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REVIEW in POLISH BOTANY CENTENNIAL

Archaeobotanical Studies in Poland – Historical Overview, Achievements, and Future Perspectives

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Abstract

Archaeobotany is the study of relationships between humans and the plant world in the past based on the analysis of plant remains preserved at archaeological sites. These studies provide us an opportunity to elucidate the history of farming economy based on transformations of plants and the natural environment caused by human activities. The present review aims to track the history of development of archaeobotanical studies in Poland, which have influenced our contemporary way of perceiving the past, as well as to present the selected and most important achievements in this field. Specifically, we emphasize the enormous contribution of Polish studies to broadening our understanding of the botanical past of Europe and the world. To the best of our knowledge, this work represents the first comprehensive attempt to summarize over a hundred-year-old activity of archaeobotanists in Poland.

Keywords

archaeobotany; plant remains; history

1. Introduction

Plants create favorable conditions for the settlement of humans, thereby significantly impacting the lifestyle of human communities. Owing to their properties, plants play important economic roles and have always been used by man for various purposes. For instance, plants serve as a source of food for humans and animals and can be used for the production of medicaments, dyes, cosmetics, and clothes. Moreover, plants are used in the construction of buildings and manufacturing of various equipment. Finally, plants are used as fuel material. Humans have always been dependent on the natural environment, and consequently, on the world of plants, which is particularly true with regard to the past. Since the ancient times, humans have utilized whatever the nature could deliver. Simultaneously, while adapting to the surroundings, humans induced, intentionally or not, changes in the natural vegetation of the regions they lived. At a certain stage of cultural development, humans started cultivating selected plants, leading to their domestication and, therefore, driving the speciation of crops and the expansion of farming, in general.

Within the interest of archaeobotany, the history of plant use, emergence of crop species and their worldwide spread, and anthropogenic impacts on the environment can be reconstructed based on fossil discoveries at archaeological sites. To this end, the present review aims to present an overview of the history of development of archaeobotanical studies in Poland. Moreover, we characterize the most important and interesting achievements in this field.

2. Archaeobotany – The Scope of Studies

The major goal of archaeobotanical studies is to recognize the past mutual relationships between humans and plants based on the analysis of plant remains preserved at archaeological sites (Jacomet & Kreuz, 1999; Lityńska-Zajac & Wasylikowa, 2005; Pearsall, 2000; Wasylikowa, 1994). Specifics of the plant material under study, contrary to other fossil flora, result from its direct connection with the human history and culture. Plant remains are collected from archaeological features or layers during archaeological excavations. The number and type of botanical materials preserved at a single site are the resultant of a set of depositional and postdepositional factors. They have a great impact on their conservation and survival until the present. The most significant of these factors are the manner of occurrence of plants in the environment, methods of their utilization and storage by humans in the past, natural properties of plants themselves or their parts that allow their preservation at a given site, and finally, the conservatory conditions of the given sediments. Consequently, plant materials preserved at particular archaeological sites are only a fragmentary reflection of the past reality.

Plant remains encountered within archaeological features and layers include fruits and seeds, wood, vegetative parts of plants, phytoliths, pollen grains, and spores (Jacomet & Kreuz, 1999; Lityńska-Zajac & Wasylikowa, 2005; Pearsall, 2000). These remains occur in various states of preservation. They can be charred, mineralized, waterlogged, or dried. At many archaeological sites, in addition to the direct remains of plants, their imprints on daub or pottery are found (i.a., Gluza, 1971; Lityńska-Zajac & Wasylikowa, 2005; Moskal-del Hoyo et al., 2017; Wasylikowa, 1994). Moreover, indirect evidence of plant utilization, such as wood preserved in the form of so-called postholes, is discovered at many archaeological sites (e.g., Czekaj-Zastawny, 2014).

The major objective of archaeobotany is to collect source material and gather factual data on the occurrence of plants in the past ages. Archaeobotanical studies unveil fundamental source information on plant remains at archaeological sites from the Paleolithic to Modern times. To evaluate plant materials preserved at archaeological sites, the context of a certain find must be properly assessed, which enables the application of appropriate research procedures and, consequently, accurate interpretation of the roles of plants in everyday life of ancient societies (e.g., deposits in storage pits, see Bieniek, 1999; or finds of objects in graves, see Latałowa, 1994a; Moskal-del Hoyo & Badal, 2009). Being rich in quality and abundant in quantity, plant sources allow palaeoecological reconstructions (e.g., Latałowa, 1999a, 1999b; Moskal-del Hoyo, 2021).

3. History of Development of Archaeobotanical Studies in Poland

The scientific documentation in 1920 by Aniela Kozłowska (1898–1981) is considered the first publication in the scope of archaeobotany. The article described remains of cereals from the Neolithic found in the Górna Cave in the Ogrojec Rocks of Ojców (Kozłowska, 1921a, 1921b). This discovery was reported as early as 1904 by Stanisław Jan Czarnowski in the journal *Gazeta Rolnicza* (Dzięczkowski, 1998). However, this was not the first publication related to subfossil plant materials from the Polish territory. In this context, floras uncovered at some archaeological sites of various cultural affiliations, such as those in Strzegom, Popęszyce, Wrocław, and Ostrowiszki, can be named (quote according to Burchardówna, 1953). Moreover, a significant amount of data on wooden objects was gathered from sites in northeastern Poland (Rossius, 1933).

Nevertheless, Józef Rostański (1850–1928) should be considered the pioneer of archaeobotanical studies in Poland, who reported on his own investigations of plant specimens found while unwrapping the Peruvian mummies donated to the Polish Academy of Arts and Sciences by Władysław Kluger. Among these, he found remains of maize, including pieces of a cake. His discussions were presented at the meeting of the Faculty of Mathematics and Natural Sciences of the Polish Academy of Arts and Sciences and published as a major thesis in 1877 (Zemanek, 2000).

Furthermore, there have been limited studies on flora retrieved from archaeological sites excavated in the 1920s and 1930s. Specifically, plant remains, mostly cereals, from the territory of Lithuania have been described (Matlakówna, 1925). Swederski (1925) addressed investigations on plant remains from Lithuania and Lesser Poland. Meanwhile, Zabłocki and Żurowski (1932) and Seild (1936) described the finds of field gromwell supplies from the Neolithic and Bronze Age sites. In another article, Moldenhawer (1939) discussed the finds of cereals and herbaceous plants at an Early Medieval site in Ostrów Tumski in Poznań. Nevertheless, the most important archaeobotanical achievements of the interwar period include the elaborations published by Jaroń, dedicated to plants obtained from the fortress of the Lusatian culture in Biskupin (Jaroń, 1938) and a Medieval settlement in Gniezno (Jaroń, 1939).

During the postwar period, a series of articles presenting finds from individual archaeological sites appeared, which extended our knowledge of plants in the past ages. At present, the database of described plant materials includes finds from approximately 1,000 archaeological sites of various chronologies. In this respect, of particular importance are articles by Melania Klichowska, who analyzed plant materials from multiple archaeological sites. This comprehensive set of elaborations is indeed an important data source, which remains valid even today (see Klichowska, 1953, 1956, 1961, 1964, 1969, 1970, 1972, 1977, 1986, 1989). Investigations by many other scholars have extended the source database of plant remains in the past (e.g., given in the chronological order, Lechnicki, 1955; Moldenhawer, 1959; Kościk, 1963; Orlicz, 1967; Wieserowa, 1967; Giźbert, 1969; Kosina, 1977; Wasylkowa, 1978a, 1978b; Czeczuga & Kossacka, 1981; Gluza, 1983–1984; Madeyska, 1984; Latałowa, 1994a, 1998; Bieniek, 1999; Tomczyńska & Wasylkowa, 1999; Koszałka, 2000; Lityńska-Zajac, 2002; Badura, 2003; Strzelczyk, 2003; Sady, 2015).

The history of development of archaeobotany encompasses not only the increase in the number of investigated sites alone but also the advances in research techniques. Contrary to early studies of plant remains that focused on fruits and seeds as well as wood, pollen analysis was introduced in the 1970s, which aided the botanical recognition of archaeological layers and features (Wasylkowa et al., 2005). The theory of application of this method is addressed in a few handbooks (Dimbleby, 1985; Jacomet & Kreuz, 1999; Latałowa, 2003; Pearsall, 2000; Wasylkowa, 2005). Pollen analysis was applied in the investigation of traces of Neolithic ploughing in Kuyavia (Dąbrowski, 1971), Slavonic barrows in the Białowieża Forest (Borowik-Dąbrowska, 1976), and specific sources, such as coprolites, from the Early Iron Age (analysis performed by K. Wasylkowa in Kowalski et al., 1976). Since the late 1990s, the scope of application of palynology in archaeological investigations has substantially broadened. Specifically, palynology was applied in studies of burial pits and crypts (analysis performed by A. M. Noryskiewicz in Jarosińska et al., 2019; Makohonienko, 2000; Makohonienko et al., 1998a, 1998b), fortress embankments (Makohonienko, 1998), moat filling (Kittel et al., 2018; Makohonienko, 2014; Schubert & Makohonienko, 2000), flax and hemp soakers (palynological analysis by A. Wacnik and analysis of macroscopic plant remains by A. Mueller-Bieniek and R. Stachowicz-Rybka in Kittel et al., 2014), and prehistoric wells (analysis performed by D. Nalepka in Papiernik et al., 2017). In addition, palynology was applied in the investigations of cultural layers at Mesolithic sites in Chwalim (Wasylkowa, 1993a), Bolków in Wkrzańska Forest (Latałowa, 1994b), Śmieli in Kuyavia (Makohonienko et al., *in press*), and sediments of a unique Palaeolithic site of Neanderthals in the Stajnia Cave (analysis performed by H. Winter in Żarski et al., 2017). Furthermore, palynology can be applied in studies of architectural instalments, such as the Renaissance gardens on Wawel Hill (Nalepka, 2009) or the relics of Palatium of the First Piasts in Ostrów Lednicki, which are some of the oldest stone architectures known from the Polish territory (Makohonienko, 2020).

Numerous archaeobotanical studies have investigated wood remains preserved at archaeological sites (e.g., Gierasimow, 1963; Gluza et al., 1988; Moskal-del Hoyo, 2021; Wasylkowa et al., 1992). Most works address fuel wood used in ancient households, while some are dedicated to the utilization of wood at funeral rites (e.g., Moskal-del Hoyo, 2012; Stępnik, 2001). Diverse wooden everyday use objects

from the Medieval Period have also been discovered, indicating that humans selected a particular species or, at least, the type of wood for making an intended piece of equipment (Cywa, 2018; Cywa et al., 2018; Stępnik, 1996).

In the 1990s, investigations on storage tissues begun, focusing on the analysis of plant materials obtained from bulbs and rhizomes, which were likely collected by humans for consumption (Kubiak-Martens, 2005; Wasylikowa et al., 2005). This method was employed for analyzing plant materials preserved at a site in Całowanie (Kubiak-Martens & Tobolski, 2014). The only study of phytoliths (Piperno, 1988, 2006; Polcyn et al., 2005) is based on materials gathered from a site of the Funnel Beaker culture in Mogiła Stradowska (Polcyn et al., 1999). Of note, however, the very first attempts in this direction were made as early as the interwar period by Swederski (1925), who microscopically observed the structure of “silica skeletons” in fruits of various plants (Lityńska-Zajac & Wasylikowa, 2005). Recent studies used stable carbon and nitrogen isotopes (Bogaard et al., 2013, 2016; Styring et al., 2014a, 2014b) for the reconstruction of cultivation conditions and modeling of paleo-diets of humans in Poland (Goslar et al., 2017; Mueller-Bieniek et al., 2019).

Archaeobotanical studies at different archaeological sites, particularly dry and marshy sites, varied in terms of habitat and plant communities. Investigations on underwater cultural sediments were initiated by Tobolski (1989) and continued by Polcyn (1991, 2003) in the surroundings of Early Medieval bridges and dikes on the Lednica Lake and in the fossil lake of Giecz. Further, underwater cultural deposits in an Early Medieval harbor sunken to the bottom of the Puck Bay (Latałowa & Badura, 1998; Pomian et al., 2000) and Early Medieval sites on lake islands in the Lubusz Land (Badura & Noryskiewicz, 2020) were explored.

4. Achievements of Polish Botanists Overseas

Scientific experience of Polish archaeobotanists has been appreciated in investigations conducted abroad during both national and foreign expeditions. One of the continents where the Polish scholars have made the most important contributions is Africa. The greatest number of archaeobotanists were or remain associated with field work in the Egyptian territory. In this regard, the most significant are the achievements of a Polish-American archaeological expedition, named Combined Prehistoric Expedition, which was, at some point, headed by Fred Wendorf and Romuald Schild, succeeded by Michał Kobusiewicz and Jacek Kabaciński (see Wasylikowa & Lityńska-Zajac, 2012). From the Late Palaeolithic complex of sites in Wadi Kubbaniya, near Aswan, abundant plant materials were retrieved and identified as bulbs of *Cyperus rotundus* and *Scirpus tuberosus*, most likely collected for consumption (Hillman et al., 1989), and as wood of *Tamarix* sp., probably utilized as fuel (Tomczyńska, 1989). Successive archaeological investigations in southern Egypt, including Nabta Playa, revealed several campsites occupied by nomadic Epipalaeolithic and Neolithic communities, who gathered numerous plants for consumption, among other purposes. In particular, numerous caryopses of sorghum (*Sorghum bicolor* ssp. *arundinaceum*) were found in features dated ca. 8,000 bp (e.g., Kubiak-Martens & Wasylikowa, 1994; Wasylikowa, 1997). Multidisciplinary analyses of this material revealed that the preserved specimens exhibited properties typical of a wild plant, which is a discovery of great importance for recognition of the history of domestication of sorghum (Wasylikowa, 1997; Wasylikowa & Lityńska-Zajac, 2012, and literature quoted there). In the discussed region of the Western Desert, the exploration of graves uncovered at the cemetery in Gebel Ramlah, where numerous charcoals were preserved, perhaps for funeral rites (Lityńska-Zajac, 2010), is noteworthy. Charcoals in similar context were also found at a campsite in Bargat El-Shab. From this complex, a considerable number of fruits and seeds of utilitarian wild plants, including sorghum, and charcoals, mainly of tamarisk and acacia, deposited within hearths, were discovered. Qualitative and quantitative abundance of plant remains built the foundation for the reconstruction of local vegetation growing around a palaeolake (Bobrowski et al., 2020). Another interesting discovery was made at the predynastic site in Tell el-Farkha, situated in the Nile delta. At this site, fragments of grains as well as husks of emmer (*Triticum dicoccon*) and two-row barley (*Hordeum vulgare*) were found in an uncovered tub,

together with a few remains of darnel (*Lolium cf. temulentum*). Detailed botanical and physicochemical analyses suggested that the discovered substances were the remains of beer (Kubiak-Martens & Langer, 2008).

Sudan is another region where many investigations have been conducted.

For instance, Klichowska (1984a) studied plant imprints preserved on fragments of Neolithic pottery from a site near Kadero. Subsequently, Kubiak-Martens continued botanical research in this region (Kubiak-Martens, 2011). In recent years, Polish scholars have undertaken archaeobotanical investigations in Sudan, in the region of the fourth cataract of the Nile River. In Wadi Umm Rahau, relics were encountered at a campsite dated to the Napatan Period, with traces of goat/sheep pens, within which remains of a few plants, including *Panicum turgidum*, *Arnebia hispidissima*, *Citrullus colocynthis*, and plants of the Cyperaceae family, were preserved, which were most likely used by humans as animal fodder (Badura, 2012). Recently, results from the Khor Shambat site were published (Dunne et al., 2021). Notably, Krystyna Wasylikowa studied abundant plant materials preserved at two rock shelter sites, namely the Epipalaeolithic Ti-n-Torha and Two Caves and Neolithic Uan Muhuggiag, located in the Acacus Mountains of SW Libya (Wasylikowa, 1992, 1993b). Moreover, in recent years, Polish archaeobotanists have been involved in the field work of Polish archaeological expeditions in the territories of Lebanon (Badura et al., 2016) and Georgia (Hamburg et al., 2019), among others.

Currently, Polish botanists are actively engaged in the description of plant materials gathered during various European expeditions. Amongst these, works on materials of various ages obtained in Slovakia (e.g., Lityńska-Zajac, 1995, 1998; Lityńska-Zajac et al., 2008; Moskal-del Hoyo et al., 2015) and Greece (Moskal-del Hoyo & Ntinou, 2017) as well as materials dated to the Neolithic from Hungary (Moskal-del Hoyo, 2013; Moskal-del Hoyo et al., 2018; Nagy et al., 2014), Bronze Age from Ukraine (Stepnik et al., 2017) and Cyprus (Fischer & Bürge, 2019, Appendix 2), Iron Age from Denmark (Kofel et al., 2017), or the Early Medieval chronology from Latvia (Brown et al., 2017) and Spain (Lityńska-Zajac & Rębkowski, 2020), are remarkable.

5. Overview of Selected Archaeobotanical Research Topics

As mentioned above, archaeobotany is a relatively young discipline of science. At the early stages of its development, only a small group of Polish botanists and archaeologists undertook studies in this direction. In recent years, the situation has improved slightly. Nevertheless, the achievements in this field must be considered significant and are discussed below in the context of some leading topics.

5.1. Structure of Crops in the Territory of Poland

The first and foremost topic of archaeobotanical studies is the identification of plants cultivated by ancient human communities. This topic is of great importance from the viewpoint of both botanical and archaeological investigations. While the former discipline revealed the history of emergence and spread of species, the latter provided information on the availability of food, which is fundamental to the existence of human groups. Collection of qualitative data from specific sites facilitated increasingly extensive studies of cereals, legumes, vegetables, fiber and oilseed plants, spices, and fruit-bearing trees and shrubs. However, quantitative data (number of specimens) remain insufficient to recreate the role played by each species in ancient farming. When considering quantity alone, only finds of similar nature, such as stored crop or remains within a features or cultural layer, can be compared (Lityńska-Zajac & Wasylikowa, 2005). In archaeobotany, the term of “crop structure” is employed to evaluate the role of particular crop species. This term refers to the current agriculture and is used to help allocate the data obtained from certain archaeological sites within an appropriate temporal and spatial perspective (Lityńska-Zajac & Wasylikowa, 2005). Crop structure can be recreated at various levels, namely, for an individual site, for a given chronological and cultural unit, or for a selected region with various chronological intervals.

Klichowska (1972) first presented the reconstruction of crop structure at various sites in northwestern Poland. Successive studies revealed differences in terms of

quantity and quality across specific cereal species from various sites dated to the Neolithic (Klichowska, 1975), to the Bronze Age and Early Iron Age (Klichowska, 1984b) throughout the territory of Poland. The source database of cultivated plants and some utilitarian plant species found at sites in East-Central Europe, including Poland, was broad and diverse (Wasylikowa, 1984; Wasylikowa et al., 1991). These comparisons covered all chronological periods and presented quantitative relationships of particular crop species. In addition, the most significant findings related to other plants in natural habitats were highlighted. The most recent summaries referring to the structure of Neolithic crops focused on Kuyavia (Bieniek, 2002, 2007), Lesser Poland, Lower Silesia (Lityńska-Zajac, 2007), and other regions of Poland (Nowak et al., 2020).

Certainly, the viewpoints on “crop structure” depend on the contemporary state of our knowledge and can never be considered ultimate. This has been proven, for instance, by studies on common millet (*Panicum miliaceum*). Until recently, this species was assumed to have been in use since the beginning of the Neolithic only in few regions of Europe (e.g., Poland, Germany, Ukraine, and Moldavia). Subsequently, during the Late Neolithic and then during the Early and Middle Bronze Age, common millet likely covered more or less the entire Europe, although its significance in general was rather inferior to that of other cereals (Lityńska-Zajac & Wasylikowa, 2005; Zohary et al., 2012). However, dating of particular caryopses of *P. miliaceum* revealed that the remains of this species within Neolithic features were younger than indicated by the archaeological structures (Filipović et al., 2020; Motuzaitė-Matuzevičiute et al., 2013). The presence of common millet diaspores within Neolithic features was most likely due to the secondary contamination of plant materials, which is probable at multicultural sites.

5.2. Reconstruction of the Natural Environment and Use of Plants in Historical Towns

Historical urban centers have always been at the core of interest of scholars, including archaeobotanists. In Poland, Władysław Szafer pioneered botanical studies on materials obtained from historical towns by analyzing plant remains from archaeological excavations in Kraków as early as the 1930s (Zemanek & Wasylikowa, 1996). In 1939, similar elaborations were published by Konstanty Moldenhawer for Ostrów Tumski in Poznań (Moldenhawer, 1939) and by Bronisław Jaroń for Gniezno (Jaroń, 1939). These publications were based on the identification of macroscopic remains, and these are considered an extremely important data source even today. These analyses focused, for the first time, on plant-based economy at the beginning of both these urban centers.

World War II ceased the development of all scientific fields. Nevertheless, shortly after its end, archaeologists resumed investigations of urban sites. Exploiting the opportunities provided by the reconstruction of destroyed towns, archaeobotanical studies were undertaken in Kraków (i.a., Giźbert, 1960; Gluza, 1970; Klichowska, 1956, 1964; Wasylikowa, 1965, 1978a, 1978b; Wieserowa, 1979), Gdańsk (i.a., Lechnicki, 1955; Lechnicki et al., 1961) and Poznań (Dymaczewski, 1961; Niesiołowska et al., 1960), among others. Small elaborations were published from Szczecin (Klichowska, 1960) or Wolin (Klichowska, 1957, 1961). Most of these papers described the remains of utilitarian plants from the Early Medieval stages of development of these towns. Kraków was one of the first archaeobotanical case studies in which novel approaches, such as palynological, xylological, or moss analyses, were employed (Karczmarz, 1979; Wasylikowa, 1978a, 1978b, 1991). Unfortunately, for a great majority of sites, only small publications are available, covering merely lists of taxa without any additional specific information on research methods. Notwithstanding, these are considered an invaluable data source.

The 1990s and modern times mark the periods of intensification of archaeological works in most of the towns in Poland due the reconstruction and modernization of their infrastructure. This offered researchers a great opportunity to undertake systematic studies of plant materials using various types of analysis and based on a concept shared among archaeologists, historians, and archaeobotanists. For instance,

in the 1990s, an Early Medieval harbor in Wolin was subjected to extensive research, with a major role played by Polish archaeobotanists (Latałowa, 1997, 1999a, 1999b; Latałowa et al., 1995). The studied harbor was significant in that it stimulated the development of the town itself in successive periods. Archaeobotanical studies conducted at the time not only furthered our knowledge of the botanical past of Kraków (i.a., Mueller-Bieniek, 2012), Poznań (Koszałka, 2005a, 2005b, 2008), or Gdańsk (i.a., Badura, 2011; Święta-Musznicka & Latałowa, 2016; Święta-Musznicka et al., 2011) but also revealed massive information on other towns, including Kołobrzeg (i.a., Badura, 2000, 2016; Latałowa et al., 2003), Elbląg (i.a., Badura et al., 2004; Jarosińska, 2004; Latałowa et al., 2003), Gniezno (Koszałka, 2000; Makohonienko, Kara, & Koszałka, 2011), Wrocław (Kosina, 1977, 1995; Sady, 2018), Lublin (Sady-Bugajska, 2020), and many more small yet extremely important historical urban centers, such as the Medieval towns Puck (Maciejewska et al., 2020; Pińska & Badura, 2017) or Tczew (Pluskowski et al., 2019) in northern Poland and Gliwice in the south (Sady, 2016a, 2016b, 2016c), among others.

Archaeobotanical studies conducted in Polish towns and cities shed light on two significant topics: use of plants (human diet, medical treatments, and trade) and reconstruction of ecological conditions of the local environment. The former is consistent with research trends in Europe and served as the basis for more comprehensive comparisons at a much greater scale. This is well exemplified by the data collected from Gdańsk, Kołobrzeg, and Elbląg, which could be discussed against the background of archaeobotanical results from other Hanseatic centers in Europe (e.g., Latałowa et al., 2007, 2009). These data confirmed a significant regional differentiation in dietary customs of people living in the towns of northern Europe. Materials from Gdańsk, Elbląg, and Kołobrzeg indicate, beyond any doubts, that between the fourteenth and seventeenth centuries, imported goods were present on the tables of the rich and were also available to moderately wealthy citizens, and the diet itself was diversified and rich in various species of fruits, in particular.

The occurrence of utilitarian plants in towns has been noted in extremely valuable written sources. Nevertheless, only after comparing the information in historical documents with the list of taxa identified based on materials gathered from archaeological sites, more coherent cognitive results can be obtained, which in turn can allow for a more comprehensive assessment of the roles played by plants in everyday life of ancient communities. Such studies have been conducted at large urban centers, including Kraków (Zemanek & Wasylkowska, 1996), Gdańsk, Elbląg, and Malbork (Badura et al., 2015).

An interesting way of interpretation of data referring to plants of both utilitarian and specific economic significance was presented for Kraków. In this case study, advanced statistical methods were employed, which are very rarely encountered in archaeobotanical elaborations of urban sites (Mueller-Bieniek & Walanus, 2012). These methods proved the distinctiveness of one of the areas under investigations. Interestingly, statistical analysis of the composition of samples in terms of occurrence of crops and allegedly cultivated species revealed the distinctiveness of the latter, the diasporas of which could have mostly been the remains of wild plants (i.a., carrots or oregano). Furthermore, these plants delivered a surprising find of diasporas of cultivated (and imported) fig. Moreover, an interesting connection of oilseed (flax, hemp, and rapeseed), flavoring (hop), and stone fruit plants with the Late Medieval wooden buildings in the northwestern part of the Main Market was revealed. Undoubtedly, this manner of data presentation is extremely valuable from the viewpoint of archaeology and sociotopography of ancient towns.

The current archaeobotanical studies of Polish towns and cities complement the archaeological data with regard to settlement conditions in the earliest extent in a manner which is rarely encountered in European research. The cooperation between archaeobotanists and palaeoecologists has resulted in the emergence of studies addressing the transformation of the environment and development of cultural landscapes starting from the very beginnings of a human settlement in a given region, through the early urban settlements, until the Industrial Epoch. The first works of this sort were conducted for Kraków, providing the basis for drawing conclusions on the nature of vegetation within the city boundaries and its wider

surroundings (i.a., Trzcńska-Tacik & Wieserowa, 1976; Wasylkowa, 1991). Subsequently, the environmental conditions for Gniezno (Makohonienko, Kara, & Koszałka, 2011) and Poznań (Makohonienko, Makowiecki, et al., 2011) were illustrated. The most recent publication in this context focused on Gdańsk (Święta-Musznicka, Badura, Jarosińska, & Latałowa, 2021; Święta-Musznicka, Badura, Pędziszewska, & Latałowa, 2021). Comparison of palaeoecological data obtained from sites in various parts of the present city indicated gradual transformation in the natural environment, as confirmed by the multistage process of formation of this Medieval agglomeration. Economic pressure and demographic development resulted in the growth of trophic level of terrestrial habitats, which in turn stimulated the expansion of abundant anthropogenic vegetation. In habitats created by humans across all districts of the city, plant communities with predominant epiphytes typical of riverine habitats, floodplain grasses, and nitrophilous scrubs developed. This great diversification of anthropogenic vegetation in the twelfth and thirteenth centuries is attributed to climatic changes that fostered the expansion of thermophilic archaeophytes as well as the introduction of new cultivated species into local gardens.

5.3. Phytosociology and Autecology in Environmental and Economic Interpretations

The development of archaeobotany and continuous progress in the recognition of an increasing number of wild herbaceous plant species preserved at specific archaeological sites of various chronologies prompted attempts at palaeoecological interpretations of these materials, consistent with European research trend at the time (e.g., Willerding, 1979, 1986). Importantly, however, as early as the interwar period, Polish botanists interpreted the findings of herbaceous plants from an ecological perspective. This approach was adopted for the presentation of plant materials preserved in Biskupin (Jaroń, 1938) and Gniezno (Jaroń, 1939). In the former publication, Jaroń (1938) distinguished and described crop field weeds, ruderal plants, and species from natural communities, including those originating from (i) forests; (ii) brushwoods; (iii) meadows; (iv) pastures, roadsides, and sands; and (v) swamps and waters. Subsequently, Giźbert (1971) discussed the roles of weeds in archaeological finds.

In a more recent approach, employed since the 1970s for the interpretation of plant materials, the phytosociological and autecological methods were used based on ecological indices introduced by Ellenberg (1950, 1974) and Zarzycki (Zarzycki, 1984; Zarzycki et al., 2002). The application of these methods is in accordance with the principle of geological actualism (Lityńska-Zajac & Wasylkowa, 2005), which in simple terms allows for determining the course of ancient processes based on contemporary observations. Theoretical assumptions for economic and ecological interpretations based on the finds of wild herbaceous plant remains, lying together with the remains of cultivated plants in storage pits or granaries of other types or dispersed within archaeological layers or features, were presented (Lityńska-Zajac, 2005; Lityńska-Zajac & Wasylkowa, 2005; Wasylkowa, 1981, 1983). Further, the above-mentioned methods were applied for the examination of botanical materials gathered from specific archaeological sites. Among these, Early and Late Medieval sources from many sites quoted above (Badura, 2011; Maciejewska et al., 2020; Wasylkowa, 1978a, 1983; Wieserowa, 1979), materials from a site of the Lengyel culture in Kraków-Nowa Huta Mogiła 62 (Gluza, 1983–1984), and materials from site of the Roman Period in Wąsosz Górny (Bieniek, 1999) are peculiar.

Relatively abundant finds of the remains of spontaneous wild herbaceous plants built the foundation for formulating hypotheses regarding the formation of certain communities of field crop and ruderal weeds as well as tracking temporal changes in synanthropic communities. The data obtained from particular archaeological sites allowed for determining the time of emergence of various archaeophytes. Moreover, autecological analyses allowed for determining the type, moisture, acidity, or abundance of trophic compounds in soils on which the crops were cultivated. Based on a few finds from storage pits, some attempts were made to evaluate the applied practices of plant cultivation and land management by determining the time

of sowing and harvest, equipment used for crop harvest, and method of seed sowing (as a mixture or in monoculture). Where possible, the degree of weed infestation of sown seeds was also determined. Such works were performed at several sites of different chronologies situated in various physical and geographical regions of Poland (e.g., feature No. 8 of the Lengyel culture in Iwanowice, site Klin, feature No. 32 of the Funnel Beaker culture in Kraków-Prądnik Czerwony, feature No. 106 of the Lusatian culture in Sobiejuchy, and the Early Medieval feature No. 18/87 at Site 12 in Parchatka) (Lityńska-Zajac, 2005).

Furthermore, analyses of wild plant species preserved at archaeological sites allowed for illustrating the manner of emergence and track the changes in flora and synanthropic vegetation in pre- and early historic times. Additionally, these analyses provided the grounds for comparing the transformation of contemporary synanthropic flora in a given region with data derived from archaeological excavations in Medieval Kraków (Trzcińska-Tacik & Wasylkowa, 1982; Trzcińska-Tacik & Wieserowa, 1976) or sites of the Roman Period in Jakuszowice, community Kazimierza Wielka (Trzcińska-Tacik & Lityńska-Zajac, 1999).

6. Conclusions

We are aware that the short overview of archaeobotanical studies in Poland presented here is undoubtedly limited in terms of reference to the existing literature and research trends. We have referred to selected works performed at specific archaeological sites, within cultural layers and archaeological features. The review excludes many elaborations addressing the cultural aspects of materials obtained from direct or close surroundings of archaeological sites. Moreover, the contributions of other branches of botany, such as plant anatomy (carpology, xylogy, and anthracology), ecology, agricultural science, and ethnology have not been discussed. To address to these shortcomings, a significantly wider elaboration is warranted.

Reconstruction of particular aspects of the past is a complex challenge and requires collaboration among various scientific disciplines. Archaeobotanical studies in Poland have been perfectly incorporated into the scheme of interdisciplinary investigations, engaging historical sciences, ethnography, geology, geography, molecular biology, and computer science (numerical analysis). Archaeobotanical sources have unearthed information on the ancient world of plants growing in the vicinity of humans since the very beginning of the Palaeolithic until the modern times. Since a long period of history, plants have been and are the sole or one of the most crucial sources of information. Polish archaeobotanical studies have made invaluable contributions to extend the database of sources for elucidating the synanthropization process of vegetation and development of cultural landscapes in the territory of Poland and other regions of the world. In recent years, the number of overseas studies by Polish researchers has increased substantially, expanding our knowledge of the history of utilitarian plants and routes of their expansion. This has further allowed for identifying the developmental stages of farming economy. Overall, archaeobotanical studies have offered valuable data for the assessment of biodiversity in the long-term.

Although archaeobotanical studies focus on the past, their results are of great significance for the understanding of the present. As such, the status of contemporary vegetation is a result of long-lasting historical processes. Without knowing the past, we cannot accurately evaluate and understand the present scenario of vegetation. Revealing the long history of the common journey of humans and the plants they utilized as well as transformations of vegetation and landscapes induced by anthropogenic activities has an important practical aspect associated with the management and preservation of cultural and natural heritage. This builds the foundation for shaping the protected landscapes, particularly surroundings of archaeological reserves and architectural objects, consistent with the given cultural epoch.

Tracing the development of archaeobotanical studies in Poland has enormous value for exploring many facets of connections between humans and the world of plants in

the past. Polish investigations are in no sense inferior in terms of their level to studies conducted in other parts of Europe or worldwide. In fact, their scope and precision, in some cases, exceeds the accepted standards. Polish archaeobotanists have successfully adopted and developed new research technics and procedures. Nevertheless, many elaborations in the form of reports or short announcements remain hidden within the “grey zone.” Archaeobotanists should aim at going beyond their previous achievements while simultaneously making the necessary effort to integrate unpublished works, particularly those that can significantly extend our knowledge of the past, in the current research.

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