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Re-thinking the preservation biases impacting the Neolithic plant record in the Iberian Peninsula: insights from La Draga (Banyoles, Spain)

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Abstract

Seeds and fruits are frequently recovered at archaeological sites in the Iberian Peninsula, mainly preserved in a charred state. Plant assemblages recovered from waterlogged and desiccated contexts show that charring leads to a biased representation of certain taxa, as not all plants are equally likely to become charred or survive charring. For instance, wild fruits rarely require processing and are often eaten raw, so their presence in the record is usually minimal. The archaeobotanical record of the Neolithic period in the Iberian Peninsula is mainly composed of charred cereals (at least in terms of absolute numbers) but does their abundance reflect actual usage or is a preservation bias? La Draga settlement (Banyoles, Spain) (5300–4700 cal BCE) has been excavated in several sectors located at different levels relative to the water table. This leads to varied preservation conditions: some areas mainly contain charred organic materials, while others preserve abundant waterlogged remains. The waterlogging of the archaeobotanical assemblage allows a wider range of taxa to be preserved, thereby enabling a more detailed and comprehensive reconstruction of economic activities. Now, based on the results from the studied sectors and new data from waterlogged sector B, we aim to emphasise the importance of this lakeshore site to reconstruct the full plant spectrum used by Neolithic farmers. We also highlight the need to continue exploring new areas as we gain further insights. Overall, this study shows that the variability in preservation at La Draga is key to identifying and interpreting biased taxon representation, contributing to broader discussions on taphonomy and subsistence reconstruction in prehistoric wetland sites.

Keywords Archaeobotany · Carpology · Waterlogging · Anaerobic contexts · Early Neolithic · Taphonomy

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Introduction

Research on plant use during the Neolithic (5800–2300 BCE) in the Iberian Peninsula has largely focused on cereals as markers of agriculture and diet, reflecting the predominance of charred cereal remains in archaeobotanical assemblages (e.g. Buxó 1997; Peña-Chocarro et al. 2018). This pattern is visible at many sites, largely due to the preservation of botanical remains in charred form, which is the most common preservation type in the region. Charred remains usually result from the accidental burning of plant foods and materials during preparation, processing, cooking or litter disposing. Dry seeds or seeds with low oil content tend to withstand burning better and to survive intact more often than fresh or oily seeds. As a result, some seeds have a broader range of survival than others (Colledge and Conolly 2014).

Archaeobotanical studies (Bishop et al. 2010; Colledge and Conolly 2014; Antolín and Jacomet 2015; Alonso et al. 2016; Vandorpe et al. 2024) and ethnographic research (e.g. Bharucha and Pretty 2010) suggest that early farmers depended not only on cultivated cereals but also on a variety of wild plants. These wild plants are often underrepresented in the archaeobotanical record because of taphonomic processes. Many taxa preserve only when accidentally charred, requiring exposure to fire, while others are more likely to be destroyed at high temperatures. In contrast, materials frequently processed near fire (e.g. through roasting), such as nuts, and thus their shells, have a higher probability of accidental charring and can survive a broader range of charring conditions (Berihuete-Azorín and Antolín 2012). As a result, the assemblage reflects differential preservation rather than actual consumption patterns, resulting in an incomplete understanding of Neolithic foodways across the region.

Recent advances in northeastern Iberia (e.g. Garay-Palacios et al. 2025) highlight the need for research frameworks that explicitly address such preservation biases, as anaerobic conditions such as waterlogging offer a wider variety of taxa and plant parts than charred-only assemblages (Jacomet 2013).

La Draga, an Early Neolithic (5300–4700 BCE) (Andreaki et al. 2022) lakeshore site located in northeastern Iberia, on the eastern side of the Lake of Banyoles, provides an exceptional case study. Today, part of the site rests on dry land, while another part is submerged beneath the lake water table. These conditions have led to the excellent preservation of archaeobotanical remains, including wood, fibres, and a wide range of plant macroremains.

Since excavations started in 1991, archaeologists have worked in three distinct sectors: A, B/D, and C (Fig. 1), each with different preservation conditions due to water table variations (Bosch et al. 2011; Palomo et al. 2014; Andreaki et al. 2022). The entire site was initially above the prehistoric lake water table, but today Sectors B–D and C containing the oldest stratigraphic layers are underwater, which has preserved organic materials in waterlogged conditions. In contrast, layers in Sector A remained above the water table during most of their post-depositional history, resulting in the decay of non-charred remains (Piqué et al. 2022) and fluctuations in the phreatic level have impacted the preservation of organic material in waterlogged conditions.

Sectors B/D have a phreatic layer that contains charred and uncharred organic materials preserved by anaerobic groundwater conditions. It holds archaeological finds such as fauna, plants, ceramics, lithic industries, wooden objects, cords, and basketry—rare at ground level. Sectors B and D are adjacent areas of the site, located next to each other. However, they were excavated during different field campaigns several years apart and are therefore treated separately in this study.

Sector C is currently underwater. With less finds than in Sector B, it still contains organic remains such as wooden objects, fauna, and plant macroremains. Due to the limited amount of archaeobotanical material, it has been excluded from the scope of the present study.

These preservation contrasts make La Draga unique in the Iberian Peninsula. They enable a direct, same-site examination of how anaerobic versus aerobic conditions shape taxon visibility, removing inter-site environmental

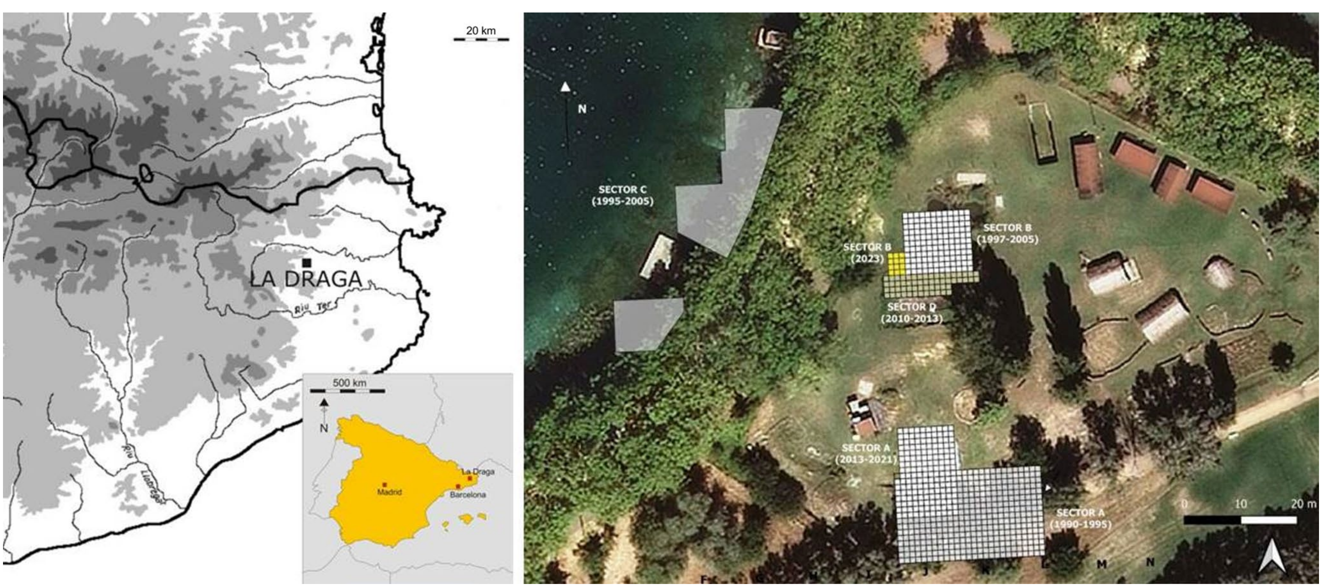

Fig. 1 Map showing the location of La Draga, along with a plan of the site indicating the different sectors

variability from the equation. Consequently, La Draga is an ideal setting to evaluate whether the lack of certain plants in typical Iberian contexts reflects genuine economic or ecological patterns—or simply taphonomic biases.

The aim of this paper is therefore to assess the role of waterlogged preservation in revealing missing components of the Neolithic plant economy considering both the charred and uncharred assemblages of La Draga. By comparing plant assemblages from different sectors at La Draga, we investigate how preservation biases affect our recovery of cultivated and wild taxa and ultimately refine interpretations of early farming and gathering strategies in south-west Europe, comparing La Draga to other lakeshore sites with similar preservation.

Materials and methods

Archaeobotanical material from different sectors of La Draga has been analysed and compared (Table 1). In the first place, structures E254, E255, and E258 identified during the 2014 excavations of Sector A and previously analysed by (A) Barberà and F. Antolín (Berrocal et al. 2025) were included in this analysis. Secondly, profile samples and 12 surface samples from layer VII of Sector B, excavated in 2023, analysed by (B) Garay-Palacios and presented here for the first time. Finally, 40 surface samples from layer VII of Sector D, excavated during the 2010 campaign, and previously studied by Antolín (2013, 2016) were also included in the analysis. Additionally, 27 samples from structure E7001 in sector D (Berrocal Barberà 2013), excavated in 2011, are included too. From sectors B and D, large items that had few chances of being represented in the small systematic samples were hand-sorted from the water-screened samples (Antolín 2013; Antolín et al. 2013).

La Draga is excavated in a 1 × 1 m grid. For the recovery of non-coordinated items, including sediment surface samples of 1 L of sediment, each square is divided into 4 sub-squares and the north-east square is processed by wash-over (with a minimum mesh of 0.35 mm) for archaeobotanical study (Steiner et al. 2015). The samples from sectors B and D were measured using the displacement volume method, and then the samples were frozen and defrosted for better processing (Antolín et al. 2015b; Vandorpe and Jacomet 2007). Additionally, 10 L per square were collected for flotation (Kenward et al. 1980), while the remaining material was water-screened with a minimum mesh of 2 mm.

Archaeological structures undergo special treatment: they are fully sampled and processed either by flotation or wash-over. Structures in Sector A were very large and were also sampled following the same grid but sieving 10 L per sample. Due to the abundance of remains in some samples, subsampling of the sieved fractions using the grid-method was often applied, with subsamples typically representing up to 20% of the total material; and the estimated total values obtained from those sub-fractions were used for our interpretations.

All samples were sorted under a binocular stereoscope with magnification up to ×40/×60, and waterlogged samples were kept in water during the process to avoid damage of the organic materials. Charred remains were dried only after sorting. Carpological remains were fully quantified, whereas other materials were described semi-quantitatively, except for bone, malacological, and entomological remains, which were fully quantified (Antolín 2016; Antolín et al. 2017).

The carpological remains were identified through seed atlases and guides (e.g. Cappers et al. 2012; Jacomet 2006; Sabato and Peña-Chocarro 2021) and reference collections from the Integrative Prehistory and Archaeological Science unit at the University of Basel, as well as the Archaeological Museum of Catalonia (Girona) and the German Archaeological Institute (Berlin). Plant species nomenclature is based on the *Flora Manual dels Països Catalans* (de Bolòs et al. 1990) and IPNI.

The results are presented in a table showing the presence or absence of identified plant taxa across the three site sectors (A, B, D), with two preservation states: charred and uncharred (Table 1). The taxa are grouped ecologically to give an overall picture of their potential distribution, based on current knowledge of their presence in the same area, which helps in understanding the results. To homogenise the classification, the same ecological groups defined by Antolín (2013) were used. These include cultivars, weeds and ruderals, woodland edges and clearings, woodland, pastures and grasslands, lakeshore, aquatic plants, and taxa with diverse or unknown ecologies. Most taxa identified to the genus or family level appear under diverse, since they can correspond to species with different ecological preferences. The analysis is based on the total number of observations per

Table 1 List of samples included for this study

Sector	Context type	Structure/level	Nº of samples	Total vol. (l)	Bibliography
A	Structures E254, E255, E258	Conc. of charred grain	27	260	Berrocal et al. 2025
D	Structure E7001	Conc. of charred grain, LayerVII	1	49	Berrocal Barberà 2013
B	Surface samples	NVII-0	12	6.95	This paper
D	Surface samples	LayerVII	40	29.79	Antolín 2016
D	Profile samples	LayerVII	15	6.1	Antolín 2016

Table 2 Total and proportion of taxa per ecological group in each sector

Ecological group	A		B		D	
	Charred	Uncharred	Charred	Uncharred	Charred	Uncharred
Cultivated	17 (71%)	0	15 (60%)	2 (3%)	17 (41%)	11 (10%)
Wild	5 (21%)	0	9 (36%)	41 (61%)	10 (24%)	64 (57%)
Diverse	2 (8%)	0	1 (4%)	24 (36%)	14 (34%)	38 (34%)
Sub-total	24	0	25	67	41	113
Total	24		92		154	

Charred and uncharred are presented to illustrate preservation differences among sectors

Table 3 Presence/absence and preservation state (charred/uncharred) of cultivar taxa across sectors

Cultivars	Remain	A		B		D	
		Preservation					
		C	U	C	U	C	U
Cereals							
Hordeum distichon	Chaff			x		x	
H. distichon/vulgare	Chaff/grain			x/x			
H. vulgare undiff	Grain			x		x	
H. vulgare var. *nudum*	Grain	x					
Hordeum sp.	Chaff/grain	/x				x/x	x/
Triticum sp.	Chaff/grain	x/x		x/x		x/x	x/
Triticum sp.	Grain (FpreC)	x				x	
T. aestivum s.l./*durum/turgidum*	Chaff/grain	x/x		x/x	x/	x/x	x/
T. aestivum s.l./*durum/turgidum*	Grain (FpreC)			x			
T. aestivum	Chaff					x	x
T. durum/turgidum	Chaff	x				x	x
T. durum	Chaff			x			
T. timopheevii	Chaff			x			
T. dicoccum	Chaff/grain	/x		x/		x/	x/
T. monococcum	Chaff/grain	x/x		x/		x/x	x/
T. dicoccum/monococcum	Chaff/grain	x/x					
Glume wheat	Chaff						x
Cerealia	Chaff/grain	x/x		x/x		x/x	x/x
Oil plants							
Papaver somniferum	Seed/Fruit	x			x	x	x
Legumes							
cf. *Lens culinaris*	Seed/Fruit	x					

FpreC, fracture prior to charring

preservation state rather than the count of remains. For each sector, totals for charred and uncharred observations were calculated, along with the proportion of uncharred observations relative to the total, to assess taphonomic preservation differences among sectors.

Results

Based on the carpological analysis, a total of 169 plant taxa have been identified at La Draga. The results by sector and ecological group emphasise key patterns in preservation and taxonomic diversity per sector and type of preservation (charred vs. uncharred) (Table 2).

A variety of cultivated taxa have been identified. The most abundant are cereals, which include naked wheat, naked barley as well as hulled wheats, such as emmer, Timopheevii's wheat and einkorn. Other cultivars include oil plants, poppy in this case, and a legume identified as cf. *Lens culinaris* (Table 3).

Clear differences in taxa representation are observed between sectors with contrasting preservation conditions (Table 3). Cereal remains are ubiquitous at the site, showing better preservation in the waterlogged assemblages. This applies to fragile remains, such as charred and uncharred chaff, as well as cereal caryopses, recovered in a charred state.

In non-waterlogged sectors, charred cereals account for the majority of the recovered cultivated taxa, while uncharred oil poppy is found mostly in sectors B and D. Finally, the lentil was recovered in sector A, in a charred state.

Most wild plants, a total of 98 taxa (Table 4), are represented in Sectors B and D, as uncharred remains. However, some taxa occur as charred remains even within anaerobic contexts, and in certain cases are only documented in this preservation state. Within the group of weeds and ruderals, *Galium aparine* (Sector B), *Hyoscyamus niger* (Sector D), and *Oxalis* sp. (Sector B) are preserved exclusively as charred remains, despite being recovered from waterlogged sectors. *Verbena officinalis* is preserved uncharred in waterlogged sectors and is also present in Sector A as charred remains; in Sector D it occurs in both charred and uncharred states. *Scleranthus annuus* is among the few taxa recovered in Sector A, where it is preserved as charred remains, and it is also attested as charred in Sector D. *Lotus* cf. *corniculatus* is restricted to Sector A and occurs only charred.

Within the woodland ecological group, charred remains are present in Sector A, represented by *Laurus nobilis*, a taxon not recorded in Sectors B or D. In contrast, Sectors B and D yield several woodland taxa preserved as uncharred remains, including *Cornus sanguinea*, *Corylus avellana*, and *Euphorbia amygdaloides*, among others. No taxa belonging to pastures and grasslands are represented in Sector A. In Sectors B and D, this ecological group is represented exclusively by uncharred remains. Both sectors contain *Hypericum perforatum* and *Apium graveolens*, while the remaining taxa within this group are restricted to Sector D. Taxa of woodland edges and clearings are absent from Sector A. In Sectors B and D, this group is represented solely by uncharred remains, including *Physalis alkekengi*, *Sambucus nigra*, *Clematis vitalba*, and *Fumaria officinalis*. Water plants are documented exclusively as uncharred remains in Sectors B and D, including taxa such as *Najas marina*, *Ranunculus aquatilis*, and *Potamogeton* sp. Lakeshore taxa are also absent from Sector A. Although most remains from Sectors B and D are uncharred, some taxa are represented in both preservation states, including *Vitis vinifera* ssp. *sylvestris*, *Lycopus europaeus*, and *Alisma plantago-aquatica*.

Fruit and seed remains are categorised as "seed/fruit" for consistency, whether they are whole fruits, seeds, or pericarp fragments.

Within the diverse ecological group (Table 5), which as mentioned comprises taxa identified only at genus or family level or with uncertain ecological preferences (Antolín 2013), Sector A shows low diversity of taxa, limited to taxa such as *Laurus*, *Quercus*, and Poaceae. In contrast, Sectors B and D include the majority of taxa in both uncharred and sometimes charred form, such as Asteraceae, Lamiaceae, and *Rubus* spp., which were found both as charred and uncharred remains.

Discussion

In the context of Iberian archaeology, La Draga represents an exceptional case for studying plant-use strategies thanks to waterlogged preservation. However, a question arises: is the knowledge we gain also exceptional and exclusive to this specific site, or does it reveal the potential typical plant use for other sites in the region usually lost due to taphonomic processes? Our results illustrate the extent to which taphonomic processes determine the composition of plant macroremain assemblages, particularly through the contrast between waterlogged (charred and uncharred) and dry (only charred) assemblages.

The implications of the charred record at La Draga for the Iberian Peninsula

At La Draga, 71% of the identified taxa in sector A, with only charred preservation, are cultivated cereals. As noted, these are more prone to accidental charring and better preservation. Without sectors B and D, La Draga would resemble any other Early Neolithic site of the region, with assemblages composed of ca. 99% of charred cereals, suggesting cereal cultivation as the main economic activity. In this scenario, the interpretation of the use and management of plants or their environment would mainly focus on cereals, while the few other plant species might be interpreted as weeds or ruderals that appear by chance in the record without economic importance. Even so, it is worth to mention that among the charred remains recovered from sector A, there are taxa previously absent from the carpological record such as *Laurus nobilis*. Although well represented among the firewood, tools and piles from the site (López-Bultó et al. 2023), the fruits of this particular taxon have only been recovered charred in the layers with dry preservation, being absent from the waterlogged sectors, indicating that different preservation conditions can provide distinct yet complementary datasets.

In contrast, the sectors of La Draga with waterlogged deposits exhibit a broader taxonomic diversity, with wild plants, weeds, and aquatic taxa playing a prominent role. And not only seeds and fruits, but also soft plant parts, underground storage organs, and fungi (Berihuete-Azorín et al. 2018; Berihuete-Azorín 2021) are preserved. As a result, assemblages from waterlogged contexts can outnumber dry assemblages with exclusive charred preservation by thousands of specimens (Colledge and Conolly 2014).

Not only wild plants are better represented at La Draga, charred and uncharred fragile elements such as cereal chaff, rare in the archaeobotanical record of the Iberian Peninsula, are present not only in waterlogged contexts but also frequently well preserved, particularly in Sector D. This

Table 4 Presence/absence and preservation state (charred/uncharred) of wild taxa across sectors

Taxa	Remain	A		B		D	
		Preservation					
		C	U	C	U	C	U
Weeds and ruderals							
Ammi majus	Seed/fruit						x
Avena sp.	Floret base						x
Avena sp.	Seed/fruit					x	
Bromus sp.	Seed/fruit			x			
Bromus cf. *arvensis*	Seed/fruit						x
Bromus hordeaceus/secalinus	Seed/fruit						x
Capsella bursa-pastoris	Seed/fruit					x	x
Chenopodium album	Seed/fruit						x
cf. *Dactylis glomerata*	Seed/fruit				x		x
Euphorbia helioscopia ssp. *helioscopia*	Seed/fruit						x
Galium aparine	Seed/fruit			x			
Galium aparine ssp. *spurium*	Seed/fruit						x
Hyoscyamus niger	Seed/fruit					x	
Lotus type *corniculatus*	Seed/fruit	x					
Mercurialis annua	Seed/fruit				x		
cf. *Neslia paniculata*	Seed/fruit						x
Oxalis sp.	Seed/fruit			x			
Polygonum aviculare	Seed/fruit						x
cf. *Polygonum convolvulus*	Seed/fruit				x		
Portulaca oleracea	Seed/fruit				x		x
Reseda phyteuma	Seed/fruit				x		x
cf. *Scandix pecten-veneris*	Seed/fruit						x
Scleranthus annuus	Seed/fruit	x				x	
Silene cf. *cretica*	Seed/fruit				x		
Silene cf. *vulgaris*	Seed/fruit			x			
Silene gallica	Seed/fruit						x
Stellaria graminea	Seed/fruit			x			
Silybum marianum	Seed/fruit				x		
Sonchus cf. *asper*	Seed/fruit				x		x
cf. *Thymelaea passerina*	Seed/fruit				x		
Urtica sp.	Seed/fruit				x		
Urtica dioica	Seed/fruit				x		x
Verbena officinalis	Seed/fruit	x			x	x	x
Pastures and grasslands							
Apium graveolens	Seed/fruit				x		x
Arenaria serpyllifolia	Seed/fruit						x
Campanula cf. *rotundifolia*	Seed/fruit						x
Epilobium sp.	Seed/fruit						x
Hypericum perforatum	Seed/fruit				x		x
Leucanthemum vulgare	Seed/fruit						x
Linum catharticum	Seed/fruit						x
Petrorhagia prolifera	Seed/fruit						x
cf. *Pulicaria dysenterica*	Seed/fruit						x
Thymelaea sp.	Seed/fruit						x
Woodland							
Cornus sanguinea	Seed/fruit						x
Corylus avellana	Shell fragment						x
Euphorbia amygdaloides	Seed/fruit						x
Laurus nobilis	Seed/fruit	x					
Laurus/Quercus	Seed/fruit	x					
Maloideae	Seed/fruit						x
Prunus cf. *avium*	Bead fragment						x

Table 4 (continued)

Taxa	Remain	A		B		D	
		Preservation					
		C	U	C	U	C	U
Pyrus malus ssp. *sylvestris*	Seed/fruit						x
Quercus sp.	Shell				x		
Quercus sp.	Seed/fruit				x	x	x
Rosaceae	Seed/fruit			x	x		
Viola cf. *alba*	Seed/fruit						x
Woodland edges and clearings							
Clematis vitalba	Seed/fruit				x		x
Fragaria vesca	Seed/fruit						x
Fumaria officinalis	Seed/fruit				x		
Origanum vulgare	Seed/fruit				x		x
Physalis alkekengi	Seed/fruit				x		x
Prunus sp.	Seed/fruit				x		x
Prunus spinosa	Fruit stone fragment						x
Rubus fruticosus agg	Seed/fruit						x
Sambucus nigra	Seed/fruit				x		
Vicia sepium	Seed/fruit					x	
Lakeshore							
Alisma plantago-aquatica	Seed/fruit			x	x		x
Alnus glutinosa	Seed/fruit					x	
Apium nodiflorum ssp. *nodiflorum*	Seed/fruit						x
Carex cf. *hirta*	Seed/fruit				x		x
Cladium mariscus	Seed/fruit				x		x
Cyperus fuscus	Seed/fruit				x		x
Eupatorium cannabinum	Seed/fruit						x
Juncus sp.	Seed/fruit						x
Lycopus europaeus	Seed/fruit			x	x	x	x
Mentha cf. *aquatica*	Seed/fruit						x
Mentha aquatica/arvensis	Seed/fruit				x		
Mentha cf. *longifolia*	Seed/fruit				x		
cf. *Phragmites* sp.	Seed/fruit						x
Phragmites australis	Seed/fruit						x
Plantago major	Seed/fruit				x		
Plantago major ssp. *intermedia*	Seed/fruit						x
Ranunculus sceleratus	Seed/fruit				x		x
Schoenoplectus lacustris	Seed/fruit				x		x
Typha sp.	Seed/fruit						x
Typha latifolia	Seed/fruit				x		
Vitis vinifera ssp. *sylvestris*	Seed/fruit			x	x	x	x
Water plants							
Chara sp.	Oospores				x		x
Characeae	Seed/fruit				x		x
Myriophyllum spicatum	Seed/fruit				x		
Najas marina	Seed/fruit						x
cf. *Nuphar/Nymphaea*	Seed/fruit				x		
Potamogeton sp.	Seed/fruit				x		
Potamogeton cf. *coloratus*	Seed/fruit						x
Ranunculus aquatilis	Seed/fruit				x		x

includes both uncharred and charred chaff from cereals, allowing a more detailed reconstruction of crop processing activities. Therefore, such deposits provide a more representative framework for reconstructing plant use and avoiding biased economic interpretations.

For instance, at most Neolithic sites in north-eastern Iberia, naked wheat (*Triticum aestivum/durum/turgidum*)

Table 5 Presence/absence and preservation state (charred/uncharred) of non-ecologically classified taxa across sectors

Taxon	Remain	A		B		D	
		Preservation					
		C	U	C	U	C	U
Diverse							
Acer sp.	Seed/fruit				x		
Ammi/Apium	Seed/fruit						x
Apiaceae	Seed/fruit				x		x
Apium sp.	Seed/fruit				x		x
Asteraceae	Seed/fruit				x	x	x
Brassica sp.	Seed/fruit						x
Carex sp.	Seed/fruit				x	x	x
Carex sp. bicarpellate	Seed/fruit						x
Carex sp. tricarpellate	Seed/fruit						x
Caryophyllaceae	Seed/fruit					x	x
Cerastium sp.	Seed/fruit					x	x
Cerealia/Poaceace	Seed/fruit						x
Chenopodium sp.	Seed/fruit			x			
Crepis sp.	Seed/fruit						x
Cyperaceae	Seed/fruit				x		x
Cyperus sp.	Seed/fruit						x
Euphorbia sp.	Seed/fruit						x
Fabaceae	Seed/fruit					x	x
Fragaria sp.	Seed/fruit				x		
Fumaria sp.	Seed/fruit				x		
Hypericum sp.	Seed/fruit				x		x
Lamiaceae	Seed/fruit				x	x	x
Laurus/Quercus	Seed/fruit	x					
Linum sp.	Seed/fruit						x
Mentha sp.	Seed/fruit				x		x
Papaver sp.	Seed/fruit						x
Papaver/Nasturtium	Seed/fruit						x
Phragmites sp.	Seed/fruit					x	
Poaceae	Seed/fruit	x			x	x	x
Polygonaceae	Seed/fruit				x	x	
Polygonum sp.	Seed/fruit				x		x
Potentilla sp.	Seed/fruit						x
Ranunculus sp.	Seed/fruit				x		x
Rosa/Rubus	Spine						x
Rosaceae	Spine						x
Rubus fruticosus agg.	Seed/fruit				x		
Rubus cf. *idaeus*	Seed/fruit				x		
Rubus sp.	Seed/fruit				x	x	x
Rumex sp.	Seed/fruit				x	x	x
Sambucus sp.	Seed/fruit				x		*x*
Scirpus sp.	Seed/fruit						x
Setaria sp.	Glume base						x
Silene sp.	Seed/fruit				x		
Solanaceae	Seed/fruit				x		x
Stellaria sp.	Seed/fruit						x
Torilis sp.	Seed/fruit						x
Trifolieae	Seed/fruit						x
Verbascum sp.	Seed/fruit				x	x	
Vicia sp.	Seed/fruit					x	
Vicia/Pisum	Seed/fruit					x	
Viola sp.	Seed/fruit				x		x

is well represented in a wide range of archaeological contexts. According to Antolín (2013), the sites discussed below show varying depositional contexts and preservation patterns, including pits at open-air dry sites such as Carrer Reina Amàlia, funerary deposits inside caves where vessels filled with charred grain were recovered (e.g. Can Sadurní), secondary deposits in abandoned storage pits (e.g. Bòbila Madurell), and pit houses such as those documented at Serra del Mas Bonet or Camp del Colomer. Hulled barley (*Hordeum distichon/vulgare*) is also recurrent and has been identified at sites such as Serra del Mas Bonet, Carrer Reina Amàlia, and Can Sadurní. Emmer (*Triticum dicoccum*) is present at Bòbila Madurell, Carrer Reina Amàlia, and Can Sadurní, while einkorn (*Triticum monococcum*) has been documented at sites including La Dou, Bòbila Madurell, and Can Sadurní. It is also the main taxa found in rock shelters like Coves del Fem (Garay-Palacios et al. 2025). All these taxa are likewise present at La Draga (Antolín and Buxó 2011; Antolín et al. 2014).

Nevertheless, La Draga stands out in this Early Neolithic record for the presence of two-row barley (*Hordeum distichon*), a taxon not identified at contemporary sites in north-eastern Iberia. This identification is based on the presence of charred chaff remains and ear fragments, which provide secure evidence for its cultivation at the site (Antolín et al. 2015a). The diagnostic rachis fragments required to distinguish two-row from six-row barley are fragile and often poorly preserved, meaning that two-row barley may be underrepresented at sites where diagnostic chaff remains are absent.

Concentrations of cereal remains (i.e. contexts containing more than 100 charred plant remains) are frequently documented at Early Neolithic sites across the area. However, the La Draga lakeshore site is exceptional, having yielded massive concentrations of charred grains (Antolín and Buxó 2011). Chaff remains are present at many early Neolithic sites in the north-eastern Iberian Peninsula, although they are generally underrepresented in charred assemblages when compared to assemblages that include uncharred material. Although chaff is generally scarce in charred assemblages, La Draga yielded substantial chaff remains, illustrating the site's exceptional preservation (Antolín et al. 2015a).

The implications of the waterlogged record at La Draga for the Iberian Peninsula

The representation of legumes and oil plants in the region's archaeobotanical record is generally sparse but relatively consistent throughout the Neolithic. A notable case is opium poppy (*Papaver somniferum*), which was recovered in large quantities in a waterlogged state only at La Draga and suggests a specific importance of this crop within early farming systems (Antolín et al. 2015a).

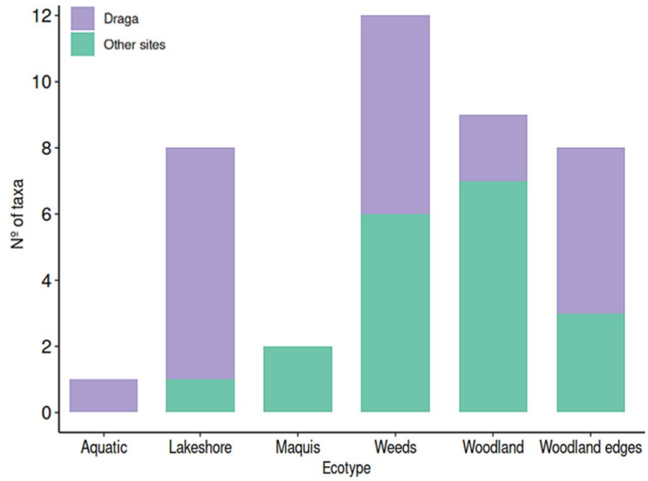

Fig. 2 Taxa found at La Draga versus other sites ($n = 12$) from north-east Iberia, according to ecological groups (based on Antolín and Jacomet 2015)

Where the waterlogged preservation of La Draga really stands out, above other Neolithic sites, is regarding the number of identified wild taxa. When comparing La Draga to other sites in the NE of the Iberian Peninsula (Antolín and Jacomet 2015) we can see that the vast majority of taxa from wild plants has been identified at the site. This might be logical for certain ecological groups, such as aquatic and lakeshore plants, but remarkable for potential weeds or synanthropic plants. While plants from woodlands are well-documented in dry sites, the record of La Draga demonstrates the great importance of open areas (woodland edges and lakeshore environments) and anthropogenic environments, where a broad taxonomic diversity can be encountered. It is possible that these ecological groups were also important at other Neolithic sites with comparable environmental settings, despite not having them represented in the archaeobotanical record. Nevertheless, the comparison of the results of La Draga to other sites with similar preservation quality can help us discriminate local ecological patterns from broader trends (Fig. 2).

La Draga in the context of Neolithic lakeshore settlements in Southern and Central Europe

The contrast between waterlogged and non-waterlogged sectors at La Draga shows patterns observed at other European lakeshore sites, where waterlogged deposits consistently yield more diverse plant assemblages than charred-only contexts (Jacomet 2013; Colledge and Conolly 2014).

The closest chronological and geographical parallel to La Draga is located in northern Italy and comes from Isolino Virginia, a small island in Lake Varese near the Swiss border, with an archaeological sequence spanning the Early Neolithic to the Bronze Age. Despite a relatively high number of charred finds, 94% of the plant remains recovered from the site are preserved uncharred (Steiner et al. 2025). The assemblage shows remarkable taxonomic and ecological diversity, comparable to that documented at La Draga, including aquatic plants, lakeshore vegetation, and taxa of woodlands and woodland-edges. As at La Draga, the majority of these ecological groups are characterised primarily by uncharred preservation, although several taxa also occur in charred form. For instance, *Lycopus europaeus* and *Quercus* sp. are present in both charred and uncharred state at both sites, as are cereals. These similarities highlight characteristics commonly observed at sites with well-developed waterlogged preservation, rather than site-specific plant-use strategies.

Comparable patterns are observed at the Late Neolithic lakeshore settlement of Grandson–Corcelettes, Les Pins (Switzerland), where 93.4% of the plant remains are waterlogged and wild plants account for 34.5% of the identified taxa (Vandorpe et al. 2024). Waterlogged preservation enabled the recovery of chaff and oil plants such as *Papaver somniferum*, which are poorly represented in charred assemblages and are also documented at La Draga. Wild fruits are abundant, particularly in uncharred form, although some taxa, such as *Malus sylvestris* and *Quercus* cotyledons, are also found charred. Additionally, cereals and oil plants are well represented in the record, with cereals more abundant in the uncharred assemblage, reinforcing the idea that even at waterlogged sites charred materials can be exceptionally well preserved. The assemblage also includes aquatic plants such as *Najas marina* and *Chara* sp., along with potential weeds such as *Chenopodium album* and *Stellaria media*, all of which are also documented at La Draga. Despite the geographical distance, the overall archaeobotanical patterns are remarkably similar.

Unlike the previously discussed sites located in more northerly regions of Europe, the lakeshore settlements in the Lake Ohrid region are comparable in latitude to La Draga in southern Europe, allowing for a more meaningful comparison beyond Alpine and circum-Alpine contexts. The Neolithic and Bronze Age pile-dwelling site of Ploča Mičov Grad, located on the eastern shore of Lake Ohrid in North Macedonia, has yielded abundant waterlogged organic remains (Holguin et al. 2024, 2025). Although the Balkans represent a key region for understanding the spread of agriculture due to the convergence of Mediterranean, Alpine and continental biogeographical zones (Holguin et al. 2025), the assemblage is characterised by a strong presence of wild fruits and wild/weed taxa, being cereals still the most abundant group recovered. Several of these wild taxa are also documented at La Draga in uncharred form, including *Quercus* sp., *Corylus avellana*, as well as other wild plants such as *Hypericum perforatum*, *Arenaria serpyllifolia*, *Chenopodium album* and *Polygonum convolvulus*. Holguin and colleagues (2025) note that some taxa, such as *Origanum vulgare* and *Mentha longifolia*, which are also present at La Draga, may have been collected as herbs, medicinal plants or food, yet they are classified as wild or weed plants due to their widespread natural occurrence. While recent studies have begun to explore the role of wild plants in prehistoric diets, this remains an area requiring further investigation. Additionally, the charred cereal chaff (*Triticum monococcum*, *T. dicoccum*, *T. timopheevii*, *Hordeum distichon/vulgare*) at La Draga is generally well preserved, reinforcing the idea that lakeshore sites preserve not only uncharred material but also charred remains in a better condition. This exceptional preservation is particularly relevant for this study, as it allows the identification of cereal grain fragments broken prior to charring—fragments that would normally be lost or unidentifiable at dryland sites. Such fragments have been recovered both at La Draga and at Ploča Mičov Grad. Fragile charred pulse seed coats, documented also at Ploča Mičov Grad, provide an additional example of remains preserved in unusually good condition even in dryland sites (Holguin et al. 2026).

Conclusions

La Draga stands out as a key archaeological site for studying plant use in the Iberian Peninsula. Its different sectors, with varying preservation conditions, provide a unique opportunity to test the influence of taphonomy on the archaeobotanical record. Charred remains, mostly cereals, are common in non-waterlogged areas like Sector A, highlighting preservation biases. Nevertheless, charred remains are also better preserved at waterlogged sectors such as Sector B, presenting a wider variety of taxa, including wild fruits, ruderals, lakeshore, and aquatic plants, offering a more comprehensive view of past plant use, management, and exploitation.

The sector comparison reveals that waterlogged preservation not only increases the number of identified taxa and the overall quality of charred remains, highlighting the value of lakeshore contexts for archaeobotanical recovery. However, non-waterlogged contexts remain important, as they provide taxa not previously found in carpological assemblages, such as *Laurus nobilis*, showing that each sector offers complementary insights. Moreover, it highlights the importance of continuing to study a well-known site like this, as the latest results have revealed new taxa.

All in all, without waterlogged preservation, many wild taxa would remain unrecovered, resulting in a biased understanding or a record dominated by cereals, which would lead to a misleading interpretation of plant economy during the Early Neolithic. Our results indicate that wild plants, even when scarce due to preservation biases in the archaeobotanical record, might have been a central part of Neolithic economies at most sites.

In summary, La Draga plays a vital role in reconstructing the plant economy of the north Iberian Early Neolithic and acts as a key reference for assessing taphonomic biases across the Iberian Peninsula. Its unique preservation of both charred and uncharred remains offers a rare and invaluable record and highlights the importance of long-term, in-depth archaeobotanical studies to build a complete picture of past economies.

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