



Plants from distant places: the 1st millennium CE archaeobotanical record from Iberia

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Received: 10 December 2022 / Accepted: 14 August 2023 / Published online: 21 November 2023
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Abstract

The 1st millennium CE in the Iberian peninsula was characterized by a continuous exchange of people, goods, food, technology, etc. which led to the transformation of agriculture and the introduction of new crops there. This paper presents the archaeobotanical evidence of the plants that were introduced there during the Roman and medieval periods. Cereals such as *Secale cereale* (rye), *Pennisetum glaucum* (pearl millet) and *Oryza sativa* (rice) appeared for the first time in the archaeological record together with new fruit taxa, *Prunus persica* (peach), *Morus nigra* (black mulberry), *Prunus armeniaca* (apricot), *Cydonia oblonga* (quince), *Mespilus germanica* (medlar) and *Citrus* species, enriching the diet of the Iberian people. There were also fibre plants such as *Cannabis sativa* (hemp) that are now first recorded. The paper provides the first records of these taxa while awaiting further research that can offer more detailed information on whether some of them may also have been present in earlier periods.

Keywords Roman · Medieval · Iberian Peninsula · Crop introductions · Agriculture · Arboriculture · Garden plants · Fibre crops

Introduction

Roman and medieval communities dedicated much of their time to acquire, produce, process and prepare food which varied according to their various habits, daily routines, social and religious customs and tastes. Plants seem to have occupied a fundamental role in the mundane and ordinary tasks of everyday life. This was particularly true for the people living in the countryside whose daily work must have been governed by the rhythms of agricultural tasks, the care of crops, the gathering of wild plants and the repetitive activities related to processing and preparing food. Plant remains provide a way of exploring and understanding various aspects of the human experience, including

food strategies, technological changes, social interactions and power relations (Montanari 2008; Woolgar 2010; Twiss 2012; Chevalier et al. 2014; Hastorf 2017; van der Veen 2018). But plant remains can also inform about their arrival from distant places, of adaptation, innovation and also of choices. Their histories are thus of interest to reconstruct the social and economic conditions of the communities where they were used.

Despite their importance for offering interesting insights into many aspects of Roman and medieval life, there has not been much interest among Iberian specialists in the plants of the 1st millennium CE, with the exception of those (mostly philologists) specialized in the rich evidence from the Islamic botanical and medical texts. Of particular significance is the work of E. García who was responsible for the series *Ciencias de la Naturaleza en Al-Andalus* (Natural Sciences in Al-Andalus, the parts of Iberia under Muslim rule) published by the CSIC (García Sánchez 1983, 1990, 1992, 1994, 1996, 1998, 2001, 2004, 2014; García Sánchez and Hernández Bermejo 2007), as well as the research carried out by many others such as J. Carabaza (Carabaza Bravo 1991, 2018), Camarero (Camarero Castellano 2008) and J.M. Millás (Millás Vallicrosa 1955) or M. Marín and colleagues (Marín 1990, 2000; Marín and Waines 1994;

Communicated by N. Payne.

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Marín and de la Puente 2005) on the culinary practices in Al-Andalus. Moreover, apart from some important cases (Alonso et al. 2014; Teira Brión 2022; Teira Brión et al. 2023; Tereso 2009; Tereso et al. 2013a; Vigil-Escalera Guirado et al. 2014; Ros et al. 2018; Peña-Chocarro et al. 2019b; Peña-Chocarro and Pérez-Jordà 2019; Seabra et al. 2022a, b, 2023a), neither have Roman or medieval archaeologists demonstrated particular enthusiasm towards integrating archaeobotany into their research projects, denying the potential that can be unlocked through the study of plant remains. Thus, current knowledge of what plants people actually produced, gathered and ate in Iberia during the 1st millennium CE is essentially based on:

- a) Information contained in different types of written sources such as the works of Latin authors on agriculture such as Cato, *On Agriculture* (Hooper 1993), Varro *On Agriculture* (Hooper 1993), Columella *Los Doce Libros de Agricultura* (Álvarez de Sotomayor y Rubio 1979) or Pliny, *Natural History* (Rackham 1968), who wrote mostly for the Roman elites describing types of cultivation, crops or agricultural tasks and processes. For the medieval period there are archival sources including a wide variety of documents such as Christian records, mostly from ecclesiastical institutions and mainly represented by the legal records of property transfers. These provide information on agricultural produce or its use as payments and valuation in kind (Davies 2002) and on land use of the transferred areas of land and agricultural infrastructure, such as water mills. These texts contain valuable information on agricultural practices and the strategies of farmers as well as on the growing and consumption of some commodities such as cereals, wine and fruits. In many cases, however, plants are classified under rather general categories such as legumes, cereals, or fruits, which limit the possibility of grasping the details of the plants involved, their growing cycles or processing requirements, and ultimately the choices made by people. On the other hand, the written records of Al-Andalus are extremely limited. The bulk of the available texts are chronicles, geographical and legal works, bio-bibliographical dictionaries, religious biographies, poetry and literature, and scientific works (Guichard 1999; Torró 2012). Far more interesting and useful for studying farming and food issues is the important collection of agricultural and medical treatises translated and/or published to a large extent, but not exclusively, by colleagues from the CSIC (see bibliography above). Over the past decades, these researchers, supported by a robust philological approach, have translated and studied numerous Islamic texts dedicated to food, medicine and agriculture, contributing
- b) enormously to a great advance in the knowledge of Islamic science and agricultural practice.
- b) A limited number of archaeobotanical studies from both periods which in most cases result from particular initiatives. The number of Roman sites studied is very small and the latest advances come from Portugal (Tereso 2009; Tereso et al. 2013a, c, 2020; Tereso and Cruz 2014; Vaz et al. 2016, 2021; López-Dóriga 2020; Seabra et al. 2022a, b, 2023a, b) and Galicia (Teira Brión 2010, 2019, 2022; Tereso et al. 2013b), while some work has been also carried out in the rest of the Iberian peninsula (Peña-Chocarro and Zapata 1996, 1997, 2005; Alonso 2005, 2008; Alonso et al. 2010, 2014; Rodríguez-Ariza and Montes Moya 2010; Montes Moya 2014; Voropaeva and Stika 2018; Peña-Chocarro et al. 2019a). More recently, two papers have provided a general overview of the archaeobotanical results for this period (Peña-Chocarro et al. 2019b, Peña-Chocarro and Pérez-Jordà *in press*). For the last part of the 1st millennium CE, the development of medieval archaeology over the past three decades has allowed the excavation of considerable number of sites across the Iberian Peninsula, but without integrating archaeobotany in the research programs except for a small number of archaeobotanical studies (see references above). More recently, the field of agrarian archaeology has started with a focus on landscapes, which are providing highly interesting information on the management of crop fields and related issues (Ballasteros Arias et al. 2010; Kirchner 2010; Fernández Mier et al. 2014; Quirós Castillo 2014; Quirós Castillo et al. 2014).

Nevertheless, despite these rather few advances, the study of plant remains in Iberia has been largely overlooked. This situation greatly differs from that of most other European and some Near Eastern countries where the development of Roman and medieval archaeology has been accompanied by a significant expansion of environmental archaeology, and in particular of archaeobotany. In countries like France (Ruas et al. 2005, 2015; Bonnaire et al. 2010; Ros et al. 2020), Ireland (McClatchie et al. 2015), the UK (Moffett 2006; Lodwick 2018; McKerracher 2018; Hamerow et al. 2019, 2020), Italy (Buonincontri et al. 2014, 2017; Rotoli 2014; Primavera 2018) or the Near East (Samuel 2001; Amichay et al. 2019; Fuks et al. 2020) to quote just a few, the archaeobotanical results on the 1st millennium CE have provided interesting insights into diet and plant resource use, fuelling the debate of the development of farming during the Roman and the medieval periods. For an excellent overview, see Lodwick and Rowan (2022).

Methodology, sites and contexts

A recent publication coordinated by the authors (Peña-Chocarro et al. 2019b) has assembled records from 83 published and unpublished sites across Spain and Portugal dated to the Roman and medieval periods, which represents the first corpus of archaeobotanical data from the 1st millennium CE in this region. Based on this paper, on those published afterwards (Ros et al. 2019; Teira Brión 2019, 2022; Lityńska-Zajac and Rębkowski 2020; Quirós Castillo et al. 2020; Seabra et al. 2020, 2022a, b, 2023a, b; Tereso et al. 2020; Teira Brión et al. 2023) and on additional unpublished archaeobotanical data from various sites across Iberia studied by the authors, this paper focuses on the plants that were grown or gathered in the Iberian Peninsula during the 1st millennium CE. Particular emphasis is given to the new crops that appeared for the first time in Iberia during this long period.

The data considered in this paper come in most cases from systematic flotation of plant macroremains at the various sites, although some are from hand-picked samples collected during the course of the site excavation. In this paper we concentrate on the first presence of particular taxa and so no information is provided on sample size, subsampling or the total number of samples or items in each sample, which can be found in the original publications. Sites mentioned

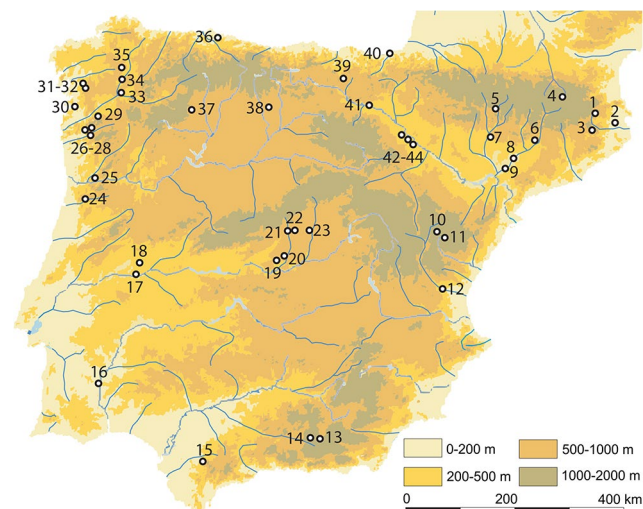


Fig. 1 Map showing the sites mentioned in the text. (1) L'Esquerda, (2) Vilauba, (3) Can Gelats, (4) Camp Vermell, (5) Roc d'Enclar, (6) Balaguer, (7) Las Sillas, (8) Ilerda, (9) Bovalar, (10) Cabezo de la Cisterna, (11) El Quemao, (12) Benaxuai, (13) Pago de El Jarafi, (14) La Gambia, (15) Cueva de la Dehesilla, (16) Mértola, (17) La Ayuela, (18) Albalat, (19) Melque, (20) Carranque, (21) Acedinos, (22) Góñez, (23) Risco de las Cuevas, (24) Senhora do Barrocal, (25) Monte Mozinho, (26) Freixo/Tongobriga, (27) Crasto de Palheiros, (28) Crastoeiro, (29) Teronha de Pinhovelo, (30) O Areal, (31) Castrolandín, (32) O Bodel, (33) Castro Arxeriz, (34) Castrovite, (35) Castromaior, (36) Tabacalera, (37) El Picón, (38) Castrillo Mota de Judíos, (39) Vitoria/Gasteiz, (40) Irun, (41) La Noguera, (42) Bureta, (43) Ambel, (44) La Mora Encantada

in the text mainly correspond to those where the taxa discussed have been identified from sites in Iberia dated within the 1st millennium CE. In some cases (see below) the first evidence of a particular plant comes from the beginning of the following millennium (11th–13th centuries), but it has been decided to include these in this review because of the importance of the taxa concerned (Fig. 1; Table 1).

What do we know about 1st millennium CE plant use in Iberia?

As already mentioned, archaeobotanical data are scarce but they suggest that Roman and medieval communities cultivated a wide variety of cereals, legumes, vegetables and fruits which represented their main foodstuffs. During the Roman period several new crops were introduced or at least cultivated and widely spread throughout the peninsula. This is the case of crops such as *Secale cereale* (rye), *Phoenix dactylifera* (date palm) and others such as *Prunus persica* (peach), *Morus nigra* (black mulberry) and several herbs and spices like *Rosmarinus officinalis* (rosemary), *Mentha* spp. (mints), *Apium graveolens* (celery) and *Brassica* spp. (cabbages and mustards etc.) which made their first appearance in Roman sites (Peña-Chocarro et al. 2019b).

Exploring plant diversity in medieval Iberia necessarily involves an assessment of the introduction and/or spread of new crops during the Islamic period (Watson 1974). In his seminal work, *The Arab Agricultural Revolution*, later expanded and reformulated (Watson 1981, 1983), Watson laid the foundation for the widespread idea of a “medieval green agricultural revolution” which occurred between the 7th and the 11th centuries CE after the unprecedented unification by the Arabs of a huge area stretching from regions of Central Asia to the Iberian Peninsula. These circumstances would have allowed the circulation not only of people and ideas, but also of technical knowledge and goods, amongst which crops occupied a central place in Watson's model. A total of 18 species, mostly foods but also fibre crops, were chosen as examples of crop diffusion, *Oryza sativa* (rice), *Sorghum bicolor* (sorghum), *Triticum durum* (hard wheat), *Citrullus lanatus* (watermelon), *Solanum melongena* (eggplant), *Gossypium hirsutum* (cotton), *Saccharum* spp. (sugar cane), *Cynara cardunculus* (globe artichoke), *Spinacia oleracea* (spinach), *Colocasia esculenta* (taro etc.), *Citrus × aurantium* (bitter or Seville orange), *C. limon* (lemon), *Citrus* spp. (lime), *Musa acuminata* (banana), *M. × paradisiaca* (cooking banana), *Mangifera indica* (mango) and *Cocos nucifera* (coconut). Some were already suitable for growing in dry areas, while others needed technical solutions such as irrigation. The model has been criticized for inaccuracies in the attribution of some introductions to the Arabs (Decker

Table 1 Sites mentioned in the text, with chronology, type of preservation of the plant material, recovery technique and reference for each site

Century CE	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Preserv.	Recovery	References
Acedinos												•		Ch	Flotation	Authors' unpublished data
Albalat											•	•		Ch	Flotation	Ros et al. 2018
Ambel												•		Ch	Flotation	Treasure 2020
Balaguer				•						•	•	•		Ch/Min	Flot./wet sieving	Alonso et al. 2014
Benaxuai											•	•		Des	Dry sieving	Authors' unpublished data
Bovalar					•	•	•	•						Ch	Flotation	Cubero 1988
Bureta						•	•	•						Ch	Flotation	Treasure 2020
Cabezo de la Cisterna											•	•		Ch	Flotation	Treasure 2020
Camp Vermell		•	•	•	•	•	•	•	•	•	•	•		Ch	Flotation	Alonso et al. 2010
Can Gelats					•	•								Ch	Flotation	López Reyes unpublished
Carranque			•	•	•	•	•							Ch	Flotation	Authors' unpublished data
Castrillo Mota de Judíos											•	•	•	Ch	Flotation	Authors' unpublished data
Castro Arxeriz	•													Ch	Flotation	Authors' unpublished data
Castromaior	•	•												Ch	Flotation	Authors' unpublished data
Castrovite	•													Ch	Flotation	Teira Brión 2022
Castrolandín	•	•												Ch	Flotation	Teira Brión 2022
Cueva de La Dehesilla											•	•		Ch	Flotation	García-Rivero et al. 2019
Crastoeiro	•													Ch	Flotation	Seabra et al. 2018
Crasto Palheiros	•													Ch	Flotation	Tereso et al. 2013a
El Picón														Ch	Flotation	Authors' unpublished data
El Quemao										•	•	•		Ch	Flotation	Treasure 2020
Freixo/Tongobriga	•	•	•		•	•								Ch	Flotation	López-Dóriga 2020
Gózquez				•		•	•	•						Ch	Flotation	Vigil et al. 2014
Ilerda	•	•	•		•	•						•		Ch/min	Flot./wet sieving	Alonso 2005
Irun	•	•		•										W	Wet sieving	Peña-Chocarro and Zapata 2005
La Ayuela										•				Ch	Flotation	Pérez-Jordà in press
La Gabia	•	•												Ch	Flotation	Rodríguez-Ariza and Montes Moya 2010
La Mora Encantada										•	•	•		Ch	Flotation	Treasure 2020
La Noguera						•	•	•	•	•	•	•	•	Ch	Flotation	López de Calle et al. 2019
La Senhora do Barrocal										•	•			Ch	Flotation	Seabra et al. 2022b
Las Sillas										•	•			Ch	Flotation	Ros et al. 2019
L'Esquerda													•	Ch	Flotation	Cubero et al. 2008
Melque									•	•	•			Ch	Flotation	Caballero Zoreda et al. 1999
Mértola											•	•		Ch/min	Flot./wet sieving	Authors' unpublished data
Monte Mozinho			•		•									Ch	Flotation	Tereso et al. 2013c
O Areal			•	•	•									W	Wet sieving	Teira-Brión 2022
O Bordel				•							•	•		W	Wet sieving	Teira-Brión et al. 2023b
Pago de El Jarañi							•	•	•	•	•	•	•	Ch	Flotation	Authors' unpublished data
Risco de las Cuevas												•	•	Des	Dry sieving	Authors' unpublished data
Roc d'Enclar						•	•	•						Ch	Flotation	Buxó 1997
Tabacalera						•	•	•						W	Wet sieving	Peña-Chocarro et al. 2019a
Terronha de Pinhovel			•											Ch	Flotation	Tereso 2009
Vilauba					•	•	•							Ch	Flotation	Colominas et al. 2019
Vitoria/Gasteiz								•	•	•	•	•		Ch	Flotation	Pérez-Díaz et al. 2015

2009). One of the crops under scrutiny is *Triticum durum* (durum wheat) which was present in Iberia since the Neolithic (Peña-Chocarro et al. 2018) as well as in other parts of Europe (Kirleis and Fischer 2014), and it was present in North Africa (Morales et al. 2013) and the Near East (Fairbairn et al. 2002) already in prehistoric times. *Oryza sativa* (rice) is another crop which was thought to have been introduced by the Arabs, but archaeobotanical data suggests that

by the Roman period rice was being already traded across the Mediterranean, and also appearing in several sites in central Europe (Muthukumaran 2014). Decker (2009) also includes cotton which has been found in pre-Islamic levels of sites in North Africa and the Near East and *Cynara scolymus* (globe artichoke), which was widely cultivated in Roman times according to written sources. Nevertheless, whether some taxa may have already been present in some

of the regions under scrutiny does not invalidate the role that Islamic communities had in their spreading of crops and bringing them to new regions, favouring their adaptation to different environments (Squatriti 2014).

Useful evidence has been obtained from a particular interesting type of site, cliff granaries, which are found in remote parts of several regions of Iberia (Andalucía, central Spain, Valencia, upper Ebro valley) are providing exciting desiccated plant material which can offer excellent insights into the variety of crops cultivated at the time when they were deposited there. Cliff granaries are inaccessible artificial caves which appear as groups of openings cut into cliff faces that were used by the Islamic people for storing food and probably other items. In some cases, there are visible remnants of external structures such as stone or brick walls and wooden platforms. The interiors consist of series of connecting chambers which sometimes preserve material such as pottery, parchment remains, wooden objects, textile fragments, animal bones etc. (Ribera i Gómez 2010). Recent proposals link these cavities to the management and storage of agricultural products (Ribera i Gómez 2016). The use of these cliff granaries in Iberia appear to be closely connected with the arrival of the first North Africans during the Islamic conquest. In fact, Iberian cliff granaries have astonishing parallels in North Africa, where several examples exist in the Moroccan Atlas and Anti-Atlas regions (Gattefossé 1934). Perhaps, the most important aspect of these features is that due to the extreme dryness of the interior of these caves, extraordinary desiccated archaeobotanical material such as complete cereal ears, grains, chaff, grapes, seeds and fruit stones have been preserved. These materials include taxa and remains that are not usually preserved by charring. Such desiccated remains found buried in the sediment or trapped in the wall plaster, and also as part of daub, offer a unique opportunity not only to explore crop diversity but also to carry out genomic analyses. The samples collected have been checked for aDNA (ancient DNA) yielding positive results (Royo unpublished data). Similar features have been studied in Gran Canaria with contexts dated to the 6th–15th centuries CE (Morales et al. 2014; Henríquez-Valido et al. 2019) from which aDNA has also been recovered (Oliveira et al. 2012; Hagenblad et al. 2017; Hagenblad and Morales 2020), affording interesting insights into the archaeology of these plants.

Cereals

During the 1st millennium CE, cereals were the main food plants. A range of wheat and barley species that had been grown since the Neolithic (Pérez-Jordà 2013; Antolín 2016; Peña-Chocarro et al. 2018) continued to be cultivated during the 1st millennium CE. This cereal “package” was

dominated by *Triticum aestivum* and *T. durum* (free-threshing wheats) and *Hordeum vulgare* ssp. *vulgare* (hulled barley) which were the staple crops. Both grains and chaff of these, the commonest cereals, have been retrieved from all over the peninsula. Other cereals, such as the hulled wheats, namely *T. monococcum* (einkorn), *T. dicoccum* (emmer) and *T. spelta* (spelt) were also grown, although much less than the free-threshing wheats. Their presence is uneven in Iberia, where they only appear occasionally as a secondary or residual crop in a few sites (Peña-Chocarro et al. 2019b). An exception is represented by northwest Iberia, where emmer and spelt seem to have played a significant role, particularly during the Iron Age. They appear in several sites in Galicia such as Castrovite and Castrolandín (Teira Brión 2019), Castromaior and Castro Arxeriz (Peña-Chocarro in prep.), and in Portugal, such as Crastoeiro (Seabra et al. 2018), Teronha de Pinhovelo (Tereso 2009) or Crasto de Palheiros (Tereso et al. 2013a), among others.

Secale cereale (rye)

Rye is one of the cereals that spread into Iberia during the 1st millennium CE (Fig. 2; Table 2). The earliest evidence comes from several Iron Age sites in Portugal (Seabra et al. 2018, 2023a, b). Six radiocarbon dates on grains place its introduction between the 3rd and 1st centuries BCE (D-AMS 2,139 ± 20, 350–55 BCE; D-AMS 016318 2,132 ± 31, 350–40 BCE; D-AMS 011304 2,027 ± 25, 100 BCE–70 CE; Beta-596,126 2,120 ± 30, 350–40 BCE; D-AMS 047814 2,158 ± 21, 355–105 BCE; D-AMS 042655 2,062 ± 22, 155 BCE–10 CE). Recent research (Seabra et al. 2023a) suggests that this early presence of rye represents weedy forms that would have grown in fields of hulled wheat, especially spelt crops. They also point to the fact that when spelt disappeared during the 1st century CE, rye also vanished. Later sites such as Monte Mozinho (Tereso et al. 2013c), Tongobriga (Seabra et al. 2023a) in Portugal, or Vilauba (Colominas et al. 2019), Ilerda (Alonso 2005) in Catalonia, Castromaior in Galicia (authors’ unpublished data) and El Picón (Zamora) (authors’ unpublished data) have also produced rye dated between the 2nd and the 4th centuries CE. In fact, the spread of rye is associated with the Roman period in Hispania (Iberia), as it was introduced then. However, evidence of its cultivation in Spain is scarce and it seems, at least during the Roman period, to have been concentrated in northwestern Iberia with a few examples in the northeastern part (sites of Vilauba and Ilerda). This regional distribution may perhaps be related to the better adaptation of the rye to the poor soils and adverse climatic conditions which characterize the northwestern part of Iberia. Later on, during the 5th century CE, rye was still cultivated in the northeast and from the 6th century it appears from many more sites in this area such



Fig. 2 Plant remains introduced in Iberia during the 1st and beginning of the 2nd millennium; **a** *Pennisetum glaucum*; **b** *Secale cereale*; **c** *Oryza sativa*; **d** *Cannabis sativa*; **e** *Cydonia oblonga*; **f** *Mespilus germanica*

Table 2 Crop introductions during the 1st millennium CE and the first centuries of the 2nd millennium CE in Iberia

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13/14th
<i>Prunus persica</i>	•	•											
<i>Phoenix dactylifera</i>	•	•	•										
<i>Secale cereale</i>			•	•									
<i>Morus nigra</i>			•	•									
<i>Brassica nigra</i>						•	•	•					
<i>Daucus carota</i>						•	•	•					
<i>Apium graveolens</i>						•	•			•	•	•	
<i>Mespilus germanica</i>								•	•	•	•	•	
<i>Nigella</i> sp.									•	•	•	•	
<i>Allium sativum</i>									•	•	•	•	
<i>Citrus</i> cf. <i>medica</i>										•			
<i>Pennisetum glaucum</i>										•	•		
<i>Oryza sativa</i>										•	•		
<i>Cydonia oblonga</i>										•	•		
<i>Prunus armeniaca</i>										•	•		
<i>Cannabis sativa</i>										•	•		
<i>Brassica rapa</i>													•

as Roc d'Enclar (Andorra) (Buxó 1997), Bovalar (Lleida) (Cubero i Corpas 1988), Vilauba (Girona) (Colominas et al. 2019) and Can Gelats (Girona) (Peña-Chocarro et al. 2019b), but also in central Spain from the sites of Gótzquez (Madrid) (Vigil-Escalera Guirado et al. 2014), Melque (Caballero Zoreda et al. 1999), Acedinos (Madrid) (authors' unpublished data) and Carranque (Toledo) (authors' unpublished data) where its presence is more limited. In Portugal, several sites have also yielded rye from this period (Seabra et al. 2023a).

Rye became more frequent in medieval times, showing a much wider distribution in both Christian and Islamic sites. It has also been found in northeast Iberia from the sites of Camp Vermell (Andorra) (Alonso et al. 2010), L'Esquerda (Barcelona) (Cubero i Corpas et al. 2008) and Las Sillas (Ros et al. 2019) and from various sites in Aragon (Treasure 2020). In northern Spain it is also found from sites of Vitoria, in the País Vasco (Basque Country) (Zapata and Ruiz-Alonso 2013) and in La Noguera farmstead (La Rioja) (López de Calle et al. 2019), in central Spain at the Jewish site of Castrillo Mota de Judíos (Burgos) (authors' unpublished data), in Extremadura at Albalat (Cáceres) (Ros et al. 2018), in Andalucía from Pago de El Jaraí (Granada) (authors' unpublished data) and from several sites across Portugal such as Senhora do Barrocal (Seabra et al. 2022b). Despite its presence in many regions, the number of remains is low, perhaps indicating that rye was never widely grown. It is likely that its survival up to recent times in mountainous areas where it is one of the main crops responds to a tradition dating back to the Roman period. Surprisingly, rye has been found in several Islamic sites in the form of desiccated complete ears (grain is absent in most cases) from two cliff granaries (see below) in the provinces of Madrid (Risco de las Cuevas) and Valencia (Cueva de Benaxuái) (authors' unpublished data).

Millet: the case of *Pennisetum glaucum* (pearl millet)

During the 1st millennium CE, millets were also widely cultivated in Iberia, particularly in the northwest. Two species, *Panicum miliaceum* (common millet) and *Setaria italica* (foxtail millet) were mainly grown. They appeared for the first time in the archaeological record of Iberia during the Bronze Age, but it is during the Iron Age when their cultivation was fully established.

Most recently (work in progress), a new millet species, *Pennisetum glaucum* (pearl millet) has been identified from Islamic contexts. Complete ears and grains preserved by desiccation have been identified from several Islamic sites in Valencia (Benaxuái cave) (Fig. 2), charred in Granada

province (authors' unpublished data) and by mineralization in Córdoba province (authors' unpublished data). Although the pearl millet has been dated to the 11th–12th centuries CE (Table 2) we have decided to include this crop in our synthesis because it is likely that it was introduced into Iberia before then, during the 1st millennium CE. This is the first evidence of this species in the western Mediterranean and as far as we know, also in Europe. It seems clear that *P. glaucum* was domesticated in the Sahel zone of West Africa around the mid 3rd millennium BCE, and from there it spread throughout the Sahara region and then into India (Fuller et al. 2021). How it arrived in Iberia is still unknown. In this regard, it is interesting to note that medieval documents from the Valencia region regularly refer to different types of cereals, among which there is a crop named *dacsa*. Various authors working with these documents have identified this crop as *Sorghum bicolor* (sorghum) (Alpera 1968) but information is still patchy and the word *dacsa* may well refer to pearl millet instead (work in progress).

Oryza sativa (rice)

A further introduction of this period is *Oryza sativa* (rice) which was brought into the Iberian peninsula in the Islamic period (Watson 1981, 1983). In fact, the cultivation of rice in Islamic Spain is already mentioned in the 10th century Cordoba Calendar, a fascinating work which includes meteorological, astronomical and associated agricultural matters (Rincón Álvarez 2003). During the 11th and 12th centuries, agronomists from Al-Andalus such as Ibn Bassal (Millás Vallicrosa 1955), Abu Jayr (Carabaza Bravo 1991), Ibn Al-Awwam or Ibn Luyun (Eguaras Ibáñez 1988) described the methods used for growing rice, providing details on its sowing, the best areas for its cultivation, both under irrigation and on dry land, transplantation and harvesting in September. Despite the finding of rice from several Roman and medieval contexts across Europe (Konen 1999; Zach 2002; Livarda and van der Veen 2008; Reed and Leleković 2019), the only archaeobotanical evidence from Iberia is represented by a single fragmented desiccated hulled rice grain retrieved from the Benaxuái cave in the Valencia region (authors' unpublished data) dated to the 11th–12th centuries CE (Fig. 2; Table 2).

Legumes

The available data suggests that farmers continued to grow the same variety of legumes as in prehistoric times: *Vicia faba* (broad bean), *Pisum sativum* (pea), *Lens culinaris* (lentil), *Lathyrus sativus* (grass pea) and several vetches such as *Vicia sativa* (common vetch) and *V. ervilia* (bitter vetch) (Pérez-Jordà 2013; Antolín 2016; Peña-Chocarro et al.

2018). As for *Cicer arietinum* (chickpea), its presence is less common. It has been only found from a couple of sites, La Gabia attributed to the Roman period (Montes Moya 2014) and the medieval site of L'Esquerda (Cubero i Corpas et al. 2008). More recently, chickpea remains have been identified in Extremadura from the site of La Ayuela (authors' unpublished data). There is no evidence of *Lupinus* (lupin) or *Vigna unguiculata* (cow pea).

Fruit

Fruit and nuts were a source of sugars, vitamins, minerals and fibre providing diversity to the usual diet. Many of the taxa already known from the Iron Age were also grown during the 1st millennium CE, such as *Prunus armeniaca* (apricot), *Juglans regia* (walnut), *Malus pumila* (apple), *Pyrus communis* (pear) *Punica granatum* (pomegranate), *Vitis vinifera* (grapevine), *Ficus carica* (fig) etc. (Pérez-Jordà 2013; Alonso et al. 2016; Pérez-Jordà 2021a, 2021b). Archaeobotanical data from the Roman and medieval periods shows an enormous diversity: grape, fig, *Olea europaea* (olive), *Phoenix dactylifera* (date), apple, *Prunus persica* (peach), *P. avium* and *cerasus* (sweet and sour cherry), *P. domestica* (plum), pomegranate, *Morus nigra* (black mulberry), *Cucumis melo* var. *flexuosus* (Armenian cucumber, *alficoz*), *P. dulcis* (almond), *Cydonia oblonga* (quince), *Mespilus germanica* (medlar), citrus fruits, walnut, *Castanea sativa* (chestnut) and almond have been documented (Peña-Chocarro et al. 2019b). Of these, peach, apricot, black mulberry, quince, medlar, date and citrus fruits were possibly introduced in either the Roman or the Islamic period during the 1st millennium CE (Table 2).

The first evidence of peach in Iberia comes from the Roman levels (1st–2nd centuries CE) of the site of Irun (Pais Vasco) where hundreds of stones were found in waterlogged levels of the ancient Roman harbour that most probably represented imports (Peña-Chocarro and Zapata 2005). Remains of similar date were also recovered from Catalunya (Canal et al. 2004), Galicia (Teira Brión 2022), Andalucía (Peña-Chocarro et al. 2019b) and northern Portugal (Fernando de Almeida and da Veiga Ferreira 1967), while later finds are also reported from sites both in Portugal (Vaz et al. 2016) and Spain (Treasure 2020; Teira Brión 2022). Other members of the Rosaceae family such as *Prunus domestica* (plum), of which several varieties have been identified, only appeared from the Roman period onwards, while almond, sweet and sour cherries and apple were also present in the late 1st millennium BCE. Several different *Prunus* spp. have also been found from several medieval sites in Iberia.

The black mulberry, however, seems to be a Roman introduction. It has been identified in Galicia from the site of O Areal (Teira Brión 2022), and later from Vilauba (Girona)

(Colominas et al. 2019). It was also found from several medieval Islamic sites in Aragón (Treasure 2020) such as Cabezo de la Cisterna and El Quemao in Teruel province, and in Bureta, La Mora Encantada and Ambel in Zaragoza province. *Morus nigra* also appeared in Albalat in Cáceres province (Ros et al. 2018). Dates also appear also for the first time in Roman levels (mid 1st–3rd century CE) as an offering in the Temple of Isis (Cádiz province) (Ruas 2008).

The Islamic period brought many novelties not only related to the variety of fruit plants but also to sophisticated grafting techniques and new ways of growing and managing crops such as by irrigation. Textual sources, mostly agricultural treatises written by Hispano-Arab agronomists, include a great diversity of plants among which fruit trees are an important component. Information is provided on methods of planting and cultivation, grafting and on the right seasons for carrying out specific tasks such as manuring, watering, pruning, storage etc., as well as on consumption and uses. Other textual sources provide information on specific plant varieties.

Most of the fruits listed by Watson (1974, 1981, 1983) are absent from the archaeobotanical record of Iberia, probably because the number of Islamic sites analysed is still so limited, but also because some of these plants were introduced to the region much later. There are, however, some data about some new fruit taxa which started to be grown in this period, for instance, *Prunus armeniaca* (apricot), which is recorded for the first time from Islamic contexts in southern Portugal (Pais 1996). Also of interest is the finding of the first remains of *Cydonia oblonga* (quince) in south-west Spain from the very beginning of the 11th century CE at cueva La Dehesilla (Cádiz) (García-Rivero et al. 2018) (Fig. 2). *Mespilus germanica* (medlar) has been identified from Pago de El Jarafrí (Granada) (authors' unpublished data), southern Spain from between the 8th and 12th centuries CE and at O Borden (A Coruña), north-western Iberia dated to the 11th–12th centuries CE (Fig. 2; Teira-Brión et al. 2023).

Perhaps the most significant finds are those of citrus fruits from the site of Mertola (southern Portugal) from a context of the 11th century CE (authors' unpublished data). Citrus was already known in the Mediterranean in Roman times, and several classical authors mention *Citrus medica* (scented citron) which appears to have been the first citrus fruit introduced into Europe. Archaeobotanical data seem to support this hypothesis (Pagnoux et al. 2013). Between the 10th and the 11th centuries CE various Hispano-Arab agronomists mentioned several citrus fruits other than the citron in their texts. These are the *Citrus limon* (lemon), *C. aurantiifolia* (lime), *C. maxima* (pomelo or shaddock) and *C. aurantium* (bitter or Seville orange) (Ramon-Laca 2003).

The oriental origin of most of the plants listed by Watson is clear, but an issue that has never been addressed is the likely introduction of new varieties of crops already cultivated in Europe or North Africa. In 1981, Watson inquired about the agents responsible for the introduction of new plants, suggesting that these could have been rulers interested in obtaining exotic plants for their gardens or elites importing plants for commercial use. He also put forward the possibility that farmers may have brought their own crops or crop varieties to the conquered areas, either because they were familiar with them, or because of their specific value. Islamic sources are almost silent in this regard, but there are some examples of the mention of novel varieties being introduced. A particular case is the description of the bringing from Damascus to Córdoba, under Abd al-Rahman I, the first emir of Córdoba, of a variety of pomegranate known as *safari*, which is still cultivated today (Samsó 1981–1982; Glick 2005). Other examples may be the *doñegal* fig or even some palm varieties (Nabhan 2014).

Vegetables, herbs and spices

The archaeobotanical record of what can be considered garden plants in Iberia is rather limited for the 1st millennium CE. In most cases, the scarce information comes from waterlogged sites where these plants represent a small part of the botanical assemblage (Peña-Chocarro et al. 2019b; Peña-Chocarro and Pérez-Jordà 2019). Gardens contained many plant categories such as food and medicinal plants, spices, herbs, dye plants, ornamentals and those producing useful materials for crafts, etc. Legumes, fruits, vegetables, tubers, etc. were grown in these gardens, contributing to diversity in the diet but also producing raw material for various purposes. Previous work (Peña-Chocarro et al. 2019b; Peña-Chocarro and Pérez-Jordà 2019) shows the presence of various herbs and flavourings, such as *Rosmarinus officinalis* (rosemary), *Mentha* spp. (mints), *Coriandrum sativum* (coriander), *Apium graveolens* (celery), *Foeniculum vulgare* (fennel), *Verbena officinalis* (common vervain) and *Lavandula* spp. (lavender) in Roman and medieval times. Moreover, vegetables such as several *Brassica* spp. (cabbages and mustards) were also present, while *Daucus carota* (carrot) has been also recovered from several sites across Iberia dated to the Roman period or later. From the medieval period, *Nigella* spp. (black caraway), *Allium sativum* (garlic) and *Brassica rapa* (turnip, etc.) appear for the first time in Iberia (Alonso et al. 2014; Treasure 2020; Teira Brión et al. 2023) (Table 2). One of the big issues when discussing garden crops, particularly when the dataset is limited, relates to the difficulty of deciding whether these plants may have been used for human consumption or if they represent wild plants. Despite the significance of the plant taxa identified

in the archaeological record, it is clear that the actual diversity of garden plants must have been much wider, as the Hispano-Arab agronomic literature suggests.

Fibre crops

Flax (*Linum usitatissimum*) is well known in Iberia since the Neolithic and continued to be cultivated throughout the 1st millennium CE either for its fibres or for its oil or both. In contrast to the results from central and eastern Europe, there is little evidence of the cultivation of *Camelina sativa* (gold of pleasure). Its seeds are present from the 1st millennium BCE (Pérez-Jordà 2013) but it is difficult to ascertain whether these come from wild specimens. Seeds were also retrieved from the medieval Islamic layers of Lleida and Balaguer (Alonso et al. 2014) and from several Islamic sites in Aragon (north-east Spain) (Treasure 2020).

Desiccated seeds from a third fibre crop, *Cannabis sativa* (hemp), have been recently identified from Islamic sites near Madrid (Risco de las Cuevas) and Valencia (Benaxuai cave) (authors' unpublished data) (Fig. 2). Although there is evidence of its cultivation in other parts of Europe from the late Iron Age (Bouby 2002) or from Roman times (Larsson and Lagerås 2015), these examples seem to be the earliest evidence from Iberia (Table 2).

Conclusions

Arable farming was a key element of the Roman and medieval economies and cereals were the main foodstuff in the 1st millennium CE. Various wheat species, both hulled and naked, barley and millets (*Setaria italica* and *Panicum miliaceum*, Italian and common millet) were widely cultivated across Iberia. Over the past few years there has been growing interest in the role of plants in the Roman and medieval periods and the body of data has grown accordingly. The application of systematic strategies for plant recovery is giving its first results, revealing that a new cereal, rye, became established in Iberia during the Roman period, while the Islamic period saw the arrival of two new species, *Pennisetum glaucum* (pearl millet) and *Oryza sativa* (rice). While rice was amongst the crops mentioned in the list of Islamic introductions, pearl millet is a completely new find. In fact, this is the first find of this species in Europe and North Africa.

In addition to the cereals, pulses were also widely grown. No evidence of new arrivals has been detected so far, but the variety of legumes identified is high, including broad beans, lentils, peas, grass pea, vetches and chickpeas. Among the fruits, peach and black mulberry were introduced in the Roman period while apricot, quince, medlar and citrus

appear for the first time in Islamic sites in Iberia, but most of the fruit taxa mentioned by Watson (1974, 1981, 1983) are still absent. Garden plants were certainly much more numerous than the small number in the Iberian archaeobotanical dataset. This group is greatly biased by preservation, but the few waterlogged contexts have provided information about the presence of herbs, spices and vegetables. Nevertheless, comparison with other contemporary sites in Europe shows that the diversity of garden plants there is much greater than that found in Iberian sites. Finally, oil and/or fibre plants include *Linum usitatissimum* (flax), *Camelina sativa* (gold of pleasure) and *Cannabis sativa* (hemp). While flax is well known since prehistoric times and gold of pleasure appeared from the 1st millennium BCE, hemp is only found in medieval contexts.

The above data suggest that the main cereals and legumes that had been grown over millennia in Iberia continued to be cultivated during the Roman and medieval periods. During the 1st and the beginning of the 2nd millennium CE there were several crop introductions of cereals, fruits, vegetables which were integrated into the Roman and medieval economies and became part of the normal diet (Table 2). However, these new data are only the beginning of a fascinating journey of discovery through a millennium of history. Current research projects by different Iberian archaeobotanists and a new ERC project (Medieval appetites: food plants in multicultural Iberia, 500–1100 CE-MEDAPP) directed by one of the authors (LP-CH) will certainly provide much more data and opportunities for advances in our knowledge of plant use in the medieval period.

Acknowledgements This research has received support from the following: projects Las plantas en el mundo medieval de la P. Ibérica: agricultura, almacenamiento y usos (PGC2018-101362-B-I00), Uso y función de las cuevas-granero peninsulares: una aproximación a partir de la arqueobotánica-CUGRABOT (PID2021-127936NB-I00) funded by the Ministerio de Ciencia y Innovación (Ministry of Science and Innovation), and Medieval Appetites: plant use in multicultural Iberia (500–1100)-MEDAPP funded by the European Research Council (ERC-AdG 101054883), all coordinated by LP-CH. GPJ has worked within the framework of FRUITCOM: Un nuevo modelo agrícola: frutales, hierro y comercio durante el I milenio A.E. (CIDE-GENT/2019/003), funded by Conselleria de Innovación Universidades, Ciencia y Sociedad Digital, Generalitat Valenciana.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

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References

- Alonso N (2005) Agriculture and food from the roman to the Islamic period in the North-East of the Iberian peninsula: archaeobotanical studies in the city of Lleida (Catalonia, Spain). *Veget Hist Archaeobot* 14:341–361
- Alonso N (2008) Crops and agriculture during the Iron Age and late antiquity in Cerdanyola Del Vallès (Catalonia, Spain). *Veget Hist Archaeobot* 17:75–84
- Alonso N, Antolín F, Burjachs F et al (2010) Food and fuel. Strategies of production and consumption from antiquity to the Middle Age in Camp Vermell (Sant Julià De Lòria, Andorra). In: Delhon C, Théry-Parisot I, Thiébault S (eds) *Des hommes et des plantes. Exploitation du milieu et des ressources végétales de la Préhistoire à nos jours*. Éditions APDCA, Antibes, pp 267–291
- Alonso N, Antolín F, Kirchner H (2014) Novelties and legacies in crops of the Islamic period in the Northeast Iberian Peninsula: the archaeobotanical evidence in Madīna Balagī, Madīna Lārīda, and Madīna Turtūša. *Quat Int* 346:149–161
- Alonso N, Pérez-Jordà G, Rovira N, López Reyes D (2016) Gathering and consumption of wild fruits in the east of the Iberian Peninsula from the 3rd to the 1st millennium BC. *Quat Int* 404 Part A :69–85
- Alpera L (1968) Los nombres trecentistas de botánica valenciana en Francesc Eiximenis. *Institució Alfonso el Magnànim, València*
- Álvarez de Sotomayor y Rubio JM (1979) Los Doce Libros De Agricultura que escribió en latín Lucio Junio Moderato Columela. *Sociedad Nestlé, AEPA, Santander*
- Amichay O, Ben-Ami D, Tchekhanovets Y, Shahack-Gross R, Fuks D, Weiss E (2019) A bazaar assemblage: reconstructing consumption, production and trade from mineralised seeds in Abbasid Jerusalem. *Antiquity* 93:199–217
- Antolín F (2016) Local, intensive and diverse? Early farmers and plant economy in the North-East of the Iberian Peninsula (5500 – 2300 cal BC). *Barkhuis Publishing, Groningen*
- Ballesteros Arias P, Kirchner H, Fernández Mier M et al (2010) Por una arqueología agraria de las sociedades medievales hispánicas. Propuesta de un protocolo de investigación. In: Kirchner H (eds) *Por una arqueología agraria. Perspectivas de investigación sobre espacios de cultivo en las sociedades medievales hispánicas*. (BAR Int Ser 2062) Archaeopress, Oxford, pp 185–202
- Bonnaire E, Wiethold J, Marchaisseau V, Gerard F (2010) L'alimentation médiévale dans l'est de la France à travers des études carpologiques de sites champenois et lorrains. In: Delhon C, Théry-Parisot I, Thiébault S (eds) *Des hommes et des plantes. Exploitation du milieu et gestion des ressources végétales de la préhistoire à nos jours*. Éditions APDCA, Antibes, pp 161–192
- Bouby L (2002) Le chanvre (*Cannabis sativa* L.): une plante cultivée à la fin de l'âge du fer en France du Sud-Ouest? Hemp (*Cannabis sativa* L.): a late Iron age cultivated plant in southwestern France?). *CR Palevol* 1:89–95
- Buonincontri M, Moser D, Allevato E, Basile B, Di Pasquale G (2014) Farming in a rural settlement in central Italy: cultural and environmental implications of crop production through the transition from Lombard to Frankish influence (8th–11th centuries A.D). *Veget Hist Archaeobot* 23:775–788
- Buonincontri MP, Pecci A, Di Pasquale G, Ricci P, Lubritto C (2017) Multiproxy approach to the study of medieval food habits in Tuscany (central Italy). *Archaeol Anthropol Sci* 9:653–671

- Buxó R (1997) Arqueología de las plantas. La explotación económica de las semillas y los frutos en el marco mediterráneo de Península Ibérica. Crítica, Barcelona
- Caballero Zoreda L, Fernández Mier M, Rubinos Pérez A et al (1999) Notas sobre el complejo productivo de Melque (Toledo): prospección del territorio y análisis de Carbono 14, polínicos, carpológicos y antracológicos y de morteros. Arch Esp Arqueol 72:199–239
- Camarero Castellano I (2008) El marco jurídico del medio rural. Teoría y práctica legales en la agricultura de Al-Andalus (s.VIII-XV). Doctoral thesis, Universidad de La Laguna, La Laguna
- Canal D, Buxó R, Piqué R, Guitart i Duran J, Pera i Isern J (2004) Excavació de dos pous d'època romana a Guissona: l'explotació dels recursos vegetals a la ciutat de Iesso als segles I a. C. - II d. C. In: Guitart i Duran J, Pera i Isern J (eds) Iesso I: miscel·lània arqueològica. Patronat d'Arqueologia de Guissona, Guissona, pp 213–277
- Carabaza Bravo JM (1991) Abu L-Jayr. Kitab al-Filaha. Tratado De Agricultura. M.A.E./Agencia Española de Cooperación Internacional, Instituto de Cooperación con el mundo Árabe, Madrid
- Carabaza Bravo JM (2018) Rosáceas en Al-Andalus. In: Dahiri M, Camarero Castellano I (eds) El saber en Al-Andalus. Editorial Universidad de Sevilla, Sevilla, pp 15–36
- Chevalier A (2014) In: E, L (eds) Plants and people: choices and diversity through time, vol EARTH 1. Oxbow Books, Oxford
- Colominas L, Antolín F, Ferrer M, Castanyer P, Tremoleda J (2019) From Vilauba to Vila Alba: changes and continuities in animal and crop husbandry practices from the early roman to the beginning of the Middle ages in the north-east of the Iberian Peninsula. Quat Int 499, Part A:67–79
- Cubero i Corpas C (1988) Aportació de la paleocarpologia al coneixement de l'explotació agrària del territori (The provision of paleocarpology to the knowledge of the agrarian exploitation of the territory). Master Thesis, Universitat de Barcelona, Barcelona
- Cubero i Corpas C, Ollich i Castanyer I, de Rocafiguera i Espona M, Ocaña i Subirana M (2008) From the granary to the field: archaeobotany and experimental archaeology at l'Esquerda (Catalonia, Spain). Veget Hist Archaeobot 17:85–92
- Davies W (2002) Sale, price and valuation in Galicia and Castile-León in the tenth century. Early Mediev Eur 11:149–174
- de Fernando D, da, Veiga Ferreira O (1967) Un poço lusitano-romano encontrado em Idanha-a-Velha. O arqueólogo Português 1:57–63
- Decker M (2009) Plants and progress: rethinking the Islamic Agricultural Revolution. J World Hist 20:187–206
- Eguaras Ibáñez J (1988) Ibn Luyūn: Tratado De Agricultura. Patronato de la Alhambra y Generalife, Granada
- Fairbairn A, Asouti E, Near J, Martinoli DC (2002) Macro-botanical evidence for plant use at neolithic Çatalhöyük, south-central Anatolia, Turkey. Veget Hist Archaeobot 11:41–54
- Fernández Mier M, Fernández Fernández J, Alonso González P, López Sáez JA, Pérez Díaz S, Hernández Beloqui B (2014) The investigation of currently inhabited villages of medieval origin: Agrarian archaeology in Asturias (Spain). Quat Int 346:41–55
- Fuks D, Amichay O, Weiss E (2020) Innovation or preservation? Abbasid aubergines, archaeobotany, and the Islamic Green Revolution. Archaeol Anthropol Sci 12:50
- Fuller DQ, Barron A, Champion L, Dupuy C, Commelin D, Raimbault M, Denham T (2021) Transition from wild to domesticated pearl millet (*Pennisetum glaucum*) revealed in ceramic temper at three middle Holocene sites in northern Mali. Afr Archaeol Rev 38:211–230
- García Sánchez E (1983) La alimentación en la Andalucía islámica. Estudio histórico y bromatológico. I: Cereales y leguminosas. In: Bosch Vilá J, Hoenerbach W (eds) Andalucía Islámica. Textos y Estudios II-III (1981–1982). Universidad de Granada, Granada, pp 139–178
- García Sánchez E (ed) (1990) Ciencias de la naturaleza en Al Andalus. Textos y Estudios, vol 1. CSIC, Escuela de Estudios Árabes, Granada
- García Sánchez E (ed) (1992) Abū Marwān 'abd Al-Malik B. Zuhr. (m. 557/1162), Kitāb Al-Agdiya (Tratado de los Alimentos). Fuentes Árabe-Hispanas. CSIC, Madrid
- García Sánchez E (ed) (1994) Ciencias de la naturaleza en Al Andalus. Textos y Estudios III. CSIC, Granada
- García Sánchez E (ed) (1996) Ciencias de la naturaleza en Al Andalus. Textos y Estudios IV. CSIC, Granada
- García Sánchez E (ed) (1998) Ciencias de la naturaleza en Al Andalus. Textos y Estudios V. CSIC, Granada
- García Sánchez E (ed) (2001) Ciencias de la naturaleza en Al Andalus. Textos y Estudios VI, CSIC, Granada
- García Sánchez E (ed) (2004) Ciencias de la naturaleza en Al Andalus. Textos y Estudios VII, CSIC, Granada
- García Sánchez E (ed) (2014) Ciencias de la naturaleza en Al Andalus. Textos y Estudios IX, Homenaje a Camilo Álvarez Morales. CSIC, Granada
- García Sánchez E, Hernández Bermejo JE (2007) Ornamental plants in agricultural and botanical treatises from al-Andalus. In: Conan M (ed) Middle East garden traditions: unity and diversity. Questions, methods, and resources in a multicultural perspective. Dumbarton Oaks, Washington pp 75–94
- García-Rivero D, Taylor R, Pérez-Aguilar LG et al (2018) Andalusian populations at La Dehesilla Cave (Sierra de Cádiz, Southern Iberia): an interdisciplinary approach to their rural economic systems. J Islam Archaeol 5:119–151
- Gattefossé J (1934) Les greniers de falaises, forme ancienne d'agadir collectif. Bull Soc Préhist Du Maroc 8:91–102
- Glick TF (2005) Islamic and Christian Spain in the Early Middle Ages. (The Medieval and Early Modern Iberian World 27) Brill, Leiden
- Guichard P (1999) Littérature Jurisprudentielle et histoire de l'Espagne musulmane: la lente intégration des *fatwā's* malikites à l'historiographie d'al-Andalus. Comptes rendus des séances de l'Académie des inscriptions. et Belles-Lettres 143:757–779
- Hagenblad J, Morales J (2020) An evolutionary approach to the history of barley (*Hordeum vulgare*) cultivation in the Canary Islands. Afr Archaeol Rev 37:579–595
- Hagenblad J, Morales J, Leino MW, Rodríguez-Rodríguez AC (2017) Farmer fidelity in the Canary Islands revealed by ancient DNA from prehistoric seeds. J Archaeol Sci 78:78–87
- Hamerow H, Bogaard A, Charles M et al (2019) Feeding anglo-Saxon England: the bioarchaeology of an agricultural revolution. Antiquity 93:e12
- Hamerow H, Bogaard A, Charles M et al (2020) An integrated bioarchaeological approach to the Medieval 'Agricultural Revolution': A case study from Stafford, England, c. AD 800–1200. Eur J Archaeol 23:585–609
- Hastorf CA (2017) The social archaeology of food. Thinking about eating from Prehistory to the present. Cambridge University Press, Cambridge
- Henríquez-Valido PE, Morales J, Vidal-Matutano P, Santana-Cabrera J, Rodríguez Rodríguez A (2019) Arqueoentomología y arqueobotánica de los espacios de almacenamiento a largo plazo: El granero de Risco Pintado, Temisas (Gran Canaria). Trab De Prehist 76:120–137
- Hooper WD (1993) Cato and Varro on agriculture. Harvard University Press, Cambridge
- Kirchner H (ed) (2010) Por una arqueología agraria: perspectivas de investigación sobre espacios de cultivo en las sociedades medievales hispánicas. (BAR International Series 2062) Archaeopress, Oxford
- Kirleis W, Fischer E (2014) Neolithic cultivation of tetraploid free threshing wheat in Denmark and Northern Germany: implications

- for crop diversity and societal dynamics of the Funnel Beaker Culture. *Veget Hist Archaeobot* 23:81–96
- Konen H (1999) Reis Im Imperium Romanum: Bemerkungen zu Seinem Anbau und seiner Stellung als Bedarfs- Und Handelsartikel in Der Römischen Kaiserzeit. *Münstersche Beiträge Zur Antiken Handelsgeschichte* 18:23–47
- Larsson M, Lagerås P (2015) New evidence on the introduction, cultivation and processing of hemp (*Cannabis sativa* L.) in southern Sweden. *Environ Archaeol* 20:111–119
- Lityńska-Zajac M, Rębkowski M (2020) Plant use in Muslim Spain: preliminary results from the medieval town of Madīnat Ilbīra. *Acta Palaeobot* 60:296–306
- Livarda A, van der Veen M (2008) Social access and dispersal of condiments in North-West Europe from the Roman to the medieval period. *Veget Hist Archaeobot* 17:201–209
- Lodwick LA (2018) Arable weed seeds as indicators of regional cereal provenance: a case study from Iron Age and Roman central-southern Britain. *Veget Hist Archaeobot* 27:801–815
- Lodwick L, Rowan E (2022) Archaeobotanical research in classical archaeology. *Am J Archaeol* 126:593–623
- López de Calle C, Tudanca JM, Peña-Chocarro L, Pérez Jordà G, Moreno-García M (2019) Human-environmental interactions in the upper Ebro Valley (Spain): plant and animal husbandry in La Noguera (La Rioja) during the Roman and medieval periods. In: Gelichi S, Olmo-Enciso L, Corro E, Castro-Priego M (eds) *Mediterranean landscapes in Post Antiquity: new frontiers and new perspectives*. Archaeopress, Oxford, pp 84–103
- López-Dóriga I (2020) Estudos arqueobotânicos em *Tongobriga*: muestreo y resultados preliminares. In: Lima A (ed) *Tongobriga: coletânea de estudos comemorativos de 40 anos de investigação*. Direção Regional de Cultura do Norte - Ministério da Cultura, Porto, pp 83–97
- Marín M (1990) Las plantas alimenticias y su utilización en un manuscrito oriental sobre alimentación y dietética. In: García Sánchez E (ed) *Ciencias de la naturaleza en al-Andalus*. (Textos y Estudios 1) CSIC, Granada, pp 207–222
- Marín M (2000) Beyond taste: the complements of colour and smell in the medieval arab culinary tradition. In: Zubaida S, Tapper R (eds) *A taste of Thyme: culinary cultures of the Middle East*. Tauris Parke Paperbacks, London, pp 205–214
- Marín M, de la Puente C (2005) El banquete de las palabras: la alimentación en los textos árabes. CSIC, Madrid
- Marín M, Waines D (1994) La alimentación en las culturas islámicas. Agencia Española de Cooperación Internacional, Madrid
- McClatchie M, McCormick F, Kerr TR, O'Sullivan A (2015) Early medieval farming and food production: a review of the archaeobotanical evidence from archaeological excavations in Ireland. *Veget Hist Archaeobot* 24:179–186
- McKerracher M (2018) Farming transformed in Anglo-Saxon England: Agriculture in the long eighth century. Windgather Press, Oxford
- Millás Vallicrosa JM (1955) *Ibn Baṣṣāl. Tratado De Agricultura*. Instituto Muley El-Hasan, Tetuán
- Moffett L (2006) The archaeology of medieval plant foods. In: Woolgar CM, Serjeantson D, Waldron T (eds) *Food in Medieval England. Diet and Nutrition*. Oxford University Press, Oxford, pp 41–55
- Montanari M (2008) *Alimentazione E Cultura Nel Medioevo*. Laterza, Roma
- Montes Moya EM (2014) Las prácticas agrícolas en la Alta Andalucía a través de los análisis carpológicos: desde la Prehistoria Reciente al siglo II d.n.e. Doctoral thesis, Universidad de Jaén, Jaén
- Morales J, Pérez-Jordà G, Peña-Chocarro L, Zapata L, Ruiz-Alonso M, López-Sáez JA, Linstädter J (2013) The origins of agriculture in North-West Africa: macro-botanical remains from Epipalaeolithic and early neolithic levels of Ifri Oudadane (Morocco). *J Archaeol Sci* 40:2:659–2669
- Morales J, Rodríguez-Rodríguez A, González-Marrero MdC, Martín-Rodríguez E, Henríquez-Valido P, del-Pino-Curbelo M (2014) The archaeobotany of long-term crop storage in northwest African communal granaries: a case study from pre-Hispanic Gran Canaria (cal. AD 1000–1500). *Veget Hist Archaeobot* 23:789–804
- Muthukumaran S (2014) Between archaeology and text: the origins of rice consumption and cultivation in the Middle East and the Mediterranean. *Pap Inst Archaeol* 24:14
- Nabhan GP (2014) *Cumin, camels and caravans. A spice odyssey*. University of California Press, Berkeley
- Oliveira HR, Cíván P, Morales J, Rodríguez-Rodríguez A, Lister DL, Jones MK (2012) Ancient DNA in archaeological wheat grains: preservation conditions and the study of pre-hispanic agriculture on the island of Gran Canaria (Spain). *J Archaeol Sci* 39:828–835
- Pagnoux C, Celant A, Coubray S, Fiorentino G, Zech-Matterne V (2013) The introduction of *Citrus* to Italy, with reference to the identification problems of seed remains. *Veget Hist Archaeobot* 22:421–438
- Pais J (1996) Paleobotânica (finais séc. XI a séc. XIII/XIV) do Sul De Portugal - Setúbal, Mértola E Silves. *Arqueologia Medieval* 4:277–282
- Peña-Chocarro L, Pérez-Jordà G (2019) Garden plants in medieval Iberia: the archaeobotanical evidence. *Early Medieval Europe* 27:374–393
- Peña-Chocarro L, Pérez-Jordà G (in press) Las plantas en la subsistencia romana: cultivos, plantas silvestres y espacios de producción en la P. Ibérica. In: Peña Y, Noguera JM, Brun J-P (eds) *De Re Rustica. Arqueología de las actividades económicas en los campos de Hispania*, Collège de France-Universidad de Murcia, Paris-Murcia
- Peña-Chocarro L, Zapata L (1996) Los recursos vegetales en el mundo romano: Estudio de los macrorrestos botánicos del yacimiento calle Santiago de Irún (Guipúzcoa). *Archivo Español de Arqueología (AEspA)* 69:119–134
- Peña-Chocarro L, Zapata L (1997) Higos, ciruelas y nueces: aportación de la arqueobotánica al estudio del mundo romano. *Isturitz* 9:679–690
- Peña-Chocarro L, Zapata L (2005) Trade and new plant foods in the western Atlantic coast: the roman port of Irún (Basque Country). In: Urteaga Artigas M, Noain Maura MJ (eds) *Mar Exterior. El Occidente atlántico en época romana*. Escuela Española De Historia Y Arqueología. CSIC, Roma, pp 169–177
- Peña-Chocarro L, Pérez-Jordà G, Morales J (2018) Crops of the first farming communities in the Iberian Peninsula. *Quat Int* 470 Part B :369–382
- Peña-Chocarro L, Orejas Saco del Valle A, Carrión Marco Y, Pérez-Díaz S, López-Sáez JA, Fernández, Ochoa C (2019a) Late Antique environment and economy in the north of the Iberian Peninsula: the site of La Tabacalera (Asturias, Spain). *Late Antique Archaeology* 11:155–171
- Peña-Chocarro L, Pérez-Jordà G, Alonso N et al (2019b) Roman and medieval crops in the Iberian Peninsula: a first overview of seeds and fruits from archaeological sites. *Quat Int* 499:49–66
- Pérez-Jordà G (2013) La agricultura en el País Valenciano entre el VI y el I milenio a.C. PhD thesis, Universitat de València, València
- Pérez-Díaz S., Ruiz-Alonso M., López-Sáez JA, Solaun-Bustanza JL, Azkarate A, Zapata L (2015) A palaeoenvironmental and palaeoeconomic approach to the Early Middle Age record from the village of Gasteiz (Basque Country, Northern Iberian Peninsula). *Veget Hist Archaeobot* 24:683–697
- Pérez-Jordà G, Alonso N, Rovira N et al (2021a) The emergence of arboriculture in the 1st millennium BC along the Mediterranean's Far West. *Agronomy* 11:902
- Pérez-Jordà G, Peña-Chocarro L, Pardo-Gordó S (2021b) Fruits arriving to the west. Introduction of cultivated fruits in the Iberian Peninsula. *J Archaeol Sci Rep* 35:102683

- Primavera M (2018) Introduzione di nuove piante e innovazioni agronomiche nella Sicilia medievale: Il contributo dell'archeobotanica alla rivoluzione agricola araba di Andrew Watson. *Archeologia Medievale* 45:439–444
- Quirós Castillo JA (2014) Agrarian archaeology in early medieval Europe. *Quat Int* 346:1–6
- Quirós Castillo JA, Nicosia C, Polo-Díaz A, Ruiz del Árbol M (2014) Agrarian archaeology in northern Iberia: Geoarchaeology and early medieval land use. *Quat Int* 346:56–68
- Quirós Castillo JA, Tereso JP, Seabra L (2020) Social history of agriculture at medieval rural sites in the northern of the Iberia Peninsula: Aistra and Zornoztegi (Alava, Spain). *J Archaeol Sci Rep* 33:102442
- Rackham H (1968) Pliny. Natural history. Harvard University Press, Cambridge Mass
- Ramon-Laca L (2003) The introduction of cultivated citrus to Europe via Northern Africa and the Iberian Peninsula. *Econ Bot* 57:502–514
- Reed K, Leleković T (2019) First evidence of rice (*Oryza* cf. *sativa* L.) and black pepper (*Piper nigrum*) in Roman Mursa, Croatia. *Archaeol Anthropol Sci* 11:271–278
- Ribera i Gómez A (2016) Covetes dels Moros: Coves finestra en el Xarq Al-Andalus. Arqueologia de les coves penjades artificials valencianes. Doctoral thesis, Universidad de Alicante, Alicante
- Ribera i Gómez A (2010) Las Cuevas de Benaxuay: Un grupo de cuevas-ventana andalusíes en el río Chelva (Valencia). *Cuad de Madinat al-Zahra* 7:343–367
- Rincón Álvarez M (2003) Mozárabes y mozarabías. Ediciones Universidad, Salamanca
- Rodríguez-Ariza MO, Montes Moya EM (2010) Paisaje Y gestión De Los recursos vegetales en El Yacimiento Romano De Gabia (Granada) a través de la arqueobotánica (Landscape and management of plant resources at the roman excavations in Gabia (Granada) by means of archaeobotany). *Arch Esp Arqueol* 83:85–107
- Ros J, Garrido García JA, Ruiz Alonso M, Gilotte S (2018) Bioarchaeological results from the House 1 at Albalat (Romangordo, Extremadura, Spain): agriculture, livestock and environment at the margin of Al Andalus. *J Islam Archaeol* 5:71–102
- Ros J, Gilotte S, Sénac P, Gasc S, Gibert J (2019) Alimentación vegetal y agricultura en los márgenes de al-Andalus: nuevos datos arqueobotánicos. In: Delgado Pérez MM, Pérez-Aguilar LG (eds) Economía y trabajo. Las bases materiales de la vida en al-Andalus. Ediciones Alfár, Sevilla, pp 43–80
- Ros J, Puig C, Passariis O, Mantenant J, Kotarba J, Guinaudeau N (2020) Archaeobotanical contribution to the history of farming practices in medieval northern Catalonia (8th–14th c). In: Quirós Castillo JA (ed) From the late Prehistory to the Middle ages. Archaeology and history of peasantries, vol 1. Universidad del País Vasco, Bilbao, pp 163–182
- Rottoli M (2014) Reflections on early medieval resources in northern Italy: the archaeobotanical and archaeozoological data. *Quat Int* 346:20–27
- Ruas M-P (2008) Annexe 1 - Offrandes de fruits à Isis. In: Dardaine S, Fincker M, Lancha J, Sillière P (eds) Belo VIII: Le sanctuaire d'Isis. Casa de Velázquez, Madrid, Collection de la Casa de Velázquez 107, pp. 221–230
- Ruas M-P, Bouby L, Mane P, Puig C, Pradat B (2005) Les fruits sur la table. Les fruits de l'alimentation médiévale en France du Sud, entre marchés, recettes et dépotoirs. *Archéologie Du Midi Médiéval* 23–24:195–206
- Ruas M-P, Mane P, Puig C et al (2015) Regard pluriel sur les plantes de l'héritage arabo-islamique en France médiévale. In: Richarté C, Gayraud R-P, Poisson J-M (eds) Héritages arabo-islamiques dans l'Europe méditerranéenne. La Découverte-INRAP, Paris, pp 347–376
- Samsó J (1981–1982) Ibn Hišām al-Lajmi y el primer jardín botánico en al-Andalus. *Revista del Instituto Egipcio de Estudios Islámicos* 21:135–141
- Samuel D (2001) Archaeobotanical evidence and analysis. In: Berthier S (ed) Peuplement rural et aménagements hydroagricoles dans la moyenne vallée de l'Euphrate fin VIIe-XIXe siècle. Institut Français d'Études Arabes de Damas (IFEAD), Damascus, pp 343–481
- Seabra L, Tereso JP, Bettencourt AMS, Dinis A (2018) Crop diversity and storage structures in the settlement of Crastoeiro (Northwest Iberia): new approaches. *Trab De Prehist* 75:361–378
- Seabra L, Santos F, Vaz FC, Leite J, Tereso JP (2020) Crops behind closed walls: fortified storage at Castelinho in the Late Iron Age of NW Iberia. *J Archaeol Sci Rep* 30:102200
- Seabra L, Pereira P, Salgado M, Martín-Seijo M, Almeida-da-Silva R, Tereso JP (2022a) Crops on the edge of a cliff: storage at Castro S. João Das Arribas (Northwest Iberia) in the late antiquity. *J Archaeol Sci Rep* 44:103528
- Seabra L, Tente C, Vaz FC, Oliveira C, González Carretero L, Tereso JP (2022b) Crops on the rocks: production, processing, and storage at the early medieval site of Senhora do Barrocal (municipality of Sátão, Cent Portugal) *Plants* 11:471
- Seabra L, Teira-Brión A, López-Dóriga I, Martín-Seijo M, Almeida R, Tereso JP (2023a) The introduction and spread of rye (*Secale cereale*) in the Iberian Peninsula. *PLoS ONE* 18:e0284222
- Seabra L, Lemos P, Nunes M, Martín-Seijo M, Almeida R, Tereso JP (2023b) Frutos E Sementes Da Casa Romana do Castro De São Domingos (Lousada, Norte De Portugal). *Al-Madan Online* 26:70–84
- Squattriti P (2014) Of seeds, seasons, and seas: Andrew Watson's medieval Agrarian Revolution forty years later. *J Econ Hist* 74:1205–1220
- Teira Brión A (2010) Wild fruits, domesticated fruits. Archaeobotanical remains from the roman saltworks at O Areal, Vigo (Galicia, Spain). In: Delhon C, Théry-Parisot I, Thiébault S (eds) Des hommes et des plantes. Exploitation du milieu et gestion des ressources végétales de la Préhistoire à nos jours. Éditions APDCA, Antibes, pp 199–207
- Teira Brión A (2019) Cambio e resiliencia na agricultura e xestión de recursos vexetais no NW da Península Ibérica (1000 a.N.E.–400 d.N.E.). Doctoral thesis, Universidad de Santiago de Compostela, Santiago de Compostela
- Teira Brión A (2022) Understanding the plant economy of the westernmost territory of the Roman state through waste: the wet site of O Areal (Vigo, Spain). *Veget Hist Archaeobot* 31:595–610
- Teira-Brión A, Constela Doce X, Sartal Lorenzo M, Gil Agra D, Rúa Carril V (2023) The city as dissipative structure: the flow of agricultural production in the medieval Kingdom of Galicia. *J Anthropol Archaeol* 69:101482
- Tereso JP (2009) Plant macrofossils from the Roman settlement of Terronha De Pinhovelo, northwest Iberia. *Veget Hist Archaeobot* 18:489–501
- Tereso JP, Cruz G (2014) Frutos e sementes da Idade do Ferro e época romana da Citânia de Briteiros. *Al-Madan* 19:83–91
- Tereso JP, Ramil-Rego P, Almeida-da-Silva R (2013a) Roman agriculture in the conventus Bracaraugustanus (NW Iberia). *J Archaeol Sci* 40:2:848–2858
- Tereso JP, Ramil-Rego P, Álvarez González Y, López González L, Almeida-da-Silva R (2013b) Massive storage in as Laias/O Castelo (Ourense, NW Spain) from the Late Bronze Age/Iron Age transition to the roman period: a palaeoethnobotanical approach. *J Archaeol Sci* 40:3865–3877
- Tereso JP, Ramil-Rego P, Pires de Carvalho T, Almeida-Da-Silva R, Vaz FC (2013c) Crops and fodder: evidence for storage and processing activities in a functional area at the Roman settlement of Monte Mozinho (northern Portugal). *Veget Hist Archaeobot* 22:479–492

- Tereso JP, Pereira SS, Santos F, Seabra L, Vaz F (2020) Cultivos de época Romana no Baixo Sabor: continuidade em tempos de mudança? In: Arnaud JM, Neves C, Martins A (eds) *Arqueologia em Portugal 2020 – Estado Da Questão*. Associação dos Arqueólogos Portugueses e CITCEM, Lisboa, 1,207–1,220
- Torró J (2012) The eastern regions of Al-Andalus before the conquest by Catalonia-Aragon: an overview. *Cat Hist Rev* 5:11–27
- Treasure ER (2020) The frontier of Islam: An archaeobotanical study of agriculture in the Iberian Peninsula (c.700–1500 CE). Doctoral thesis, Durham University, Durham
- Twiss K (2012) The archaeology of food and social diversity. *J Archaeol Res* 20:357–395
- Van der Veen M (2018) Archaeobotany. The archaeology of human-plant interactions. In: Scheidel W (ed) *The science of roman history. Biology, climate, and the future of the past*. Princeton University Press, Princeton, Oxford, pp 53–94
- Vaz FC, Martín-Seijo M, Carneiro S, Tereso J P (2016) Waterlogged plant remains from the Roman healing spa of Aquae Flaviae (Chaves, Portugal): utilitarian objects, timber, fruits and seeds. *Quat Int* 404:86–103
- Vaz FC, Braga C, Tereso JP et al (2021) Food for the dead, fuel for the pyre: symbolism and function of plant remains in provincial roman cremation rituals in the necropolis of *Bracara Augusta* (NW Iberia). *Quat Int* 593–594:372–383
- Vigil-Escalera Guirado A, Moreno-García M, Peña-Chocarro L, Morales Muñoz A, Llorente Rodríguez L, Sabato D, Uccesu M (2014) Productive strategies and consumption patterns in the early medieval village of Góznuez (Madrid, Spain). *Quat Int* 346:7–19
- Voropaeva I, Stika H-P (2018) Plant remains from roman period town of Obulco (today Porcuna) in Andalusia (Spain)—distribution and domestication of olive in the West Mediterranean region. *Archaeol Anthropol Sci* 10:865–882
- Watson AM (1974) The arab agricultural revolution and its diffusion. *J Econ Hist* 34:700–1100
- Watson AM (1981) A medieval green revolution: new crops and farming techniques in the early Islamic world. In: Morony MG (ed) *Production and the exploitation of resources*. Ashgate, Aldershot, pp 219–248
- Watson AM (1983) *Agricultural innovation in the early Islamic world: the diffusion of crops and farming techniques*. Cambridge University Press, New York, pp 700–1100
- Woolgar CM (2010) Food and the middle ages. *J Mediev Hist* 36:1–19
- Zach B (2002) Vegetable offerings on the roman sacrificial site in Mainz, Germany – short report on the first results. *Veget Hist Archaeobot* 11:101–106
- Zapata L, Ruiz-Alonso M (2013) Agricultura altomedieval y usos forestales en Gasteiz (siglos VIII-XII d.C.). Datos carpológicos y antracológicos. In: Azkarate Garai-Olaun A, Solaun Bustinza JL (eds) *Arqueología e historia de una ciudad: Los orígenes de Vitoria-Gasteiz*. Servicio Publicaciones Universidad del País Vasco, Vitoria, pp 253–278

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