

THE HISTORY OF BROOMCORN MILLET (*Panicum miliaceum* L.) IN THE CARPATHIAN-BASIN IN THE MIRROR OF ARCHAEOBOTANICAL REMAINS II. FROM THE ROMAN AGE UNTIL THE LATE MEDIEVAL AGE

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Abstract

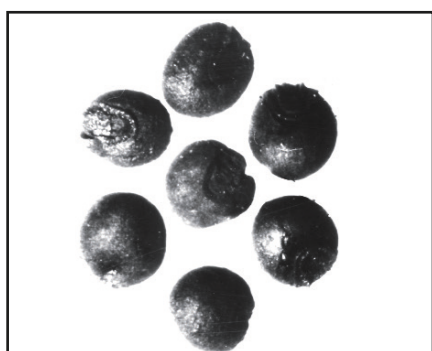
The domestication of broomcorn millet based on latest archaeobotanical investigations occurred in the arid areas of North China and in same time in Central Asia. The knowledge of cultivation of broomcorn millet the Carpathian Basin before the 6th thousand BC. Since this time in all archaeological ages are available but in different frequency. Broomcorn millet was a widespread and favoured cereal. Knowing the eating habits of nomadic and semi-nomadic people, this find is expected, as broomcorn millet is a favoured cereal with a short growing season and rapid development requiring relatively little tending. This is expected as broomcorn millet was a key crop for Hungarians in the Middle Ages. A significant amount was grown traditionally by Hungarians through time until the appearance of maize, the new gruel plant. In the second part will be present the history of broomcorn millet in the Carpathian Basin from the Roman Age until the Late Medieval Age.

Keywords: broomcorn millet, archaeobotany, macroremains, Carpathian-Basin, historical ages

History of broomcorn millet from the Migration Period until the Late Medieval

Broomcorn millet was also eaten in roman Pannonia (1st-4th Century AD) albeit its amount and significance fell behind those of wheat and rye. The majority of carbonised grains come from Late Roman barbacans and other military settlements (canabae): Budakalászluppa csárda, Budapest-Körte Street, Leányfalú-Móricz Zsigmond Street, Óbuda, Bécsi Street 38–42, Óbuda Corvin Square, but it can be found at other places as well: Dunaújváros, Nemesvámos-Balácapuszta, Sopron-Beloianisz

Figure 1. Broomcorn millet naked grains found on the peel of an oven in a Late Roman building, Budapest, Körte utca 29. Inventory of the Hungarian Agricultural Museum, Budapest.



Square and Városház Street, Tokod (Hartyányi, Nováki & Patay 1967/68) (Fig. 1).

According to the investigations made by Miklós Füzes in 1970-72 and in 1974, cereals account for the overwhelming majority of seed remains coming from the Late Roman Period in Keszthely-Fenekpuszta, naked barley occupying first place among them. There is somewhat less of common bread wheat and rye followed by the rarely seen broomcorn millet with common oat least. In 1993, at the western fortress gate of the Keszthely-Fenekpuszta fortress, at the excavation led by Róbert Müller, a substantial amount of Roman botanical material was collected (Gyulai & Kenéz 2009). Significant amounts of broomcorn millet as well gruel fragments were also found in by Orsolya Heinrich-Tamácska conducted excavations 2009 (Gyulai, Kenéz & Pető 2013).

While the high level crop production practices of the inhabitants in Pannonia are supported by considerable evidence, relatively little is known of the plant growing habits of the „barbarians” who lived in the Great Hungarian Plain. Addressing this issue will substantially improve our awareness of the culture and lifeways of these peoples.

Their cropping culture must have differed from that of the Romans to a great extent, particularly in terms of the cultivars as no changes had taken place since the prehistoric ages (Hartyányi, Nováki & Patay 1967/68). Its naked grains were identified in the sites of Földeák, Garadna. Contemporary literature offers little information of the Sarmatian Period. Ptolemaeus wrote of their cities in the middle of the 2nd Century AD (in: Párducz 1971), while Plinius Secundus (Nat. hist. 18, 100) reports that their staple food was millet porridge mixed with horse milk and blood. According to archaeobotanical findings from the Late Sarmatian Period so far (Hódmezővásárhely-Solt Palé, Szalkaszentmárton-Dögtemető) their main crop was broomcorn millet, yet hulled emmer wheat was also cultivated (Hartyányi, Nováki & Patay 1967/68).

Botanical macrofinds, analysed between 1987 and 1990 by Dénes B. Jankovich, gave similar results to the pollen analysis at Endrőd No. 170. Botanical samples came from Sarmatian (4–5th Centuries) houses and pits of different uses. The relatively great number of barley and broomcorn millet finds suggest the survival of nomadic dietary patterns (Gyulai 2011).

Further significant results of Sarmatian archaeobotany were obtained by Csaba Szalontai and Katalin Tóth in 1998 and 1999 at the Kiskundorozsma-Nagyszék site dated to the 3rd–4th centuries AD. Their most important cereals were six-rowed barley and broomcorn millet, reflecting doubtlessly a continuation of their nomadic traditions (Gyulai 2003).

Botanical finds from the Carpathian Basin and surrounding countries indicate that in the Migration Period a much more modest crop production system replaced Roman agriculture. Broomcorn millet is dominant, a characteristic type of cereal for quickly moving nomadic people (Wasylikowa et al., 1991).

It is well known that the Huns, who settled in during the middle of the 5th century, were nomadic, warfaring people.

Unfortunately, no botanical material has been recovered to date associated with their settlement in the territory of Hungary. We know from Priscos rhetoris' contemporary description that their food was made of broomcorn millet, their drinks of barley (in: Harmatta 1952).

Caches associated with the Gepids, a people who lived in the area beyond the Tisza, are explicit evidence of a farming lifestyle (Müller 1982). Cereals that were found in remains in Eperjes-Csikóstábla (excavations by Csanád Bálint 1976–77) in earth samples taken from the floor of a house destroyed by fire must have been grown locally. Most are broomcorn millet, the rest are common bread wheat and six-rowed barley grains (in: Gyulai 2010).

In 1986 excavations were carried out in Devín (Dévény), near Bratislava, Slovakia, along the limes at the time, at a settlement dated to the 5th century AD, populated by Danube Germans or maybe Kvads (Pieta 1988; Pieta & Plachá 1989). The composition of the cereals obviously stocked for kitchen use shows an advanced level of agriculture: 66% rye, 21% common bread wheat, 11% barley, 1.6% broomcorn millet.

We do not know much of the lifestyle of the Avars, the people moving in to the Carpathian Basin in 568 AD and again later in 670. It is thought that the main crop of the Avars was broomcorn millet, yet this does not mean that they continued to be nomads, but rather that they insisted on their historical tradition with respect to eating habits. One can assume for certain that by the 7–8th Centuries, the Avars have changed their way of living. They settled down and conducted a farming system mixed with livestock husbandry (Kollautz & Miyakawa 1970).

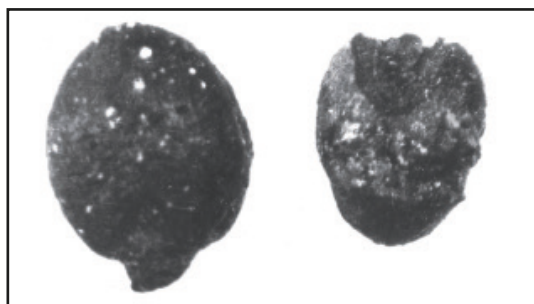
It is certain, however, that a major staple food was bread (gruel) from broomcorn millet, as indicated by carbonised grains from the Szirák Avar graveyard (Hampel 1897).

The botanical remains in Szegvár-Oromdűlő are typical for a settled population growing tillage crops and garden produce (Gyulai 2010).

One of the favourite plants of those living here was doubtlessly broomcorn millet. Both their food and drink were made of it. During the flotation of a sample coming from grave ceramics, two pieces of husked broomcorn millet grain was also observed, burnt together with – or rather burnt into – food scraps. They lacked the germ portions that are usually broken away when husked.

One of the most important botanical findings in Hungarian archaeobotanical research was uncovered from the late Migration Period Fonyód-Bélatelep site, the excavation of Béla Horváth in 1964 (Gyulai, Hertelendi & Szabó 1992). Based on 14C tests, the age of the settlement, made up of lake dwellings, can be dated from the second half of the 7th century to the end of the 9th Century. The main crops of the inhabitants were barley, common bread wheat, club wheat, broomcorn millet, rye and common oat (Fig. 2).

Figure 2. Broomcorn millet naked (husked) grains with and without the germ disk from Fonyód-Bélatelep Late Migration Period lake dwelling. Photograph by the author.



Decades of excavations, led by Ágnes Ritoók and Miklós Béla Szóke, of a parking lot exposing the 9th Century site of Zalavár-Vársziget, initiated collection and flotation of soil samples for botanical remains in 1994 (Gyulai 1998). According to historical data, the Carolingian court centre was populated by common people of mixed ethnic composition. Most seeds and fruit remains come from the fill of a „well”, which was probably a planked storage pit. The botanical material is dominated by cultivated plants and their weeds.

The most important crops were broomcorn millet, six-rowed barley and common bread wheat. Only a very few seed finds are available from the conquest age which relates to crop production (Hartyányi, Nováki & Patay 1967/68). An exception is a conqueror belonging to the elite, whose grave was located within the current country boundaries in Zemplén, which contained broomcorn millet grains. Consequently the most important food was gruel (Rapaics 1934; Gaál 1978).

The main Hungarian botanical find from the age of the conquest (beginning of the 10th Century) comes from Lébény-Billedomb, the 1993 excavation of Miklós Takács (Gyulai 1997). Hulled wheat types, typical in prehistoric ages, were not grown at all, only the more advanced naked grain common wheat are found. An important gruel plant was broomcorn millet, as unearthed carbonised broomcorn millet gruel pieces show.

Similar remains were found from the Early Árpáadian Period site of Gyomaendrőd (excavation by Dénes B. Jankovich 1987–90) and from the Árpáadian Period site found at the exploration of the M0 motorway in Rákospalota-Újmajor (excavation by Zoltán Bencze 1995–96). These gruel-like foods prepared from broomcorn millet imply the survival of nomadic eating habits (in: Gyulai 2010).

When exploring Edelény-Földvár in 1992–2001, Mária Wolf found clay pots placed on their sides near the oven of a burnt house from the 10th Century. One remain consisted of many carbonised fragments with no contamination as it was homogenous. Embedded in fine groats, husked millet grains were also observed (Gyulai 2014).

Relatively more evidence has been recovered from the period (10th–11th Centuries) after the conquest (Hartyányi, Nováki & Patay 1967/68). In the early period, broomcorn millet continued as the primary grain crop. In Kardoskút, during excavation of a 10th–13th Century village, cereal

grains were found among burnt straw under an oven. Numerically, the most important grain was broomcorn millet followed by bread wheat and rye. In Tiszaörvény, during excavation of an 11th–13th Century village, broomcorn millet awn remains were observed, apparently stored in considerable amounts in a corner of a house.

Dominance of broomcorn millet remains supports the contention that, in the Great Plain after the conquest, nomadic lifestyle and nomadic pasture rotating large livestock husbandry continued to a significant degree. Broomcorn millet, to be grown more easily and ripening more quickly when compared to wheat, was the typical crop of nomadic and semi-nomadic husbandry.

In contrast to this, in Transdanubia along the river Danube and northern Hungary examining finds from the 10th–11th Centuries, common bread wheat, a crop assuming much more advanced production skills than broomcorn millet, appears, although only sporadically.

The same can be said about the remains coming from the northern part of the country: more valuable kinds of crops were grown here as well (Hartyányi, Nováki & Patay 1967/68). Adjacent to the Roman church at Esztergom-Kovácsi, 11th century graves provided botanical materials characterised by common bread wheat and rye, both having longer growing seasons.

When one compares the earliest finds of the period after the conquest, the conclusion is that broomcorn millet played an important role mainly in the Great Plain, while common bread wheat and rye did the same in Transdanubia. The finds from the Plain support the notion of limited nomadic patterns in the period after the conquest. The finds from Transdanubia and from the northern part of the country suggest a sedentary lifestyle and a more advanced level of agriculture.

The Danube River, which is a historical as well as floristic boundary, also divided the country into two major areas of different crop production: the Great Plain, producing more archaic plants (see production of emmer below) and Transdanubia,

a more advanced region integrating the traditions of Roman agriculture.

Grain finds from later excavations in the 12th–13th Centuries in the Plain start to show similarities with those found in Transdanubia both in terms of species composition and their relative importance (Hartyányi & Nováki 1973/74). Apparently, the population in the Great Plain became settled only a century later, by the 12th–13th Centuries. The alteration of sowing seeds, representing a quality change in crop production, was completed by this time. Growing high nutrient common bread wheat and rye became customary. The significance of broomcorn millet declined but it was retained in production up to the Modern Period as an aftercrop providing gruel dishes.

In 1996 at the Rákospalota-Újmajor site, most probably another segment of Sikátor village, was excavated by Anna Gyuricza. This time, a well, dated to the 13th–14th Centuries, rich in plant residues was also identified. Expansion means, when compared to the Early Árpáadian Period, club wheat and common oat. The number of club wheat grains, like that of broomcorn millet grains, is low, both of them being typical for the Middle Ages in Hungary (Gyulai 2010).

The objects explored in Solt Tételhegy in 1999 contained three culture layers (Late Bronze Age, Árpád-Age and Late Medieval). In the Bronze Age objects only one broomcorn grain was found. Much more, near by 400 pieces were available in the Árpád-Age objects (pits, fireplaces and houses). In the Late Medieval (15th Century) ashy layer not only dozen broomcorn millet grains were found but also charcoal cerealgruel (Gyulai in press).

Compared to other sites, the culture layer explored in the cellar under Hunyadi Street 22 in Budapest, first district in 1973, is unusually rich in cultivated plant remains. Here, a series of locally grown and gathered plants were obtained from a pot dated to the 13th century, but a number of broomcorn millet remains and several weed species were also encountered. Seeds were

identified by István Skoflek and Mrs. Hortobágyi (in: Hartyányi & Nováki 1973/74).

Written sources (Diploma-Archives from the Sigismund-period) mention wheat six times, broomcorn millet three times, oat and hemp once between 1387–1399. Likewise, between 1400–1410 references occur to millet three times (in: Gaál 1978).

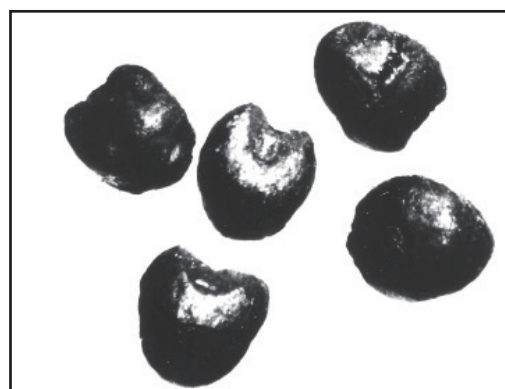
Important evidence for a uniform medieval crop production culture is seen in the late medieval botanical material of Muhi (in: Gyulai 2010). Although the samples collected and locally floated in 1995 at the Muhi medieval excavation site led by József Laszlovszky and Tamás Pusztai are still not completely processed, the cereals identified so far (common bread wheat, club wheat, rye, six-rowed barley, broomcorn millet) confirm the level of farming typical for the age.

Led by András Horváth Pálóczi, archaeologist at the Agricultural Museum, several wells were explored at the late medieval Cuman settlement in 1984–87 at Lászlófalva-Szentkirály. It is not known whether six-rowed barley, a grain crop that occurred most frequently in the finds, was grown as fodder or was intended for human consumption. However, broomcorn millet, common bread wheat and rye necessarily must have served for human consumption (in: Gyulai 2010).

Half of the archaeobotanical material found at Dunaföldvár-Öregtorony site (ruins of a 17th century house) consist of rye, somewhat less of common wheat and even less of broomcorn millet (Hartyányi & Patay 1970) (Fig. 3). A favourite gruel plant was broomcorn millet in the Hungarian Middle Ages.

It can be found at almost all medieval sites: for instance, in the destruction layer of a 15th–16th Century housing estate in Nagyvázsony-Csepely (in a 40 cm³ mass of mostly hulled aggregate) and in the 17th Century dwelling- house at Székesfehérvár-Palotai Street 5 (Hartyányi, Nováki & Patay 1967/68). In the course of the exploration and reconstruction of Buda castle over the past fifty years, archaeologists found

Figure 3. Broomcorn millet naked grains from Dunaföldvár-Öregtorony, beginning of the 17th century. Inventory of the Hungarian Agricultural Museum, Budapest.



a number of wells. The first archaeobotanical examinations were made at the well of Dísz Square No. 10, led by Imre Holl. Seeds from the well, dated to the 14th century, were identified by Zoltán Zsák (in: Holl 1966). In 1955 Győző Gerő explored a 13th–14th century well at Úri Street 40. (Hartyányi, Nováki & Patay 1967–68). In 1966, at Dísz Square No. 8., yet another well with seeds was found, dated by Katalin I. Melis to the 13th–14th Centuries based on associated ceramics (Hartyányi & Nováki 1973/74). Compared to other contemporary sites, an unusually large quantity of garden produce remains were identified in a medieval well filling explored in a cellar of Hunyadi Street 22 in 1971. A wide variety of produced and gathered plants were unearthed from a pot dated to the 13th century surrounded by a burnt layer. Broomcorn millet and a number of weeds also occurred (Seeds were identified by István Skoflek and Mrs. Hortobágyi (Skoflek & Hortobágyi 1973).

Carpological remains (seeds and fruits) from the two Buda castle 14th–15th Century wells are all direct botanical finds. Water created anaerobic conditions that in turn prevented microbes from decomposing the diaspores. Although no broomcorn millet grains were found, husking refuse in forms of one thousand husks occurred in a non-carbonised form. The endospore fell out of the grains. This is evidence of cleaning as the eye often breaks out during threshing.

Glumellae coming from the cleaning procedure did not carbonise (Gyulai 2010). In Vác, Piac utca 14th-15th Century settlement (excavation by Orsolya Mészáros 2008–2009) were also some broomcorn millet grains found but in special way by iron salts conserved forms (Kenéz, Pető & Grynaeus in print).

Devastation layers from the Turkish Period are relatively well researched from a botanical point of view. Between 1969 and 1974 Imre Holl and Nándor Parádi led the excavation of a village razed during the Turkish era in the 16th century in Sümeg-Sarvaly. Botanical finds from six houses devastated and burned during the Turkish Period and adjacent debris were processed by István Skoflek (1984–85) and Borbála Hartyányi (in: Nováki 1984/85). Beside grains and seeds of carbonised common bread wheat, rye, broomcorn millet and weeds, fruit remains were also encountered.

In Színház Street, which is situated in an area where the Buda castle existed in the Turkish Period (excavation by István Feld 1995) and in Óbuda, Medve street (excavation by András Végh 1995) common bread wheat and six-rowed barley grains were also found, but the numbers indicated that they must have not been very significant. Much more important were broomcorn millet and common oat (in: Gyulai 2010).

Cereals (common bread wheat, rye, broomcorn millet) mentioned in the tithe census were found without exception in the houses of Nagyvázsöny-Csepely dated to the 15th–17th Centuries (Júlia Kovalovszky 1957–58 in: Hartyányi, Nováki & Patay 1967/68) (Figs. 4, 5).

In 1998 near Baj Öregkovács-hegy in the forest, excavated by Sándor Petényi, were also dated to the Middle Ages. Two pot fragments contained unusually large millet grains, incremented due to burning into the wall of the pot. Burnt grains were stuck together in smaller or larger clumps, obviously solidified in this way during cooking (Gyulai 2010). The millet gruel found here characterised Hungarian food culture in the

Figure 4. Broomcorn millet naked grains from Nagyvázsöny-Csepely (15th–16th centuries). Inventory of the Hungarian Agricultural Museum, Budapest.

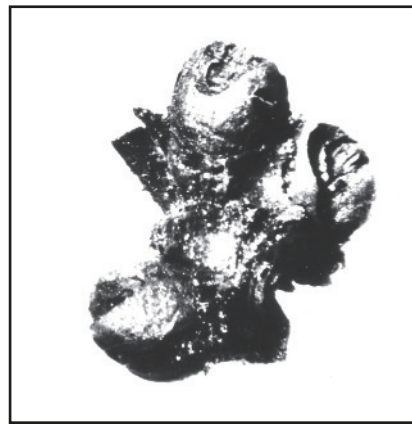
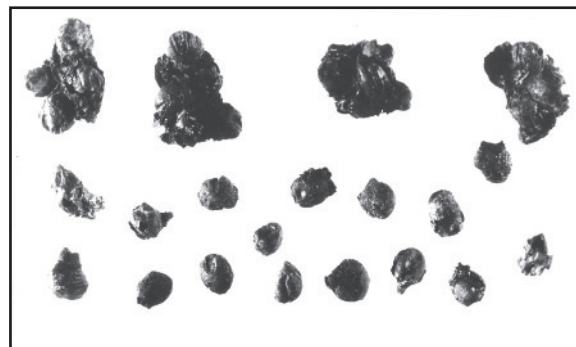


Figure 5. Broomcorn millet naked grains and gruel fragments from Nagyvázsöny-Csepely (15th–16th centuries). Inventory of the Hungarian Agricultural Museum, Budapest.



Middle Ages. Millet gruel used to be a traditional staple food for Hungarians, which can be traced back to the times before the conquest. It is known from a number of sources that in the life of Hungarians, just as in the case of any other European people, the consumption of gruel made of husked millet played a decisive role.

Millet gruel was a common dish, irrespective of social rank and privileges, and it continued to be so up to the 18th–19th Centuries until the spread of maize „Turkish wheat” coming from the New World provided a new gruel plant.

Modern examinations of ancient millet grains

The current technology of plant biotechnology and genetics makes it possible to regenerate

plant individuals from only one cell (Dudits & Heszky 2000). If only one cell of the seed tested remained intact and untouched over the centuries, plant regeneration is technically possible (Gyulai et al., 2001). Plants can be developed from cells of surviving callus, provided the DNA content of the nucleus is not impaired. For this purpose broomcorn millet was taken first from the well dated to the beginning of the 15th Century, found under the building of the former Military Headquarters, Teleki Palace in Buda Castle, (excavation by Zoltán Bencze, Dóra B. Nyékhelyi, András Végh 1998–99), as well as from the well dated also to the beginning of the 15th century in Budapest I., Kapucinusok Street (excavation by András Végh 2000). The seeds were incubated using the same procedure as with recent plants, on culture medium supplemented with growth promoting hormones.

Germinating tissues were found only in broomcorn millet, muskmelon, cantaloupe and watermelon cells, unfortunately however the „resurrected” cells were soon killed by endogen infections (mycoplasmas, phytoplasmas).

DNA was isolated based on the methods developed by Gyulai et al. (2000) for molecular genetic studies only from material suitable for

the extraction of the genetic material (broomcorn millet). Comparative genetic assessment of the material was tested using the PCR method (Williams et al., 1990). The genetic tests carried out confirmed that medieval broomcorn millet theoretically might contain intact surviving cells. Even though the plant regeneration experiment was not successful this time, the plants still contained a large amount of extractable DNA. The PCR method confirmed that the DNA extracted is of plant origin and does not come from the decomposing bacteria and fungi. PCR reactions verified easy to reproduce DNA, suitable for genome analysis and cultivar comparison. It seems to be an important result that DNA extracted from the nearly 700 year old seeds has a pattern different from those in the current broomcorn millet varieties. Genetic material of broomcorn millet recovered from the 15th Century well in the yard of the Buda castle Teleki palace (Gyulai et al., 2004). Further molecular genetic analyses might reveal the genetic relationships between today's and 15th century broomcorn millet, their heritage and genealogy as well as the origin of today's varieties (Lagler et al., 2006). Results in the longer run could be used for genetic improvement aiming at resistance.

References

- Dudits, D. & Heszky, L. (2000): *Növénybiotechnológia*. Agroinform, Budapest.
- Gaál, L. (1978): *A Magyar növénytermesztés múltja*. Akadémiai Kiadó, Budapest, 637 p.
- Gyulai, F. (1997): *A honfoglaló magyarság ételeinek régészeti-növénytanai forrásai. „Nyereg alatt puhítjuk...? Vendéglátási és ételkészítési szokások a honfoglaló magyaroknál és a rokon kultúrájú lovas népeknél.” Kereskedelmi, Vendéglátó és Idegenforgalmi Főiskola Tudományos Közlemények II. Ómagyar kultúra 10: 113–134.*
- Gyulai, F. (1998): *A Kis-Balaton térségének archaeobotanikai kutatási eredményei. A Kis-Balaton térségének magasabbrendű növényzetével kapcsolatos kutatási eredmények. Magyar Hidrológia Társaság és a NYUVIZIG konferenciája, Keszthely, 1998. március 24., 17-24.*
- Gyulai, F. (2003): *Kiskundorozsma-Nagyszék szarmata kori település növénymaradványai. In: Szalontai Cs.: Úton útfélen. Múzeumi kutatások az M5 autópálya nyomvonalában. Móra Ferenc Múzeum, Szeged, 141-148.*
- Gyulai, F. (2010): *Archaeobotany in Hungary. Seed, Fruit, Food and Beverages Remains in the Carpathian Basin: an Archaeobotanical Investigation of Plant Cultivation and Ecology from the Neolithic until the Late Middle Ages. Archaeolingua, Budapest, 479 p.*

- Gyulai, F. (2011): The archaeobotanical study of plant remains from the Sarmatian Period and the Árpád Period recovered at the site of END0170. In: Vaday, H. A., Jankovich, B. D. Kovács, L.: Archaeological Investigations in County Békés 1986–1992. Budapest, 360 p. *Varia Archaeologica Hungarica* 25: 359-404.
- Gyulai, F. (2014): Újabb eredmények a honfoglaló magyarság étkezési kultúrájának feltárásában: Edelény-Borsodi földvár ételmaradványainak vizsgálata. In: Révész, I. & Wolf, M.: (eds.): A honfoglalás kor kutatásának legújabb eredményei. Tanulmányok Kovács L. 70. Születésnapjára. Monográfiák a Szegedi Tudományegyetem Régészeti Tanszékéről 3. Szeged, 2013, 885 p., 715-734.
- Gyulai, F. (in print): Solt-Tételhegy régészeti lelőhely archaeobotanikai kutatása. In: Szentpéteri, J. (ed.): Solt-Tételhegy. *Archaeologia Cumani*.
- Gyulai, F. & Kenéz, Á. (2009): Mediterrane Landwirtschaft in Pannonien? Makrobotanische Forschung in Keszthely-Fenekpuszta. In: Heinrich-Tamaska, O. & Straub, P. (eds.): Keszthely-Fenekpuszta in Spiegel der Jahrtausende (Keszthely-Fenekpuszta az évezredek tükrében). A Balatoni Múzeum időszakos kiállításának katalógusa. Yeloprint, Leipzig/Zalaegerszeg, 2009. 172 p., 31-35.
- Gyulai, F., Hertelendi, E. & Szabó, I. (1992): Plant remains from the early medieval lakeshore settlement Fonyód-Bélatelep (Lake Balaton, Hungary) with especial emphasis on the history of fruit cultivation in Pannonia. *Vegetation History and Archaeobotany* 1: 177-184. DOI: 10.1007/BF00191557
- Gyulai, F., Kenéz, Á. & Pető, Á. (2013): Archaeobotanical analysis of crop and food remains from the excavation in 2009 at the Late Roman fortification of Keszthely-Fenekpuszta. In: Heinrich-Tamaska, O. (ed.): Keszthely-Fenekpuszta: Katalog der Befunde und Ausgewählter Funde sowie neue Forschungsergebnisse. *Castellum Pannonicum Pelsonense* Vol. 3. Verlag Marie Leindorf GmbH, Budapest–Leipzig–Keszthely–Rahden/Westf., 2013. 716 p., 635-646.
- Gyulai, G., Gémesné, J. A, Sági, Zs., Heszky, L., Venczel, G. & Zatykó, L. (2000): Doubled haploid development and PCR-analysis of F1 hybrid derived pepper (*Capsicum annuum* L.). *J. Plant. Physiol.* 156: 168–174. DOI:10.1016/S0176-1617(00)80302-8
- Gyulai G., Magda A., Kiss J., Gyulai F., Holly L. & Heszky L. (2001): DNS izolálás és PCR-amplifikáció 700 éves növénymagvakból. 7. Növénynevelési Tudományos Napok, Budapest. Összefoglalók, 89.
- Gyulai, G., Humphreys, M., Gyulai, F., Szabó, Z., Skot, L., Heywood, S., Kiss, J., Lovatt, A., Skot, K., Horváth, L., Abberton, M., Bittsanszky, A., Roderick, H. & Heszky, L. (2004): Ancient DNA Analysis of Broomcorn millet (*Panicum miliaceum* L.) from the 4th and 15th Centuries. 13th Symposium of the International Work Group for Palaeoethnobotany, Girona 16 th-22th May 2004. Programme and Abstract.
- Hampel, J. (1897): A régibb középkor (IV-X. század) emlékei Magyarhonban 2, Budapest.
- Harmatta, J. (1952): A hun birodalom felbomlása. *A Magyar Tudományos Akadémia II. Oszt. Közlem.* 2: 147-192.
- Hartyányi, B. & Nováki, Gy. (1973/74): Növényi mag- és termésleletek Magyarországon az újkőkortól a XVIII. sz.-ig II. *Magy. Mezőg. Múz. Közlem.* 1974, 23-73.
- Hartyányi, B. & Patay, Á. (1970): A dunaföldvári öregtoronynál előkerült régészeti növények vizsgálata. *Szekszárdi Balogh Ádám Múz. Évk.* 1970, 209-222.
- Hartyányi, B., Nováki, Gy. & Patay, Á. (1967/68): Növényi mag- és termésleletek Magyarországon az újkőkortól a XVIII. sz.-ig I. *Magy. Mezőg. Múz. Közlem.* 1968, 5-85.
- Holl, I. (1966): Mittelalterliche Funde aus einem Brunnen von Buda. *Studia Arch.* 4: 90 p.
- Kenéz, Á., Pető, Á. & Grynaeus, A. (in print): Vác-Piac utca késő középkori régészeti lelőhely komplex archaeobotanikai értékelése. In: Mészáros, O.: Vác – Piac utcai mélygarázs: A középkori Vác német városrészének régészeti feltárása. In: Kvassay, J. (ed.): VIA Kulturális örökségvédelmi kismonográfiák. Budapest: Magyar Nemzeti Múzeum.
- Kollautz, A. & Miyakawa, H. (1970): Geschichte und Kultur eines völkerwanderungszeitlichen Nomadenvolkes. Die Jou-Jan der Mongolei und die Awaren in Mitteleuropa. I. Teil. Geschichte. II. Teil. Die Kultur. Klagenfurt. Aus Forschung und Kunst. Hrsg. v. Geschichtsverein für Kärnten, 10.

- Lágler, R., Gyulai, G., Szabó, Z., Tóth, Z., Bittsanszky, A., Horváth, L., Kiss, J., Gyulai, F. & Heszky, L. (2006): Molecular diversity of broomcorn millet (*P. miliaceum*) compared to archaeological samples excavated from the 4th and 15th centuries. *Hung Agric Res* 2006/1: 14-19.
- Müller, R. (1982): A mezőgazdasági vaseszközök fejlődése Magyarországon a késővaskortól a törökkor végéig I-II. Zalai Gyűjt. 19. Balatoni Múzeum (Keszthely).
- Nováki, Gy. (1984/85): Szántóföldek maradványai a XIV-XVI. századból a Sümeg-Sarvalyi erdőben. *Magy. Mezőg. Múz. Közlem.* 1985, 19-32.
- Párducz, M. (1971): Einige Probleme der Sarmatenforschung des Karpatenbeckens. *Actes du VIIIe Congres International des Sciences Préhistoriques et Protohistoriques. Tome I, Beograd, 267-274.*
- Pieta, K. (1988): Die Slowakei im 5. Jahrhundert. Germanen, Hunnen und Awaren. *Schätze der Völkerwanderungszeit. Germanisches Nationalmuseum, Nürnberg, 385-417.*
- Pieta, K. & Placha, V. (1989): Getreide- und Brotfunde aus der Völkerwanderungszeit in Devin. *Slovenska Archeologia* 37: 69-88.
- Rapaics R. (1934): A kenyér és táplálékot szolgáltató növényeink története. Népszerű természettudományi könyvtár 16. Budapest.
- Skoflek, I. & Hortobágyi, I. (1973): Medieval seed and fruit finds from the Castle Hill of Buda. *Mitteilungen des Arch. Inst. der Ung. Akad. der Wissensch.* 4.
- Wasylikowa, K., Carciumaru, M., Hajnalová, E., P. Hartyányi B., Pashkevich, G. A. & Yanushevich, Z. V. (1991): East-Central Europe. In: Behre, K. E. (ed.): *Progress in Old World Palaeobotany.* A. A. Balkema, Rotterdam–Brookfield, 207-239.
- Williams, J. G. K., Kubelik, A. R., Livak, K. J., Rafalski, J. A. & Tingey, S. V. (1990): DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acid Research* 18: 6531–6535. DOI: 10.1093/nar/18.22.6531

