Evaluation of Desiccated and Deformed Diaspores from Natural Building Materials

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Abstract: *With the increasing sophistication of paleoethnobotanical methods, it is now possible to reconstruct new aspects of the day-to-day life of past peoples, and, ultimately, gain information about their cultivated plants, land-use practices, architecture, diet, and trade. Reliable identification of plant remains, however, remains essential to the study of paleoethno-botany, and there is still much to learn about precise identification. This paper describes and evaluates the most frequent types of deformed desiccated diaspores revealed from adobe bricks used in buildings in Southwestern Hungary that were built primarily between 1850 and 1950. A total of 24,634 diaspores were recovered from 333.05 kg adobe samples. These seeds and fruits belong to 303 taxa, and the majority were arable and ruderal weed species. A total of 98.97% of the diaspores were identified to species. In other cases, identification was possible only to genus or family (0.93% and 0.10% of diaspores, respectively). Difficulties in identification were caused mainly by morphological changes in the size, shape, color, and surface features of diaspores. Most diaspores were darker in color and significantly smaller than fresh or recently desiccated seeds and fruits. Surface features were often absent or fragmented. The most problematic seeds to identify were those of* Centaurea cyanus, Consolida regalis, Scleranthus annuus *and* Daucus carota *ssp.* carota, *which are discussed in detail. Our research aids archaeobotanists in the identification of desiccated and deformed diaspores.*

Keywords: archaeobotany, desiccated seeds, deformity, seed identification, thousand seed weight

Supplementary Files available at ojs.ethnobiology.org/index.php/ebl.

Introduction

Plant remains from archaeological excavations offer direct evidence of species presence and imply direct interrelationships between humans and plants in the past (Ford 1979; Gyulai 2001; Paušič et al. 2010). Plant remains can reflect many aspects of past societies from past land-use practices, to diet, architecture and trade, as well as information about the natural environment (McGovern et al. 1995; Miller 1989). As a result, the reconstruction of historical flora requires the correct identification of archaeobotanical remains (Cappers and Neef 2012; Pearsall 2000). Accurate identification depends mainly on the quality of the botanical material recovered from excavations as well as the quality of the analysis and interpretation of such remains (Antolín 2012; Csontos 2001; van der Veen 2007).

The accurate identification of diaspores from modern seed banks is often difficult (Conn 1984; Gross 1990); the identification of seeds and fruits from archaeological sites is even more complicated and often misleading (Pearsall 2000). Although there are many special seed atlases and reference books available for the identification of recent diaspores (e.g. Bojňanský and Fargašová 2007; Cappers et al. 2006; Delcourt et al. 1979; Liu et al. 2008), their use does not ensure successful identification of archaeologically excavated diaspores. Pearsall (2000) suggested that only a limited number of characteristics can be used to identify seeds recovered in flotation or fine-sieve samples because taphonomic processes can change them appreciably. Archaeological diaspores often differ in color, shape, and size compared to recent seeds. Moreover, chemical or biochemical processes can also change the appearance of excavated diaspores (Gyulai 2001; Hillman et al. 1993).

Many studies in the last few decades have dealt with the identification of charred seeds and fruits, which constitute the most studied types of archaeobotanical remains (see e.g. Goette et al. 1994; Pearsall

Figure 1. Ruinous cob cottage in Rózsafa (2012) with adobe bricks.

2000; Renfrew 1973; Stewart and Robertson 1971; van der Veen 2007). Moreover, detailed overviews on the properties of waterlogged and desiccated diaspores have been published recently (e.g. Cappers and Neef 2012; Hosch and Zibulski 2003; Jacomet 2013; Matthews 2010; Pearsall 2000; van der Veen 2007; Vandorpe and Jacomet 2007). Several papers on desiccated plant material discuss difficulties of identification related to diaspore deformation, but, problematically, most do not provide detailed descriptions of deformation morphology.

Although the richest sources of desiccated plant remains from the last few centuries come from natural building materials, with added straw and chaff (Zohary et al. 2012), palaeoethnobotanical analysis of these materials in Europe is uncommon (Ernst and Jacomet 2005). Many studies demonstrate that old buildings and building materials such as adobe and mud bricks (Hendry 1931; Hendry and Bellue 1936; Hendry and Kelly 1925; O'Rourke 1983; Paušič et al. 2010), daub (Carruthers 1991), filling material for

floor cavities (Ernst and Jacomet 2005; Fischer and Rösch 1999; Lohmann 1987), roofing materials (de Moulins 2007; Willerding 1996), and other materials (Dickson 1996; Latałowa et al. 2003) are rich sources of desiccated plant micro- and macro-remains, especially seeds and fruits. Despite good preservation, difficulties in identification of desiccated diaspores has not been addressed (Day 2013; Hendry and Bellue 1936). In our previous research (Henn et al. *in press*), a large number of, poorly preserved, desiccated diaspores were recovered and evaluated from 60-160 year old adobe bricks from Southwestern Hungary. In this study we discuss the preservation status of recovered desiccated seeds and fruits, particularly focusing on deformation. The present study summarizes common morphological changes of desiccated diaspores and provides details for improved identification methods.

Materials and Methods

Collecting and processing of adobe samples

Table 1. List of excavated taxa with altered seed coat color.

Taxa	Fresh seeds and fruits			Desiccated seeds and fruits		
	Color	Shininess	Pattern	Changed color	Shininess	Pattern
Camelina microcarpa Andrz. ex DC.	reddish-brown	-	-	dark brown	-	-
Capsella bursa-pastoris (L.) Medik.	yellow to orange	✓s	-	dark reddish-brown or brown	-	-
Cardaria draba (L.) Desv.	yellowish-brown or reddish-brown	-	-	dark brown to black-brown	-	-
Cerastium arvense L.	reddish-brown	-	-	dark brown	-	-
Cerastium dubium (Bastard) Guépin	light yellowish-brown	✓s	-	dark brown	-	-
Erysimum odoratum Ehrh.	rusty-brown	✓	-	dark brown	-	-
Fallopia convolvulus (L.) A. Löve	black	-	-	light brown	-	-
Lathyrus nissolia L.	greyish to brown	✓	dark brown marbled	dark reddish-brown to black	-	-
Lathyrus pratensis L.	yellowish-brown to red-brown	✓	dark marbled	dark reddish-brown to black	-	-
Medicago falcata L.	brown	-	-	dark brown or dark violet-grey	-	-
Medicago lupulina L.	yellow, yellowish-green	✓s / -	-	dark violet-gray or gray	-	-
Medicago minima (L.) L.	yellow to sandy-yellow	✓s / -	-	dark brown	-	-
Microrrhinum minus (L.) Fourr.	blackish-brown	-	-	light grey or whitish	-	-
Myosotis arvensis (L.) Hill	dark brown to black	✓	-	light grey or light brown	-	-
Rumex crispus L.	dark reddish-brown	✓	-	sandy-brown to light brown	✓s	-
Rumex patientia L.	red-brown	✓	-	sandy-brown	✓s	-
Stellaria graminea L.	brown, papillae greyish	-	-	dark brown	-	-
Stellaria media (L.) Vill.	greyish-brown to reddish-brown	-	-	dark brown to black-violet	-	-
Trifolium arvense L.	greenish-yellow or light green	✓s / -	-	brown	-	-
Trifolium pratense L.	yellowish-green or sandy-brown up to violet	✓s / -	-	dark violet-brown or brown	-	-
Trifolium repens L.	yellow to yellowish-brown	✓s	-	dark brown	-	-
Verbena officinalis L.	dorsal side reddish-brown, ventral side whitish	✓s	-	dark brown to black-brown	-	-
Veronica arvensis L.	yellowish to orange	-	-	reddish-brown	-	-
Veronica hederifolia L.	light reddish-brown	-	-	dark brown to black-brown	-	-
Veronica persica Poir.	yellowish to pale-brown	-	-	dark brown	-	-
Veronica polita Fr.	pale-yellowish	-	-	reddish-brown	-	-
Vicia angustifolia L.	greyish or brown	-	dark and light spotted or marbled	dark violet-brown to black-brown	-	-
Vicia cracca L.	greyish-green to olive, with	-	dark blotched or marbled	dark violet-brown	-	-
Vicia hirsuta (L.) Gray	light greyish-green or yellowish-green	-	spotted to mottled	dark violet-brown to black-brown	-	-
Vicia lutea L.	grey or olive-brown	-	dark spotted to marbled	dark violet-brown or brown	-	-
Vicia pannonica Crantz	yellowis-grey to brownish-grey	-	spotted to mottled	dark greyish-brown	-	-
Vicia tetrasperma (L.) Schreb.	olive-green to nutbrown	-	dense dark spotted	dark brown	-	-

Note: ✓s - slighhtly shiny, ✓ - shiny

Figure 2. Crushed adobe brick sample.

In total, 60 adobe brick samples (330.05 kg) were collected from 29 settlements from old untenanted and/or ruinous cob cottages (Figure 1) in Southwestern Hungary (see Supplementary Table 1). Most of the bricks were constructed between 1850 and 1950. In some cases, the year of building construction was known (e.g., signed on the pediments), but in other cases construction could only be dated to the decade based on information from the owners or neighbors. Adobe bricks were typically made of local building materials near construction sites (Büki 2003; Juhász 1991). Preserved plant remains in bricks are representative of local anthropogenic flora, including plants cultivated in surrounding arable fields, vineyards, and home gardens.

To recover plant remains, the bricks were crushed using a simple hammer and a ceramic mortar. Our preliminary investigation (Henn et al. *in press*) shows that desiccated plant macro-remains are resistant to crushing and other mechanical impacts, as fragmentation of desiccated diaspores was insignificant during recovery. Refuse (Figure 2) was sifted over sieves of 2.0, 1.0 and 0.5 mm mesh size to remove most of the loam. After dry-sieving, extraction by flotation (Malone 1967) was used to separate the organic plant material (chaff, straw, fruits, seeds, etc.) from the inorganic components of adobe. Common salt (sodium chloride, NaCl) solution with 1.1261 g cm^{-3} specific gravity was used as flotation medium (Gonzalez and Ghermandi 2012; Henn et al. *in press*). The supernatant was processed using a 0.25 mm sieve after sedimentation, which was then rinsed under tap water and air-dried. Our previous investigation also showed that diaspores of all preserved taxa were present in the supernatant (Henn et al. *in press*). The recovered and desiccated plant material consisted mainly of chaff and straw (Figure 3), which are typical constituents of adobe, but also contained fruits and seeds of cultivated and wild plants.

Separation, identification and analysis of the recovered diaspores
The final step in analysis was hand-sorting of the

Table 2. List of excavated taxa with degraded seed surface features.

Taxa	Deformed/abraded structure	Degradation
Bidens tripartita L.	spines	partly/completely
Caucalis platycarpos L.	spines	partly
Centaurea cyanus L.	crest/fruit coat	partly/completely
Centaurea stoebe ssp. micranthos (Gugler) Hayek	crest	completely
Chelidonium majus L.	ventral aril	completely
Consolida regalis Gray	ving-list lobates/seed coat	partly/completely
Crepis biennis L.	crest	completely
Crepis rhoeadifolia M. Bieb.	crest	completely
Crepis tectorum L.	crest	completely
Daucus carota ssp. carota L.	spines/spiny ridges	partly/completely
Hieracium pilosella L.	crest	partly
Lactuca saligna L.	crest	partly/completely
Lactuca serriola L.	crest	completely
Lappula squarrosa (Retz.) Dumort.	prickles	partly
Leontodon autumnalis L.	crest	completely
Pastinaca sativa L.	verge	partly
Ranunculus arvensis L.	spines	partly
Scleranthus annuus L.	perianth/sepals	partly/completely
Scorzonera sp. L.	crest	completely
Sonchus arvensis L.	crest	completely
Sonchus asper (L.) Hill	crest	completely
Sonchus oleraceus L.	crest	completely
Taraxacum officinale Weber	crest	partly/completely
Tilia sp. L.	wing	completely
Tordylium maximum L.	verge/strerchers	partly
Torilis arvensis (Huds.) Link	spines/seed coat	partly/completely
Tragopogon orientalis L.	crest	completely
Turgenia latifolia (L.) Hoffm.	spines	partly
Xanthium spinosum L.	spines/thornes	partly
Xanthium strumarium L.	spines/thornes	partly

diaspores under a binocular stereomicroscope (Leica Zoom 2000 – Model No. Z45V). The seeds and fruits were identified using special seed atlases and reference books (Bojňanský and Fargašová 2007; Hunyadi et al. 2000; Király et al. 2011; Radics 1998; Schermann 1967) and also an extensive reference collection of seeds and fruits from synanthropic plant species of the region. The difficulties of identification (changes in color, shape, surface structures, size, etc.) were described and also illustrated in some cases. Thousand-seed weights (TSW) of 13 species were measured on laboratory analytical scales and compared to literature data to determine changes in seed size (Radics 1998; Schermann 1967). Statistical analyses were carried out using PAST software (Hammer et al. 2001). The Shapiro-Wilk Test was performed to

assess whether or not the data were normally distributed. Because the data were not normally distributed, the Wilcoxon Signed-Rank Test was then used for comparison of thousand-seed weights. The nomenclature of plant species follows Király (2009).

Results

Evaluation of recovered diaspores
Our results indicate that natural building materials in Hungary contain a large amount of plant remains. A total of 24,634 desiccated diaspores were recovered from 333.05 kg of adobe samples, which belonged to 303 taxa. Cereal crop remains (mostly chaff and straw) are dominant in the recovered plant material; seeds of domesticated and other cultivated plants account for 4.73% of the diaspores. A total of 15 cultivated

Figure 3. Desiccated plant material from sample AB05 (Olasz).

species were identified. The proportion of *Triticum aestivum* L. seeds is the highest, but numerous seeds of *Avena sativa* L., *Brassica ´ napus* ssp. *napus* L., *Papaver somniferum* L. and *Vitis vinifera* L. were also identified. Interestingly, stones of some fruit-trees, e.g. *Amygdalus communis* L., *Juglans regia* L., *Persica vulgaris* Mill. and *Prunus domestica* L. were also found in the studied samples.

In addition, 95.27% of the recovered diaspores are from wild plants, most are weed species associated with arable (Secalietea), ruderal (Chenopodietea), and roadside (Artemisietea) vegetation. Within the arable species, there are many cereal weeds (e.g. *Agrostemma githago* L., *Bromus secalinus* L., *Centaurea cyanus* L., *Papaver rhoeas* L., *Ranunculus arvensis* L.) and also stubble weeds (e.g. *Ajuga chamaeptys* (L.) Schreb, *Consolida regalis* Gray, *Euphorbia falcata* L., *Kickxia spuria* (L.) Dumort., *Stachys annua* L.). A large number of noxious ruderal and roadside weed species (e.g. *Amaranthus* L. spp., *Chenopodium* L. spp., *Rumex* L. spp., *Sambucus ebulus* L., *Verbena officinalis* L.) were also recovered. In addition

to the dominant weed species, several grassland, wetland, and woodland species have also been recovered from the adobe bricks. For the entire list of identified taxa see Supplementary Table 1.

Preservation and deformation of excavated diaspores
The preservation condition of desiccated diaspores from our adobe samples is excellent. A total of 98.97% of the excavated fruits and seeds could be identified to the species level. However, in some other cases the identification was possible only to genus (0.93% of diaspores) or family level (0.10% of diaspores) because morphological changes of desiccated diaspores were significant, as was fragmentation of seeds and fruits (Figure 4A). In several cases, the seed coat (the most important characteristic in the identification process) was lost or badly eroded, and proper identification became extremely difficult or impossible. Although diaspores tended to be well preserved in this study, there is important taphonomic information related to the small proportion of poorly

Table 3. Changes in the size of desiccated diaspores - comparison of thousand-seed weight (TSW) of some excavated species to literature sources.

Taxa	Thousand Seed Weight (g)			Relative shrinkage (%)
	Radics (1998)	Schermann (1967)	Adobe bricks	
Amaranthus retroflexus L.	0.3-0.5	0.3-0.5	0.118-0.185[a]	61.85
Anagallis arvensis L.	0.4-0.8	0.4-0.7	0.178-0.229[b]	62.49
Apera spica-venti (L.) P. Beauv.	0.12	0.12-0.17	0.079-0.090[a]	40.61
Centaurea cyanus L.	2.8-3.8	2.8-3.8	1.700[c]	47.27
Chenopodium album L.	0.8-1.8	0.8-1.0	0.318-0.494[a]	62.48
Cirsium arvense (L.) Scop.	2.0	1.1-1.3	0.247-0.385[b]	77.11
Datura stramonium L.	5.5-8.2	5.5-8.2	3.592[c]	45.45
Geranium molle L.	1.15	1.15	0.207-0.223[b]	81.31
Papaver rhoeas L.	0.09-0.15	0.08-0.1	0.077-0.084[a]	21.11
Polygonum aviculare L.	2.7	0.7-2.7	0.819-1.102[b]	42.19
Stachys annua L.	0.8-1.2	0.8-1.2	0.612[c]	36.25
Verbena officinalis L.	0.3-0.38	0.3-0.38	0.276[c]	19.18
Vicia hirsuta (L.) Gray	4.0-6.5	4.1-6.2	2.148-3.122[a]	48.80

[a] 3 x 100 seeds weighed
[b] 2 x 100 seeds weighed
[c] 100 seeds weighed

preserved diaspores. In the following sections, we discuss the most significant changes of desiccated diaspores recovered from adobe bricks.

Changes in seed coat color
Many of the excavated diaspores differ in color from the recent material. Most of these diaspores absorbed a notably darker brown, reddish-brown, or black color (Table 1). In our findings, Brassicaceae, Caryophyllaceae, and Scrophulariaceae species were the most dominant (Figure 4B and C). Also, seeds of some Fabaceae species, especially *Lathyrus* L. and *Vicia* L. taxa (e.g. *Vicia hirsuta* (L.) Gray, Figure 4D), became not only darker, but their characteristic spots and marbled patterns completely disappeared from the surfaces of seed coats. In contrast, we also found many diaspores that became a lighter brown or grey (e.g. *Fallopia convolvulus* (L.) A. Löve, *Microrrhinum minus* (L.) Fourr., *Myosotis arvensis* (L.) Hill and some *Rumex* L. species). In addition, lustrous and glossy seed coats generally became dull.

Changes in the shape of diaspores
Our research indicates that desiccated diaspores from building materials often become degraded and that surface features are often abraded. This phenomenon hampers the correct identification of many diaspores recovered from adobes, e.g. *Caucalis platycarpos* L.,

Chelidonium majus L. (Figure 4E), *Consolida regalis* Gray, *Daucus carota* L., *Lactuca* L. spp., *Lappula squarrosa* (Retz.) Dumort., *Ranunculus arvensis* L. (Figure 4F), *Sonchus* L. spp., *Turgenia latifolia* (L.) Hoffm. (Figure 4G), *Xanthium* L. spp. and other Asteraceae species (see Table 2). Biological and/or chemical degradation of diaspores was also observed in some cases if the adobe sample got wet before recovery. In our samples, only a few diaspores (e.g. *Amaranthus retroflexus* L. and *Chenopodium album* L.) were affected. Also, many 'hollow' grains were found in the samples, from which the endosperm had disappeared but in which the hulls maintained their original seed shapes or became plastic. Such diaspores (e.g. *C. album*, *F. convolvulus* and *T. aestivum*) are usually extremely fragile.

Changes in the size of diaspores
Although TSW is characteristic for species, seed weights could not be used to identify seeds because of the significant weight changes of desiccated diaspores. We compared the seed size of 13 recovered species to recent material. Our data show a significant decrease in size (Wilcoxon Signed-Rank Test; $t = 3.108$, $df = 12$, $p = 0.00037$) of the recovered seeds from expected (recent) values (Table 3). Use of seed weight for identification is also problematic if there are many 'hollow' grains within the recovered diaspores of examined taxa as this changes TSW dramatically (e.g.
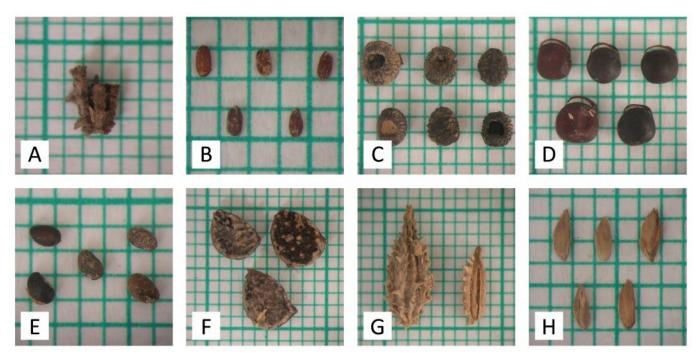
Figure 4. Deformed diaspores: fragmented achene of *Caucalis platycarpos* (A), discolored seeds of *Capsella bursa-pastoris* (B), *Veronica hederifolia* (C) and *Vicia hirsuta* (D), abraded diaspores of *Chelidonium majus* (E), *Ranunculus arvensis* (F) and *Turgenia latifolia* (G), chaff-like seeds of *Cynodon dactylon* (H).

Chenopodium album L., *Cirsium arvense* (L.) Scop.).

Other difficulties of identification
The correct identification of desiccated diaspores can also be influenced by several other factors. We found many similar diaspores of *Papaver* L., *Potentilla* L., *Silene* L. and some Asteraceae and Poaceae species (e.g. *Poa annua*/*P. trivialis*) that were difficult to identify. We also experienced difficulty in the case of Poaceae species, as many of these diaspores (e.g. Figure 4H) were morphologically similar to other plant remains (e.g. chaff, stem and leaf fragments).

Deformation of seeds and fruits can be problematic during identification, and neither reference books nor reference collections can solve these problems. For that reason, we emphasize the diapsores of four species below that were exceptionally difficult to identify because we encountered intact and eroded diaspores that were diverse in terms of diagnostic characteristics. Eroded diaspores could not be identified unless partially eroded forms were recovered. These partially eroded forms served as a midpoint reference in the continuum of erosion, and greatly aided in the correct identification of completely eroded diaspores. New criteria for identification for each of the species is described in detail below;

photos that are referred to for each species are presented in Appendix 1.

1. Centaurea cyanus L. (cornflower)
Characteristic achenes of cornflower (Photo 1A) were always recognizable in the desiccated plant material. On the other hand, highly eroded seeds (Photo 1B) were also encountered that completely differed from the crested achenes of cornflower (Photo 2). Based on our observation, the eroded seed is cylindrical, but a bit stocky, 2.5-3.0 ´ 1.2-1.5 mm. The base is lengthened, 0.5-1.0 mm, and other features and the outer seed coat are totally absent. The surface is smooth, light brown to dark brown or dark purple-brown and dull.

2. Consolida regalis Gray (forking larkspur)
Like the achenes of cornflower, seeds of forking larkspur (Photo 3A) are also recognizable. However, we also found some eroded seeds (Photo 3B) from which the characteristic wing-like flakes and the outer seed coat were totally abraded. The eroded seed is ovate, obovate, or almost roundish, 1.4-1.8 ´ 1.0-1.2 mm. The hilum forms a small pinnacle on the base, while the apex is almost rounded with an expressed annulus. The surface is smooth, yellow to brown, and dull.

3. Scleranthus annuus L. (annual knawel)
Undamaged capsules (Photo 4A) of annual knawel were not found in our samples. The recovered fruits (Photos 4B and 5) are deformed, sepals are parceled (remains of harder main and lateral veins could be found as spikes or stumpy spikes, 2.0-3.5 ´ 1.3-1.5 mm), or are totally abraded (1.4-1.8 ´ 1.3-1.5 mm). The surface is even more waved or ribbed, the neck is more pronounced, and color is yellowish-grey to light brown and dull.

4. Daucus carota ssp. carota L. (wild carrot)
We did not find undamaged achenes (Photo 6A) of wild carrot. The spiny secondary ridges are partially or, in most cases, totally abraded from the dorsal side of achenes. The eroded achene (Photo 6B) is ellipsoid, the non-spiny ridges are visible, the lateral spiny ridges are absent, and the medials are reduced to simple ribs, 2.4-3.0 ´ 1.2-1.5 mm. The surface is smooth, brownish-grey or dark brown to black, and dull.

Discussion
The main focus of archaeobotanical research is to study people/plant relationships, including the reconstruction of agricultural strategies, diet, the social and cultural roles of food, the exploitation of wild resources, and the production of fodder (van der Veen 2007). Ernst and Jacomet (2005) and Paušič et al. (2010) demonstrated that the analysis of desiccated plant remains from natural building materials can be used to reconstruct contemporary house constructions, plant cultivation methods, crop processing procedures, and other kinds of human activities. However, to obtain accurate reconstructions, it is essential to correctly identify archaeobotanical remains. This overview of the effects of diaspore preservation on identification can be of aid to researchers who study fruits and seeds from archaeological sites and from natural building materials.

The archaeobotanical study of plant materials preserved in mud bricks and daub or other building structures is important in arid regions, such as North Africa (e.g. Marinova et al. 2012; Newton 2004; van der Veen 1999), but is rare in the temperate region of Europe (see e.g. Carruthers 1991; Ernst and Jacomet 2005; Paušič et al. 2010). While desiccated North African assemblages originate from a wide range of contexts (pit fills, middens, hearths, dung, wall plaster, mud brick, etc.), those from Europe originate from one specific context: cob and adobe buildings of

medieval and later dates (van der Veen 2007). Our examination of adobe bricks from the 19th and early 20th centuries shows that natural building materials contain a large number of plant remains. Many different kinds of plant materials (mainly cereal chaff and straw) were used for tempering adobe bricks in Hungary. Similar to the study of Hendry and Bellue (1936) and Marinova et al. (2012), a wide spectrum of diaspores of domesticated and other cultivated plants were recovered from our adobe samples. Beyond cultivated species, a large number of fruits and seeds from wild plants (mostly weed species) were recovered and identified. As Jones (1987) concluded, plant remains from archaeobotanical samples can also be products and by-products of crop processing. Hendry (1931), Hendry and Bellue (1936), and Juhász (1991) confirmed that remnants from winnowing, threshing, and other crop processing procedures were used for tempering adobe bricks. (c.f., Ernst and Jacomet 2005, Paušič et al. 2010). However, as de Moulins (2007) demonstrated, it is difficult to ascertain the origin of the incorporated taxa because of complex taphonomic processes. Further, Jones (1987) determined, that remains of wild species from archaeological samples can also originate from adobe pits and their surroundings or from courtyards and other anthropogenic and wild environments (Carruthers 1991; Green 1979; Rösch and Fischer 1999).

Identification of archaeological diaspores can be problematic. As Martin and Barkley (1961) and Schermann (1967) determined, the most useful characteristics for recognition of seeds are shape, size, peculiarities of the surface, and coloring; in most cases combinations of these features are required for a correct identification. The seed coat provides many of the most important diagnostic characteristics, including color, texture, attachments, and scars (Cappers and Neef 2012; Pearsall 2000). Changes of seed coat color of desiccated diaspores have previously been reported by Gyulai (2001), Pearsall (2000), and van der Veen (2007), but these studies did not list species or taxa. In our investigation, several discolored diaspores were identified; these taxa are listed in Table 1 and color changes have been precisely documented. Pearsall (2000), van Bergen et al. (1997), and van der Veen (2007) also found that most of the discolored diaspores became notably darker and dull, and patterns disappeared from surfaces. In contrast, here many diaspores were found that lightened in color (e.g. *Microrrhinum minus* and *Myosotis arvensis*), which has not been described previously. Beyond coloring, the

shape of diaspores also provides important diagnostic characteristics (e.g. features and peculiarities); the presence or absence of these can also significantly influence identifiability (Cappers and Bekker 2013; Radics 1998; Schermann 1967).

Preservation of desiccated diaspores is usually excellent, thus surface features and growths (hairs, wings, spikes, etc.) and papery tissues (e.g. palea and lemma) are often present (van Bergen 1997; van der Veen 2007). However, desiccated materials may also be fragile, thus preservation is primarily dependent on burial conditions (Cappers and Neef 2012; Pearsall 2000; van der Veen 2007). In addition, Pennington and Weber (2004) and Schermann (1967) suggest that specific traits of plant species may also be important factors in preservation. In our findings, most diaspores affected by degradation have different kinds of surface features (hairs, spikes, wings, etc.) (Table 2). Final identification of our degraded diaspores in many cases was only possible if intact, partially and completely degraded seeds of the same species (e.g. in the cases of *Centaurea cyanus* and *Consolida regalis*) were also recovered. This allowed direct comparison of similar seeds in different preservation stages and also comparison to seeds in reference collections (c.f. Cappers and Neef 2012; Gyulai 2001). Beyond mechanical impacts, diaspores may also be degraded by chemical and biological processes, resulting in distended, deformed materials and corroded surfaces (Gyulai 2001; Hillman et al. 1993; Pearsall 2000; van Bergen et al. 1997). However, de Moulins (2007) and Miller (1989) note that desiccated materials are usually not affected by these processes because chemical and microbial degradation is lacking or is slow in continuously dry conditions. In some cases adobe samples may have been exposed to moisture prior to recovery, thus biochemical processes may have degraded the diaspores and 'hollow' grains (van der Veen 2007) and partially decomposed seeds may form. These kinds of remains tend to be very fragile.

Seed size is another important characteristic for identification; no previous studies have reported change in size of archaeological diaspores to be problematic for identification. In this study, beyond the changes in the color and shape of the recovered diaspores, a significant change has been observed in the size of desiccated fruits and seeds (Table 3). We contend that size change must be considered as an important factor during the identification process.

Conclusion

This paper presents the most common deformation types of desiccated diaspores in adobe bricks from Southwestern Hungary and provides a species list with changes in the morphology of diaspores. This aids in the identification of desiccated fruits and seeds from natural building materials from archaeological contexts. Diaspores from many other archaeological contexts are influenced by similar taphonomic process that change size, texture, color, and shape of seed and fruit remains. Therefore, the results reported here are important for archaeobotany more broadly. The correct identification of palaeoethnobotanical plant remains is essential for producing reliable biological, ecological, and sociological data.

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Biosketches

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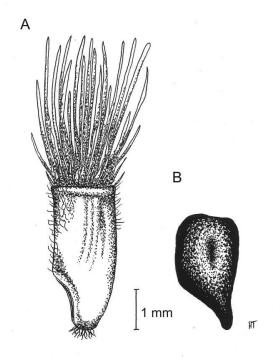
Appendix

Photo 1. Intact (A) achene and eroded seed (B) of *Centaurea cyanus*.

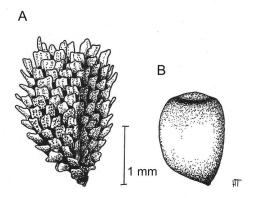**Photo 2.** Achenes of *Centaurea cyanus* found in sample AB02 (Véménd).

Photo 3. Intact (A) and abraded seed (B) of *Consolida regalis.*
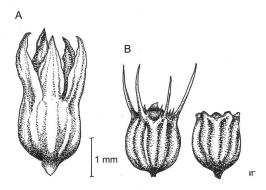

Photo 4. Intact (A) and abraded capsules (B) of *Scleranthus annuus.*

Photo 5. Deformed diaspores of *Scleranthus annuus* found in sample AB34 (Abaliget).
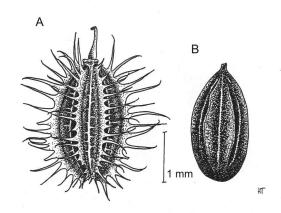
Photo 6. Intact (A) and abraded polachenarium (B) of *Daucus carota* ssp. *carota.*