THE DEVELOPMENT OF WEED VEGETATION IN THE PANNONIAN BASIN AS SEEN IN THE ARCHAEOBOTANICAL RECORDS

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(Received 22nd Jun 2020; accepted 16th Sep 2020)

Abstract. Thanks to archaeobotanical investigations, we can now treat it as a fact that the territory of Hungary is one of the longest inhabited parts of Europe. The Pannonian Basin plays a bridging role in the spread of plant cultivation knowledge along the path leading from the Middle East to the Balkans. The relationship between cultivated plants as well as weeds has been determined by the lifestyles of the populations that have lived in the Pannonian Basin and local climatic conditions. The cultivation of several species of plants is only associated with a specific archaeological era or a specific culture. The populations that have lived here have always brought and grown their own cultivated plants with them when they moved into the area. The archaeobotanical research in Hungary reaches back more than 140 years. During this long period of time 50 researchers were active in this topic and about 400 archaeological sites have been processed. Near 10 million seeds of 700 plant taxa (mostly species) were identified in the Pannonian Basin. Our catalogue of the weed remains from Hungarian excavations, indicates species and number of items, is classified on the basis of periods and sites, and ranges from the Neolithic to the Late Middle Ages.
Keywords: *excavation, archaeophyton, Carpathian Basin, ecology, plant cultivation*

Introduction

The study of prehistoric and historic weeds is an important topic of archaeobotany. Many attempts are made to match existing archaeobotanical data with the known agricultural systems of different archaeological eras. Küster (1985) was one of the forerunners who dealt with the distribution and origin of cereal weeds (Secalietea). Based on Rademacher (1968), and Willerding (1986) distinguished five different phases of weed flora development. Almost at the same time Knörzer (1984) described the prehistoric weed association of the North Rhein region under the botanical term *Bromo-Lapsanetum praehistoricum*. Recently, Frumin (2013, 2015, 2017) – partly based on Pysek's results (2002) – proposed an evaluation criterion for archaeobotanical weed records.

The ecological evaluation of weed species is based on the adaptation of ecological indicator values published in Raunkiaer's lifestyle system (1934). This was later re-introduced by Ellenberger et al. (1991). The so-called area classification evaluation system was developed by Ehrendorfer (1973) and further improved later on by Oberdorfer (1983).

The terms *thanatocoenology* and *thanatocoenosys* were created by Willerding (1983) based on the analysis of the ecological properties of weed remains recovered from

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1805_74317444

various excavations. Later on Jacomet et al. (1989) recommended a metric evaluation system of the possible habitats instead of attempting to reconstruct once existing plant associations. The so called *'comprehensive weed history method'* turned out to be an important and significant approach to understanding the agricultural development of archaeological cultures (Willerding, 1986; Jacomet et al., 1989; Kreuz et al., 2005; Kreuz and Schäfer, 2011).

In Hungary, the history of weed association development studies was written by herbologists and ecologist. Identification guides that were compiled in the last century also dealt with the dispersion of weed species. The works of Schermann (1966), Hunyadi (1988), Radics (1998), and Hunyadi et al. (2000) have to be mentioned among others. The ecological history and recent distribution of weeds within the Pannonian Basin has always been a significant issue and was dealt by numerous scholars such as Ubrizsy (1955), Ujvárosi (1957, 1973), Czimber (1987), Bartha (2000), Csontos (2001), Priszter (1997), Dancza (2011), and Lehoczky et al. (2013).

Weed associations were identified and described by Soó (1964-1985) and Borhidi et al. (2012). Based on the works of Ujvárosi (1952), Kárpáti et al. (1968), Soó (1973), Horváth et al. (1995), and Borhidi (1995) the so called life-form classification system and scale of Hungarian weed flora was also developed; a system aiming at the numerical and ecological analysis of weed associations.

The problems of apophytes (native species), archaeophytes (non-native, arriving before the 15th century) and neophytes (non-native, arriving after the 15th century) within the Pannonian Basin was first addressed by Terpó et al. (1999), Pinke and Pál (2005), Botta-Dukát and Balogh (2008), Balogh and Gyulai (2014) as well as by Henn et al. (2014) later on.

The study of invasive plants falls also within the issues of weed studies (Mihályi and Botta-Dukát, 2004). Processes of *synanthropisation* and anthropogenic effects influencing landscape changes were studied by Terpó (2000) and Pinke et al. (2011). Grouping of synanthropic plant species of different archaeological eras was done by Berzsényi (2000). Due to the effects of intensive agriculture many of the archaeophyton species are endangered by extinction in the Pannonian Basin today. For this reason, their examination also falls within the interest of historical agro-biodiversity research. A few of the adventive weeds are already on the list of protected and endangered plant species of Hungary (Udvardy, 2000).

In comparison to the above mentioned works, only very few studies dealt with the history, dispersion and development of weed species from an archaeobotanical perspective (Füzes, 1990; Gyulai et al., 1992; Berzsényi, 2000; Gyulai et al., 2013; Gyulai and Lakatos, 2013; Kenéz, 2014; Pósa et al., 2015). The basis of these is a catalogue of the weed finds sorted according to cultures and taxa, which was first compiled by Hartyányi et al. (1968, 1974), and later on improved by Gyulai (2010).

Materials and methods

The archaeobotanical record

Since the beginning of archaeological research (1860) in Hungary, nearly 50,000 sites were found. Out of these, 414 sites (1%) have been studied from an archaeobotanical aspect (*Fig. 1*). Most settlements are known to be from the Middle Neolithic (55 sites), the Roman Age (53 sites), and the Late Middle Ages (37 sites) (*Fig. 2*). Our research is based on the supplemented and updated archaeobotanical

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DOI: http://dx.doi.org/10.15666/aeer/1805_74317444

dataset compiled by Gyulai (2010). This is a catalogue consisting of the seed, fruit, food and beverage remains from Hungarian excavations, indicating species and number of items, classified on the basis of periods and sites, ranging from the Neolithic to the Modern Ages, from the beginning of archaeobotanical research, up to the present, and in a chart form.

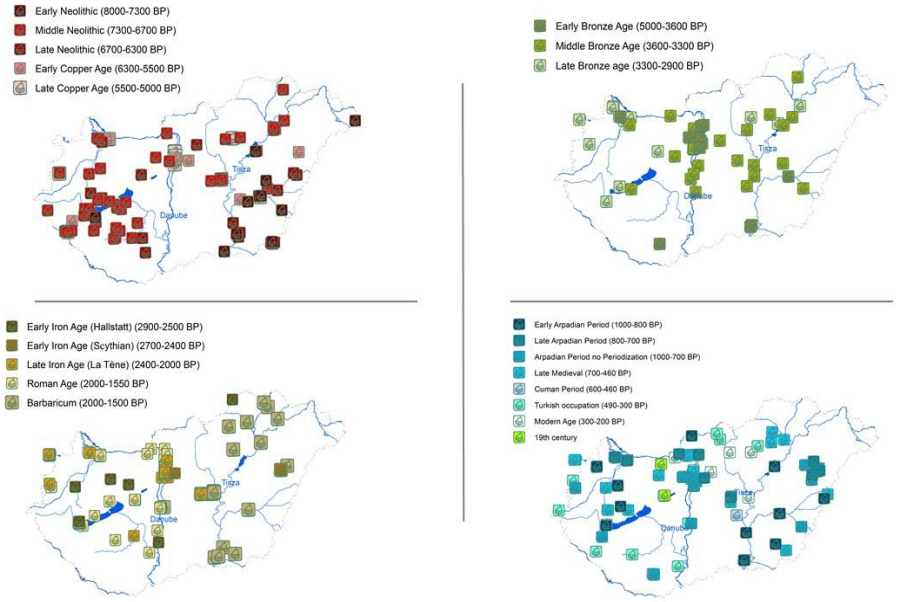

Figure 1. *Map of the archaeological sites in Hungary*

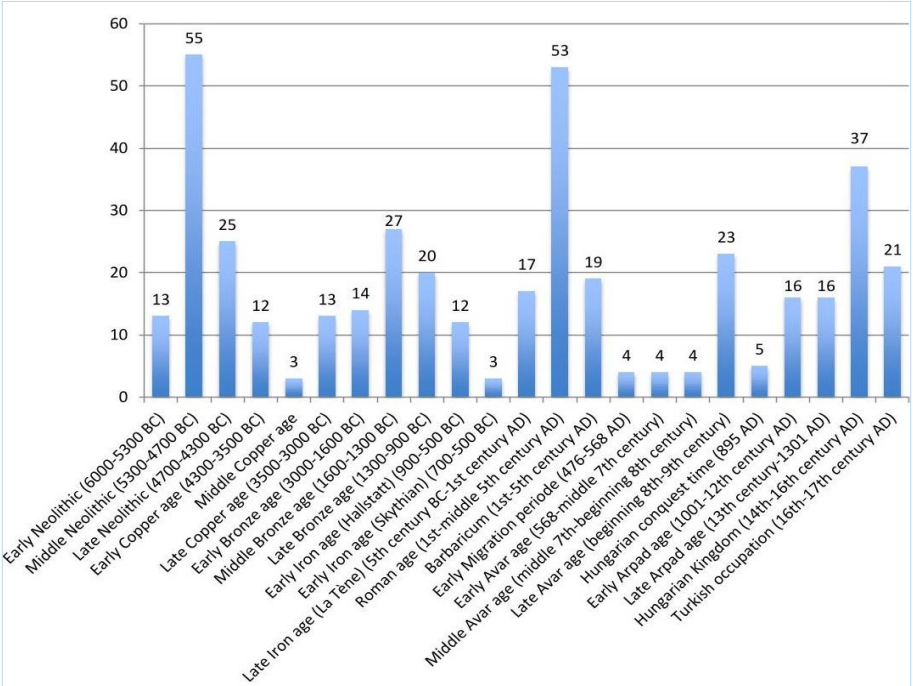

Figure 2. *Number of archaeological sites in every archaeological era, at which archaeobotanical analysis was carried out*

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Methodological considerations

The research dataset was completed by the selection of weeds, based on the identification criteria published earlier by Jacomet et al. (1989). This resulted in the list of weed species according to archaeological periods. The weed species have been classified as follows: cereal weeds, root- or summer crop weeds and ruderal weeds. The database has been expanded with additional data: type of area, life-form, residence time status (apophyte, archaeophyte, neophyte) and height (low, medium, high). In the list of weed species, a value of '1' was assigned to species which were present in the archaeological period, whereas '0' means they weren't present. In case a weed was present in multiple periods, all instances were assigned a '1', since if we didn't, our results would've been deformed. Analysing the huge data set was conducted using the IBM SPSS Statistics 22.0 software. The statistical analysis encompassed the following:

- Relationship between cereals and cereal weeds.
- Fluctuation of cereal weed species.
- Distribution of cereal weed species, depending on if they are present in the latest age or not, regarding first appearance.
- Distribution of cereal weed species by plant height, first appearance.
- Distribution of cereal weed species by life form, first appearance.
- Distribution of cereal weed species by area.

Results

The distribution of the plant species broken down to the archaeological eras of the Pannonian Basin gives us an overview of when the number of weeds increased throughout the history of the geographical area. The periods of increase of weed species: Middle Neolithic, Middle Bronze age, Roman age, Late Middle Ages (*Fig. 3*).

It is interesting to note that the number of weed species of the settled nomadic cultures with steppe origins coming from the east (Middle Copper age, Scythians, Sarmatians, Avars, Hungarians) was always higher than in the previous period. Some segetal weeds (e.g. *Agrostemma githago*, *Bromus sp.*) arrived with Neolithic farmers from the south-east, who later migrated slowly towards the west accompanied by indigenous species of Central and Eastern Europe.

Distribution of cultivated and weed species

Together with the rising number of cultivated species the diversity of weeds grew as well (*Fig. 4*).

However, there is no significant difference in the proportion of cereal weed, root- or summer crop weed and ruderal weed species during the different periods. Although the typical process is growth, yet in some age to fall: Copper Age, Early Bronze Age, Migration Period. In our opinion, the separation of winter- and summer crop weeds was not realised in the Pannonian Basin; they arrived into this separated geographical area in with their original ecological 'faith'.

The increasing number of ruderal species may be closely related to the rising number of settlements in certain periods. At the beginning of the Neolithic era (e.g. Körös culture), new, foreign species associated with plant cultivation appeared in the landscape. At the beginning of cereal cultivation, einkorn wheat, emmer wheat and barley were the characteristic cereals with shorter growth-cycle common millet was

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added in the Bronze Age. Both cultivated and wild ones also arrived, primarily from Asia Minor and the Mediterranean, and to a lesser extent from Asia. These had lived in association with domesticated plants, often as wild relatives of domesticates in their places of origin. But, in a cultivated context, they were simply weeds. The first segetal associations of the Neolithic and the Bronze Age had relatively high number of species, much higher than expected. According to archaeological plant material, white goosefoot (*Chenopodium album*) was present in very large quantities, while *Avena fatua*, *Bromus arvensis*, *B. secalinus*, *Chenopodium hybridum*, *Fallopia convolvulus*, *Galium spurium*, *Vicia angustifolia* were also common. In the Roman age several new segetal species appeared: *Abutilon theophrasti*, *Anthemis cotula*, *Bifora radians*, *Centaurea cyanus*, *Cynodon dactilon*, *Diplotaxis muralis*, *Lathyrus hirsutus*, *Lepidium draba*, *Myagrum perfoliatum*, *Myosotis arvensis*, *Torilis arvensis*, *Vicia villosa*. In the Middle and in the early Modern Age the weed flora enriched with new species, in which grain trade also played a role: *Alopecurus myosuroides*, *Amaranthus retroflexus*, *Euphorbia exigua*, *Galeopsis tetrahit*, *Lepidium perfoliatum*, *Ranunculus sardous*, *Silene noctiflora*, *Vaccaria pyramidata*, *Valerianella carinata*.

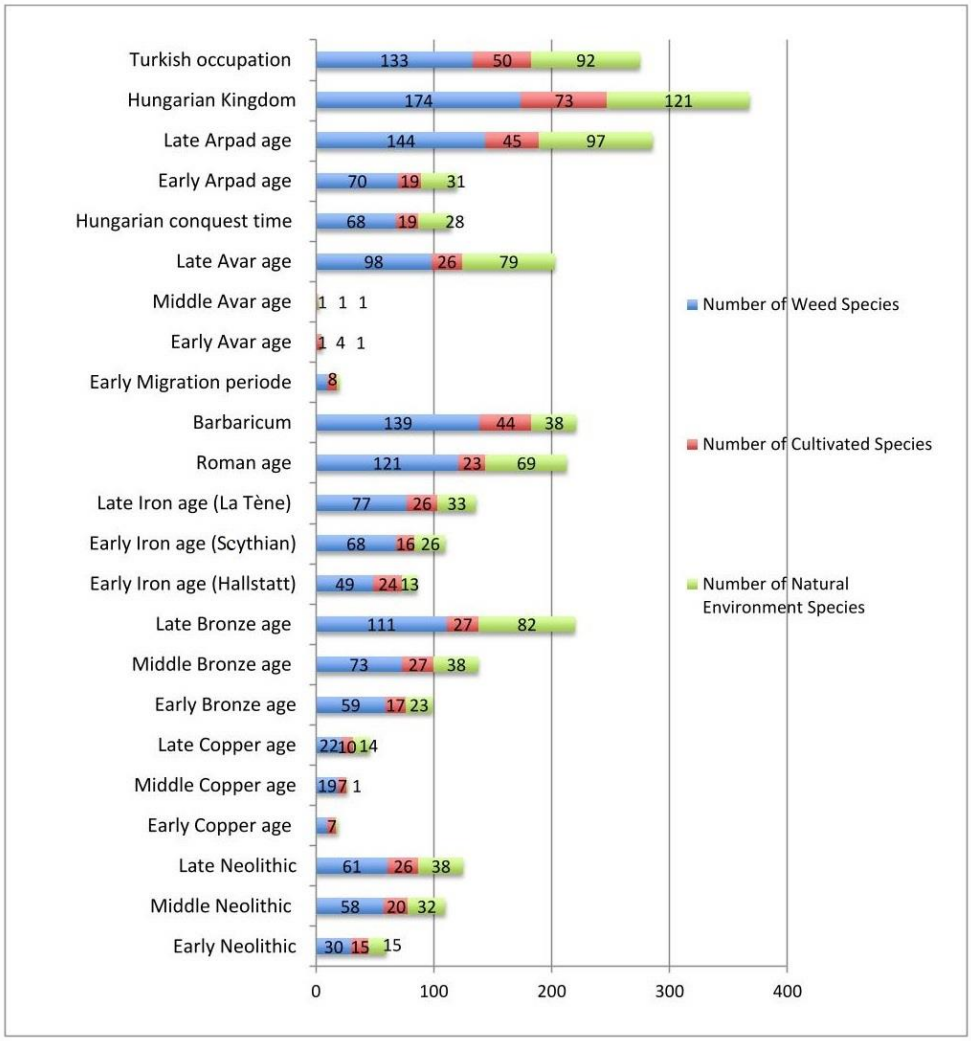

Figure 3. *The number of weed, cultivated and natural environment plant species throughout the archaeological eras of the Carpathian Basin*

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	Early Neolithic (6000–5300 BC)	Middle Neolithic (5300–4700 BC)	Late Neolithic (4700–4300 BC)	Eneol /Copper age (4300–3000 BC)	Early Bronze age (3000–1600 BC)	Middle Bronze age (1600–1300 BC)	Late Bronze age (1300–900 BC)	Early Iron age (900–500 BC)	Late Iron age (La Tène) (5th century BC–1st century AD)	Roman age (1st–middle 5th century AD)	Barbaricum (1st–5th century AD)	Migration periode (5th–9th century)	Hung. conq. - Early Arpad age (895–12th century)	Late Arpad age (13th century–1301 AD)	Late medieval/Hung. Kingdom (14th–16th century AD)	Early New Age/Turkish occupation (1526–17th century AD)
Number of cultivated species	15	20	26	13	17	27	27	24	26	23	44	32	28	45	73	50
Number of cultivated seeds	655	394918	476944	9573	2816	278687	159441	101339	10644	225212	232938	118180	367965	38835	3632970	241954
Number of cereal species	12	12	12	9	10	13	12	11	12	13	13	10	10	13	13	10
Number of cereal grains	644	394549	457496	9563	2806	253622	156806	101102	10402	218719	231847	115578	332292	37444	1728354	171661
Number of cereal weed species	21	42	43	26	45	58	77	64	63	90	97	73	80	96	123	92
Number of cereal weed seeds	203	3622	751	232320	272	39394	4480	5494	1327	5169	4792	141808	8774	80887	156471	89006
Number of root-or summer crop species	3	8	12	4	7	13	14	10	11	6	15	11	13	17	30	21
Number of root- or summer crop weed species	10	17	11	6	10	13	27	24	18	31	27	24	23	33	36	27
Number of root- or summer crop weed seeds	64	3346	460	160	65	36988	3756	3816	942	3955	2276	140517	52874	75825	89864	5493
Number of ruderal species	10	22	26	14	25	25	47	35	26	47	60	38	42	68	78	68
Number of ruderal seeds	247	3234	470	179	57	37609	3695	3381	1058	24586	2338	140986	53385	90195	50526	241011
Number of natural environment species	15	32	38	16	23	38	82	48	33	69	38	86	82	97	121	92
Number of natural environment seeds	395	175	1589	1786	116	185	3660	107	811	928	476	2401	987	2693	1538224	6568

Figure 4. *The most important data of the Hungarian Archaeobotanical Database*

Distribution of weed species by residence time status

There is no significant difference between the proportion of apophytes and archaeophytes during the different archaeological eras (*Fig. 5*).

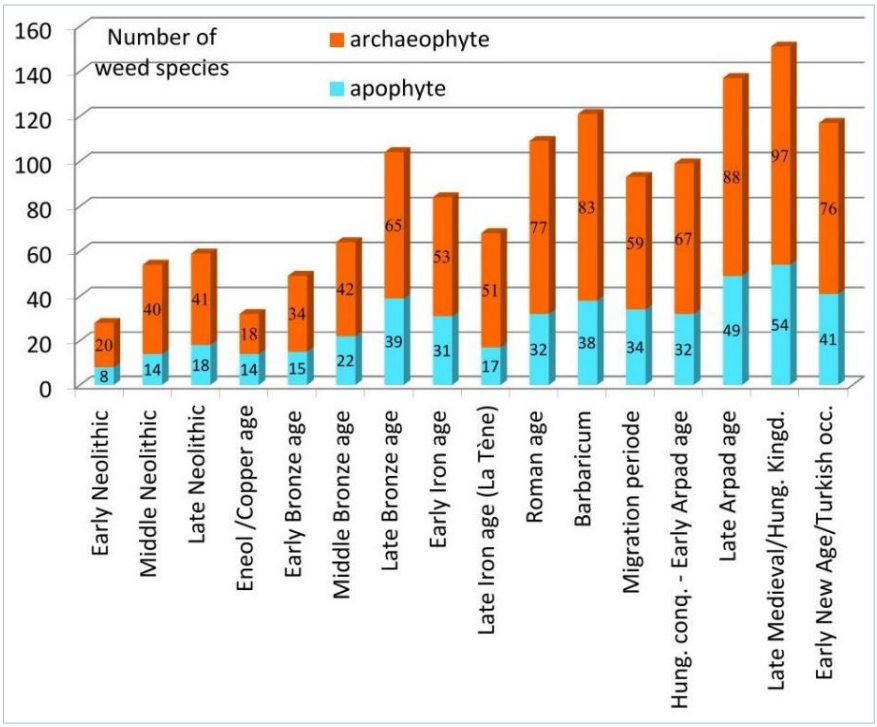

Figure 5. *The number of archaeophyte and apophyte weed species throughout the archaeological era of the Carpathian Basin*

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Until the Early Modern Age apophyte and archaeophyte species were dominant. However, there are terminological errors of their interpretation. When compared to western Europe, Bulgarian and Hungarian LBK species, five of them cannot be Hungarian apohytes because they also occurred in Bulgaria. So, the current division in other ages should also be reviewed. In addition to weeds introduced with sowing-seeds, elements of the previous flora were also present for some time. Domesticated species cultivated on arable land meant competition for the components of natural vegetation. Other plant species were less able to adapt to the changed conditions resulting from cultivation and subsequently disappeared. During the Middle and Late Neolithic period, a whole range of foreign weed species migrated to the central regions of Europe. Before AD 1500, the landscape was dominated by associations of archaeophytes and apophytes: archaeophytes: e.g. *Agrostemma githago*, *Centaurea cyanus*, *Echinocloa crus-galli*, *Papaver rhoeas*, *Setaria pumila*, *Sinapis arvensis*, *Stachys annua*, apophytes: *Artemisia vulgaris*, *Agropyron repens*, *Centaurea cyanus*, *Consolida regalis*, *Digitaria sanguinea*, *Portulaca oleracea*, *Raphanus raphanistrum*.

Relationship among cereals and cereal weeds

The number of cereal species in the Early Neolithic was higher than in later periods (*Fig. 6*). The existing cereal species were supplemented with new ones. In the latter two the high number of weeds may be related to manuring. In the beginning hulled wheats (einkorn wheat, emmer wheat) and naked barley, but later, after the Roman Age common wheat and rye were dominant. Until the Late Iron age, the number of cereal weed seeds were low compared to cereal grains. (Seed treatment was more effective perhaps?) The trend changed in the Roman Age. The number of cereal weed remains are many times higher than that of cereal grains. The number of weed species by winter cereals (einkorn wheat, emmer wheat, spelt, common wheat, dwarf wheat) and rye was proportionally higher than that of hulled wheat.

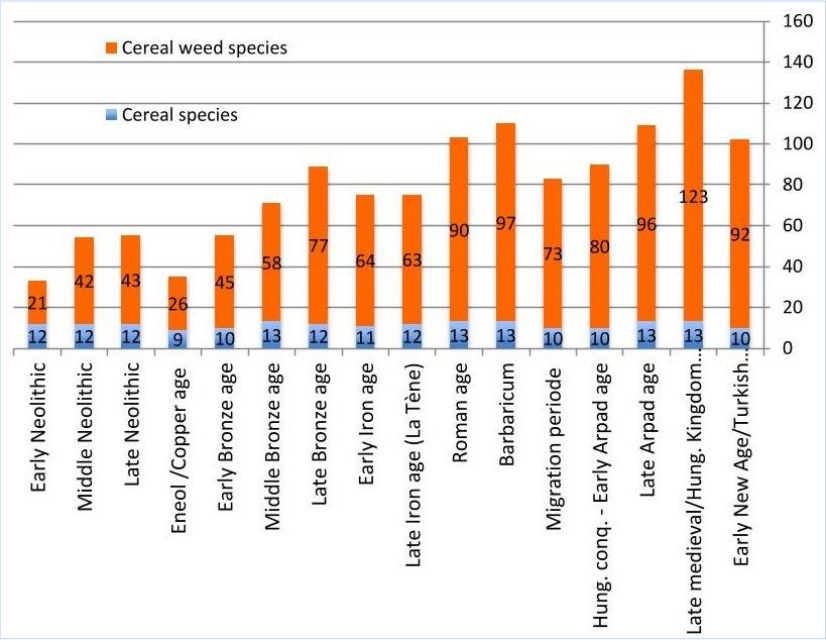

Figure 6. *The relation between cereal and cereal weed species throughout archaeological eras of the Carpathian Basin*

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The Neolithic, Bronze Age, Roman Age/Barbaricum and Late Middle Ages were the periods when most cereal weed species appeared (*Fig. 7*). Many cereal weed species disappeared in the Roman period (7) and even more in late Middle Ages (50!). In the Roman Age and late Medieval period, the weed flora changed thoroughly. Why? Both periods saw the use of ploughshare and manuring (*Fig. 8*).

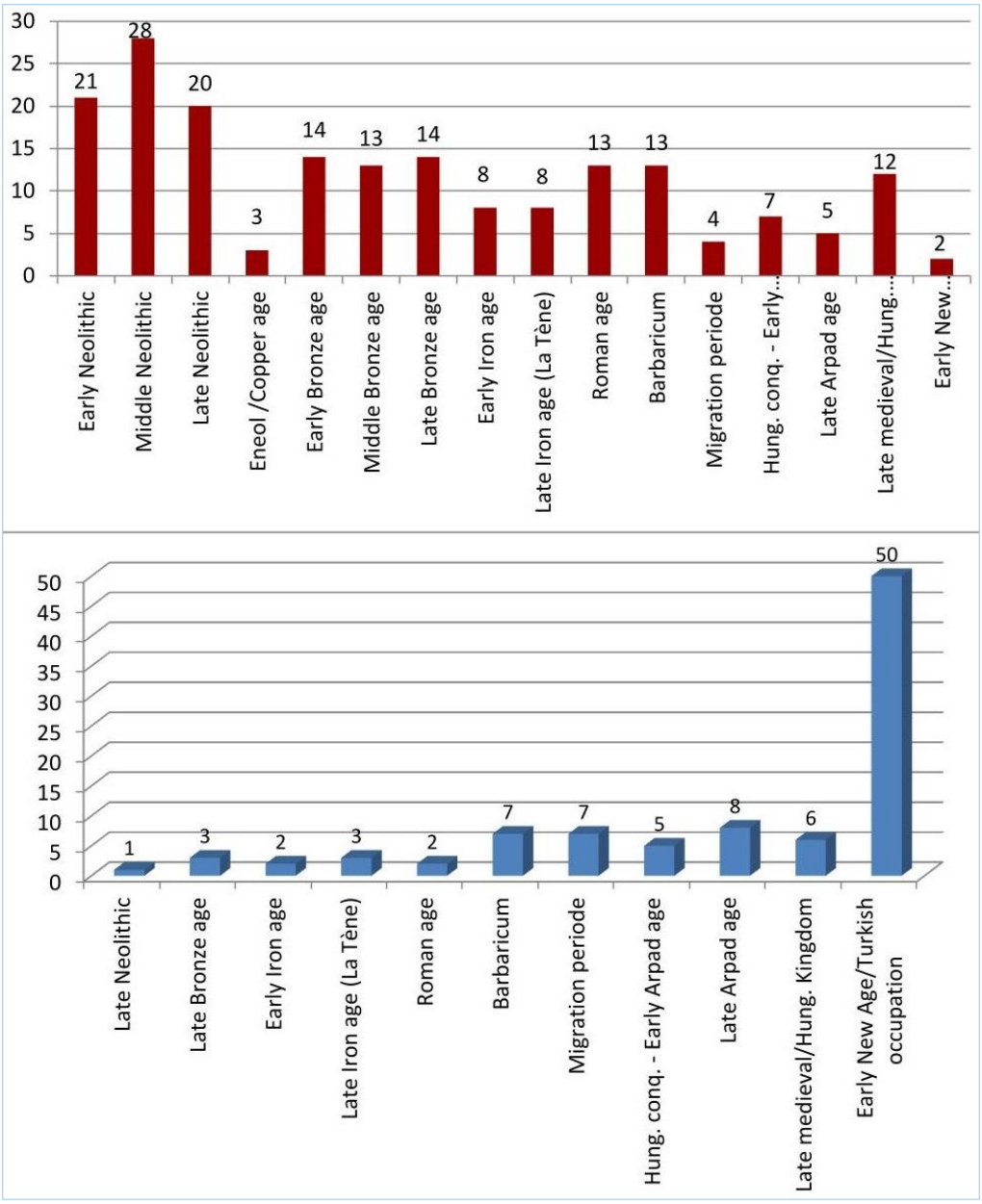

Figure 7. *The number of appearing (above) and disappearing (below) weed species within the archaeological eras of the Carpathian Basin*

Distribution of cereal weed species by plant height in first appearance

The presence of cereal weeds allows us to infer the time of sowing and the method of cultivation of cereals and the method of harvesting (high or low, with a sickle or with a scythe). Distribution of cereal weeds by height suggests that from the beginning until

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Late Middle Ages the use of sickle for harvesting was common. Dominant are the medium, medium/high and high species (*Fig. 9*). They are mostly high weed plants, which indicates that cereals were harvested using a sickle, at about two-thirds of the height of stalks. In the Modern Age the new weeds are higher, therefore the harvesting method starts to change: from sickle to scythe. Of course, do not forget that the cereals were previously higher than they are today.

	Early Neolithic (6000–5300 BC)	Middle Neolithic (5300–4700 BC)	Late Neolithic (4700–4300 BC)	Eneol /Copper age (4300–3000 BC)	Early Bronze age (3000–1600 BC)	Middle Bronze age (1600–1300 BC)	Late Bronze age (1300–900 BC)	Early Iron age (900–500 BC)	Late Iron age (La Tène) (5th century BC–1st century AD)	Roman age (1st–middle 5th century AD)	Barbaricum (1st–5th century AD)	Migration periode (5th–9th century)	Hung. conq. - Early Arpad age (895–12th century)	Late Arpad age (13th century–1301 AD)	Late medieval/Hung. Kingdom (14th–16th century AD)	Early New Age/Turkish occupation (1526–17th century AD)
Climate phase	Boreal/Atlantic	Atlantic	Atlantic	Atlantic	Subboreal	Subboreal	Subboreal	Subboreal	Subatlantic	Subatlantic	Subatlantic	Subatlantic	Subatlantic	Subatlantic	Subatlantic	Subatlantic
Number of settlements	13	55	25	28	14	27	20	15	17	53	19	35	19	16	37	21
Number of Culture	1	6	3	6	3	7	4	2	1	1	1	5	1	1	1	2
Culture	Körös-Starčevo	LBK Great Hungarian Plain, LBK Transdanubia group, LBK Notenkopf and Sopot-Bicske cultural phases, Sopot, Szakálhát-Szilmeg group, Tiszadob group	Tisza, Herpály, Lengyel	Bodrogkeresztúr, Balaton-Lasinja, Ludanice, Protoboleráz, Boleráz, Baden	Bell Beaker, Somogyvár-Vinkovci, Makó	Füzesabony,Nagyrév, Vatya, Magyarád, Hatvan, Pécel, Otomány	Gáva, Urnfield, Tumulus, Kyjatice	Hallstatt, Skythian	La Tène (Celtic)	Roman	Sarmatian	Gepid, Longobard, German, Avar, Slav	Hungarian	Hungarian	Hungarian	Hungarian, Turks
Mode of life	settled	settled	settled	wandering livestock/settled	settled	settled	settled	settled, settled nomad	settled	settled	settled nomad	nomad/settled nomad	settled	settled	settled	settled
Land use	slash-and-burn agriculture	slash-and-burn agriculture	slash-and-burn agriculture	slash-and-burn agriculture	slash-and-burn agriculture	not controlled fallow change	not controlled fallow change	not controlled fallow change	not controlled fallow change	controlled fallow change + manuring	not controlled fallow change	not controlled fallow change	controlled fallow change	controlled fallow change	controlled fallow change	two-field rotation + manuring
Soil tillage equipment	digging stick	digging plow (ralo)?	digging plow (ralo)?	digging plow (ralo)?	digging plow (ralo)	digging plow (ralo)	digging plow (ralo)	digging plow (ralo)	digging plow (ralo) with iron slippers	single-sided plow with iron slippers	digging plow (ralo)	digging plow (ralo) with iron slippers	single-sided plow with iron slippers	single-sided plow with iron slippers	single-sided plow with ploughshare	single-sided plow with ploughshare
Harvest	with hand, primitive sickle/harvest knife	primitive sickle or harvest knife	primitive sickle/harvest knife	primitive sickle or harvest knife	primitive sickle or harvest knife	bronze sickle	bronze sickle	sickle	iron sickle	serrated or "toothed" iron sickle	sickle	curved and hooked sickle	curved and hooked sickle	curved and hooked sickle	curved and hooked sickle	curved and hooked sickle + scythe

Figure 8. *Land use, harvest and other important data of the Hungarian Archaebotanical Database*

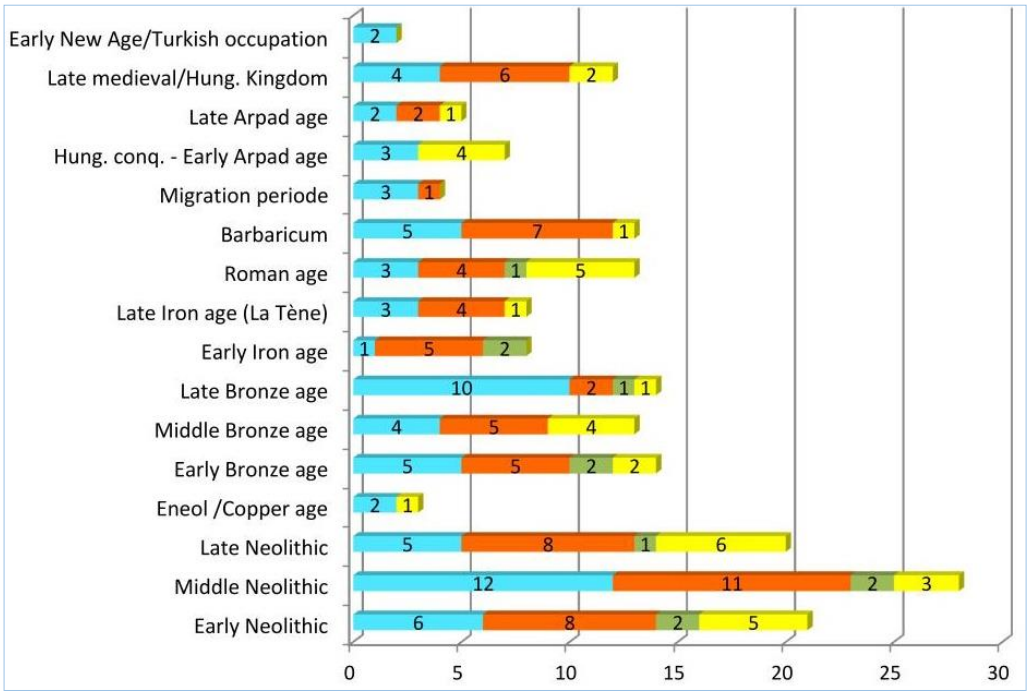

Figure 9. *Distribution of cereal weed species by plant height and first appearance*

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Discussion and conclusions

The up-to-date archaeobotanical database of Hungary contains the results of each known archaeological site, which was studied from an archaeobotanical point of view. Regardless of their publication the database contains all accessible data. This database, which provides an overview of the archaeobotanical results from 186 onwards was the basis of the present study, in which we analysed the development of weeds in the Pannonian Basin. Not only the list, but the changes in the appearance of apophyte and archaeophyte species was also compiled. The weed species were sorted according to height, by life form and by distribution area.

The appearance of weeds is connected to certain archaeological ears and phases: Early and Middle Neolithic, Middle Bronze age, Roman age, Late Medieval. This overlaps with the expansion of harvested species and a connection between the harvested and weed flora is emphasised.

The earliest dominant weed species in the Neolithic are: *Agrostemma githago, Avane fatua, Bromus arvensis, Bromus secalinus, Chenopodium album, Fallopia convolvulus, Galium spurium*. The most widespread and dominant seven weed species of the Pannonian Basin were studied.

The examination of the weeds according to their height shows that the ratio of medium and high species does not change from the beginning (Neolithic), which suggests that sickle was used until the Early Middle Ages to harvest cereals. Scythe was probably only used for harvesting later on.

No significant change can be detected in the ratio of the apophytes and the archaeophytes over time.

The fluctuation in the area-based distribution of the weed species is high. The strong Mediterranean effect in the Neolithic decrease by time and the number of Eurasian and Circumpolar species increases.

The species composition and the change of the number of the cereal weeds is related to land management practices (e.g. use of plow), soil fertilising techniques (e.g. manuring) and with the increase of the level of arable crop production.

The weeds of autumn- and spring-sown cereals already separated at the beginning of the Neolithic. This ecological separation already appeared outside the Pannonian Basin. At the beginning the presence of winter crop weed species was higher, but with the appearance of the leguminous plants in the Bronze Age and the garden species in the Late Middle Ages, the significance of summer crop weeds or row crop weeds increased.

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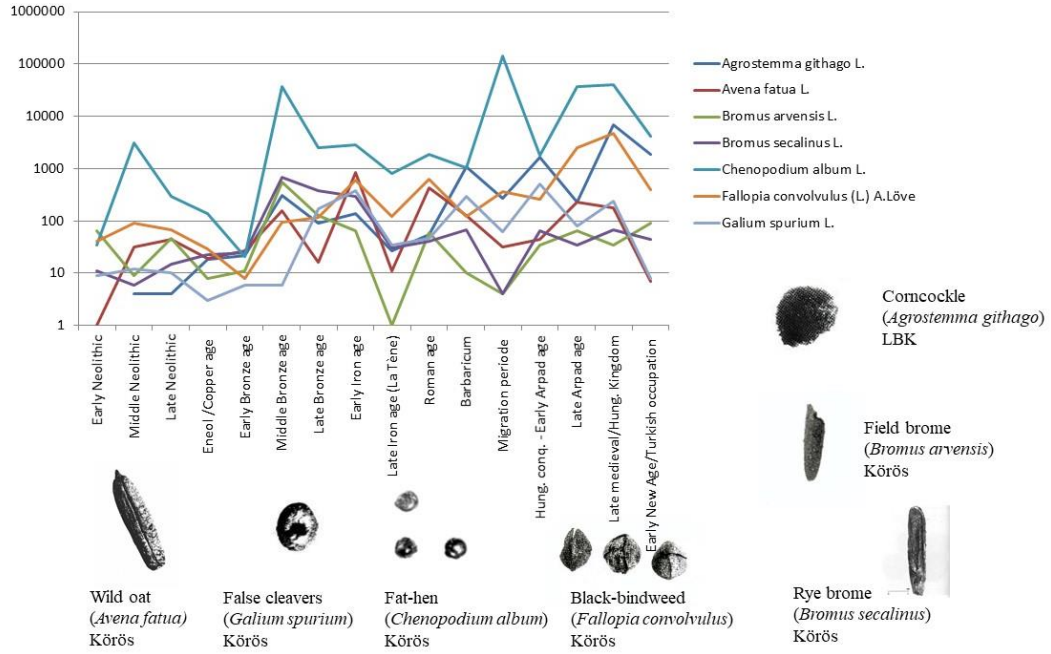
APPENDIX



Appendix 1. *Career of the "seven great evil". Number of grains in logarithmic distribution*

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