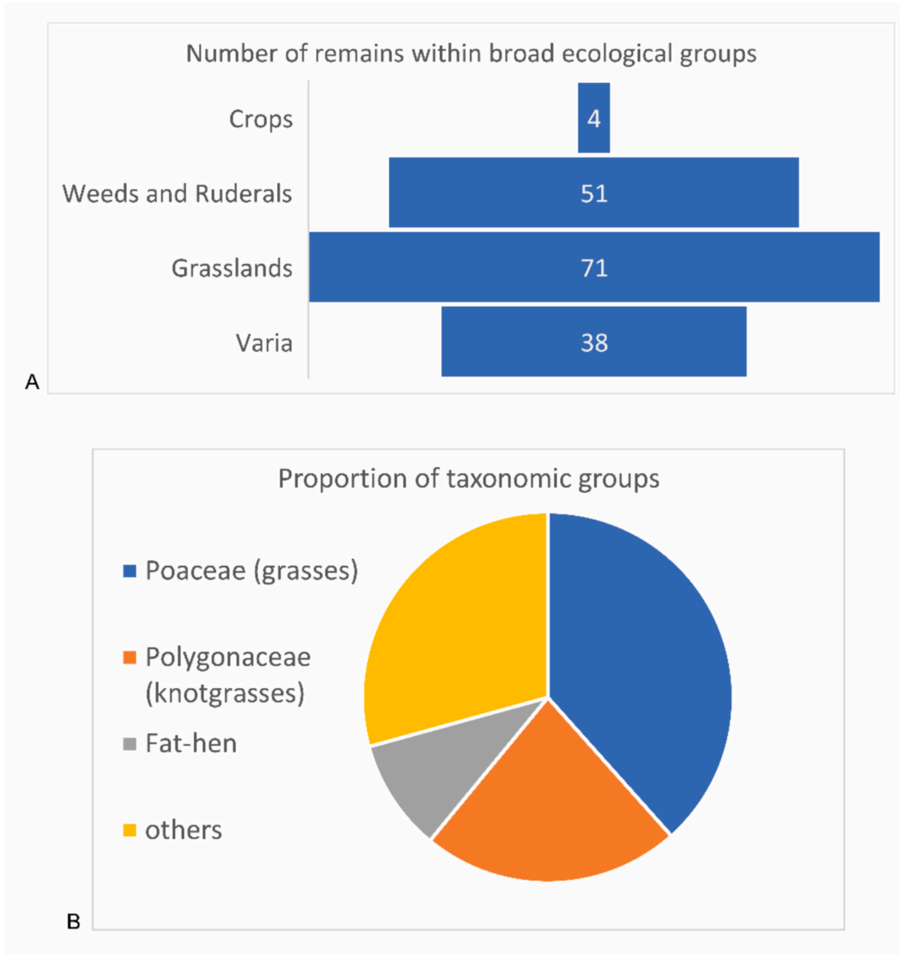

Fig. 5. Zaborów V/22, composition of plant macro-remains divided into broad ecological groups (A) and taxonomic groups (B).

Denmark, crop straw (with weeds) that was used to fill the underground part of a furnace was an important part of the technological process (Mikkelsen, 1997). In Zaborów, the picture is not so clear. The plant remains belong to taxa growing in anthropogenic (ruderal and segetal) communities and pastures or meadows (Table 2, Fig. 5). They could grow in the neighbouring, deforested area disturbed by human activity (for example fat-hen, *Chenopodium album* type, family Polygonaceae in general, Fig. 6:1) and would regularly get trampled (for example *Plantago major*, Fig. 8:D, and *Polygonum aviculare*). While crops are not visible in the material, other grasses (Poaceae) are significant (Figs. 5, 7, 8:A–C), including several grains and single fragments of straw. Most of the grasses belong to the group producing small grains that were not identified to genus or species level. Some fragmented grains belong to brome grass (*Bromus* sp.), which produces large grains that reach sizes similar to those of crops (Rutkowski, 2008). The group of plants more or less characteristic for grassland vegetation is relatively significant in the studied material, while it was rather limited in the Danish assemblages (Henriksen, 2003). It must be mentioned, however, that the taxa usually are not very distinctive for one ecological group, but the appearance of St John's ward (*Hypericum perforatum*, Fig. 9:A) and oregano seeds, though very rare, can be seen as indicative for grasslands (Table 2). Nevertheless, they could have been gathered at some distance too, due to their usefulness as medicines, spices, or ornamentals, but their limited number do not support gathering activities (Broda and Mowszowicz, 2000; Mueller-Bieniek, 2012, pp. 89, 100; Rostafiński, 1900). Additionally, it should be mentioned that most of the plants growing in Poland has some useful properties, known from folklore, or documented in scientific literature. Some taxa (like fat-hen or brome grass) are edible and there are archaeobotanical proofs that their seeds were used for food in the past (for example Zech-Matterne et al., 2021; Mueller-Bieniek et al., 2019).

The presence of charred remains of nettle (*Urtica dioica*, Fig. 9:B), a plant growing in untrampled habitats that are rich in nutrients, and either wet or well-drained, is very interesting. The very small and delicate seeds of nettle are frequently found when preserved by waterlogging, while charred remains are not common in archaeobotanical assemblages (Lityńska-Zając, 2012; Mueller-Bieniek, 2012). At Zaborów, nine seeds of nettle were found in three samples, which objectively may be a small number, but in the context of the whole assemblage, it is noteworthy. It is known from a 18th century historic source that juice squeezed form nettle leaves was used in steel processing (Kluk, 1788, p. 142). In general the role of the plants in the process of iron smelting is unclear. We suggest some similarities to the observations made for the Danish Iron-Age smelting, but the data from the site of Zaborów are very limited. We suppose that instead of rye or barley, the craftsmen from the Mazovian Centre of Metallurgy used other grasses (like brome grass) as well as fat-hen, nettle, and possibly other plants growing in the local area, which already was deforested at the time. Some of the seeds also could have entered the slag-pits by chance, growing in the place or being used for other purposes. The observed lack of direct evidence of crop cultivation practiced at the Zaborów site in the same time horizon in which the studied slag-pit furnaces were used is the most important difference between the two compared areas till now.

Another aspect of the Zaborów project is the use of plant macro-remains for a series of radiocarbon tests. Despite the 50-year history

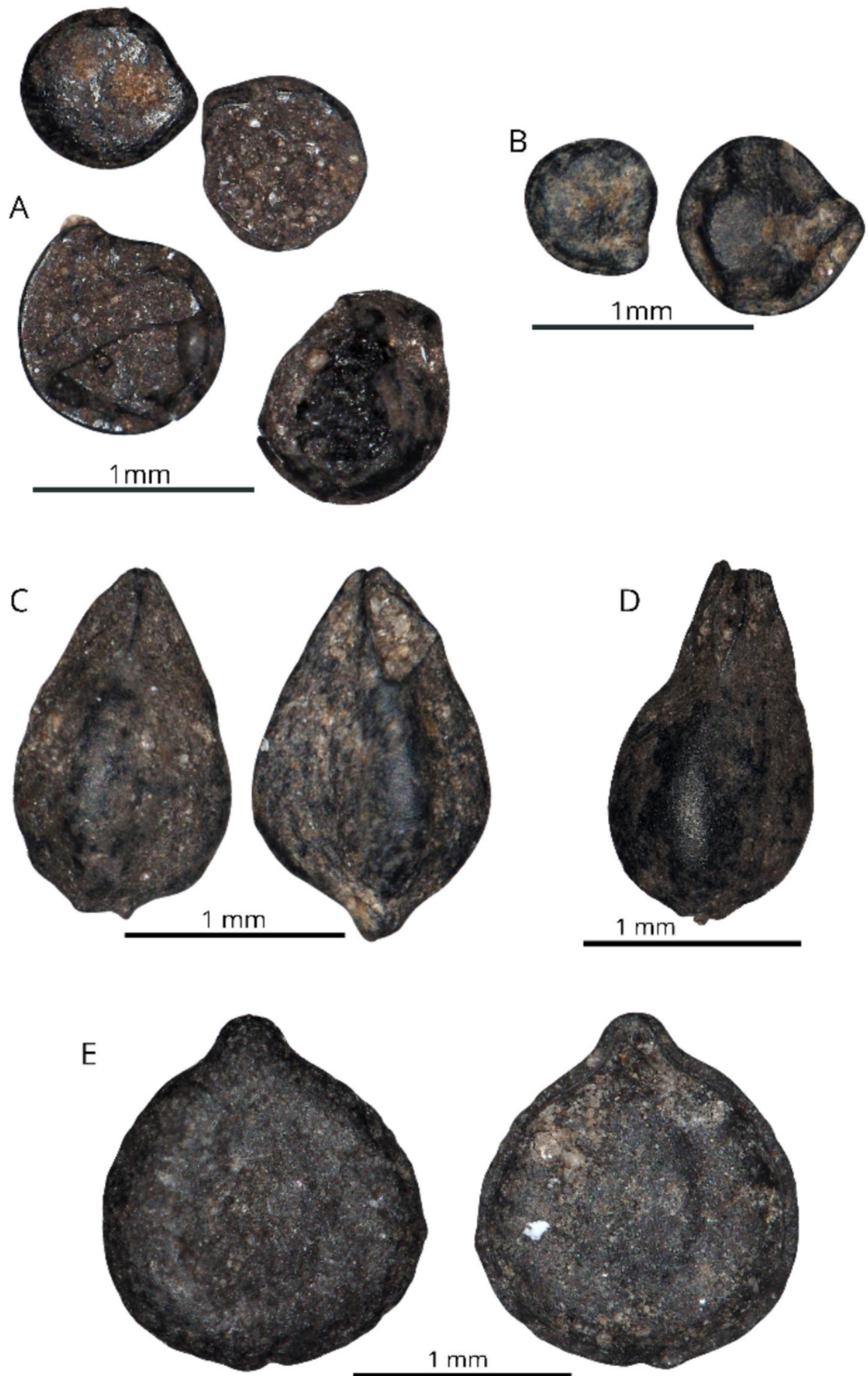

Fig. 6. Charred seeds and fruits from slag-pits at Zaborów V/22: A and B – fat-hen (*Chenopodium album* type); C and D – *Polygonum aviculare*; E – *Polygonum lapathifolium*.

of field work in Mazovian metallurgical settlements, this has been done for only three sites so far (Janiszewski, 2018). Some of these analyses are old (from the 1970 s), and their precision is insufficient. The dated material was charcoal, which was not analysed anatomically – the results may therefore be affected by the so-called "old wood effect" (Dean, 1978). In this context, new ^{14}C analyses provided valuable information on the chronological framework of the metallurgical centre's operation (Cieśliński et al., 2025).

Samples for Accelerator Mass Spectrometry (AMS) radiocarbon dating were collected from eight relatively large seeds found in the slag-pit furnaces, namely of *Bromus* sp. and *Fallopia convolvulus*. The analyses were conducted at the ^{14}C and Mass Spectrometry Laboratory of the Silesian University of Technology in Gliwice, using an AMS MICADAS spectrometer (Piotrowska, 2024). Radiocarbon dates were calibrated using OxCal 4.4 (Bronk Ramsey, 2009) and the IntCal20 calibration curve (Reimer et al., 2020). The results of radiocarbon analyses for the seeds indicate dates ranging from the 4th to the 2nd century BCE, e.g. GdA-7654.1.1: 2243 ± 26 BP (calibrated age 95.4 % probability:

Fig. 7. Charred macro-remains of *Bromus* sp. from slag-pits at Zaborów V/22:

388–204 BCE) and GdA-7658.1.1: 2234 ± 27 BP (calibrated age 95.4 % probability: 387–202 BCE). These findings shed entirely new light on the origins of the Mazovian Centre of Metallurgy and the beginnings of centralised mass iron production in the barbarian regions of Europe. This phenomenon now appears to be at least one hundred years older than previously assumed, with its creators identified as the Jastorf culture population rather than the Przeworsk culture community. Originating from the Jutland Peninsula, the Jastorf culture thus played a more significant role in the spread of iron production in the Vistula basin than the Celts, who inhabited southern Poland (cf. Lehnhardt 2020: 156; Orzechowski 2020: 216–217).

5. Conclusions

The plant macro-remains from the slag-pit furnaces of the site of Zaborów allow for a description of the local landscape in that part of the Mazovian Centre of Metallurgy at the time of its formation, which, thanks to radiocarbon dates of seeds, appeared to be earlier by about one hundred years than it was previously known, being one of the oldest in central Europe. The local area probably was deforested and covered by grasslands and ruderal plants. The presence of crop fields is not

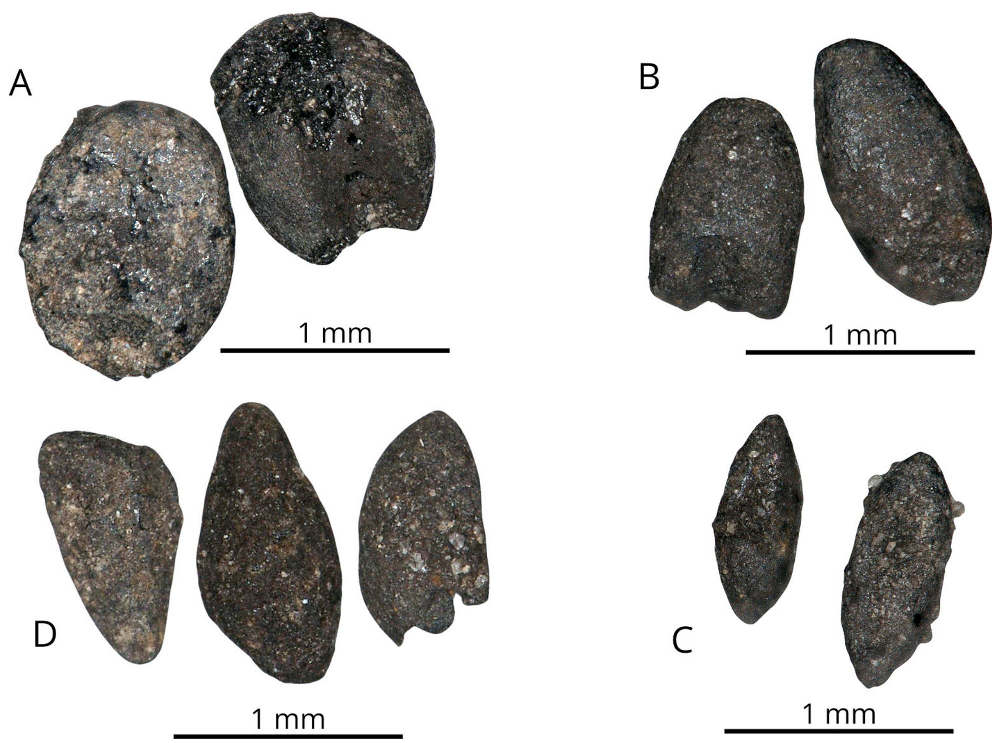

Fig. 8. Charred macro-remains from slag-pits at Zaborów V/22: A – *Echinochloa crus galli*; B – *Digitaria* sp.; C – Poaceae indet. (small grained); D – *Plantago major*.

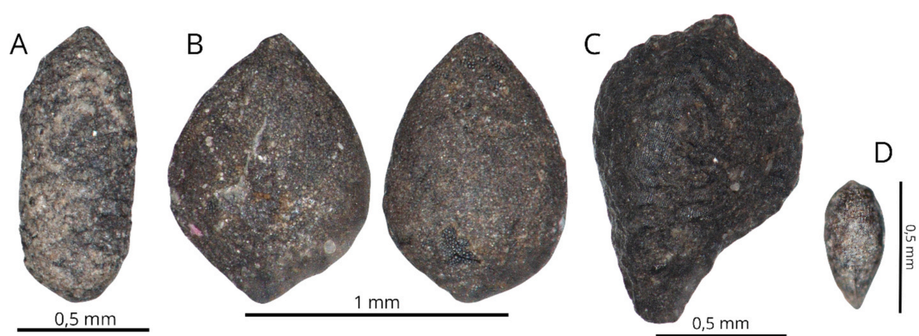

Fig. 9. Charred macro-remains from slag-pits at Zaborów V/22: A – *Hypericum* sp.; B – *Urtica dioica*; C – cf. *Cyperus flavescens*; D – *Juncus* sp.

confirmed by the current data.

The presented study is a first stage of research concentrated on local metallurgy in a broader European context. In the area, off-site palaeoecological studies are not accessible due to strong anthropogenic changes to the landscape and lack of waterlogged, undisturbed sediments dated to the Iron Age, though the search of proper sediments is still conducted. Thus, charred macro-remains, including seeds, fruits, and wood charcoal, as ecofacts closely linked to the archaeological context serve as a source of information about ancient local landscape and its changes caused by human activity. It will be also very interesting to trace changes in smelting technology, while taking into account the extent of the metal production in the Mazovian Centre of Metallurgy, which is estimated to have produced about 120,000 to 150,000 slag-pit furnaces and centuries of metal-production activity. The archaeobotanical investigations followed by series of radiocarbon dates can provide new light on the genesis of large centres of metallurgy in Barbarian Europe, exchange of ideas and culture in central and northern Europe.

CRediT authorship contribution statement

Aldona Mueller-Bieniek: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Adam Cieśliński:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Eliza Drogosz:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Marcin Woźniak:** Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data are stored and available in open repository danebadawcze.uw.edu.pl

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