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Fruits arriving to the west. Introduction of cultivated fruits in the Iberian Peninsula

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ABSTRACT

Agricultural activities, including practices, crops and techniques have evolved throughout history undergoing tremendous changes. From the early Neolithic farmers in the Mediterranean focused on cereal agriculture and only later, during the 4th/3rd millennium cal. BC in the Eastern basin, other species such as fruit trees were introduced into the agrarian system transforming the model that had been in use for millennia. Fruit tree management required innovation and investment and more importantly multi-year foresight as the new crops entailed a new pace of work with delayed returns and, thus, a greater entanglement with the land. Processes of social complexity and urbanization accompanied the emergence of arboriculture which occurred at different pace at both ends of the Mediterranean. This paper focuses on the Iberian Peninsula, the most western Mediterranean region, during the 1st millennium cal. BC when arboriculture spread after commercial encounters with oriental seafarers. Here we report the earliest archaeobotanical evidence (seeds and fruits) for the introduction of fruit cultivation in Iberia. Results from several sites indicate that the spread of fruit cultivation was a long process that varied regionally. In some areas the new crops were rapidly adopted and integrated into the Mediterranean trading networks while in other regions arboriculture was not developed until the end of the millennium. Of the various fruit products that were commercialized, wine occupied a most relevant role.

1. Introduction

Mediterranean agriculture has been traditionally associated to the triad of cereal, vine and olive that provided the basis of eating habits of peoples living in this region. However, this was not the only agricultural model existing in this area. In fact, technological changes and a variety of crops were introduced throughout time shaping different agricultural systems. The first Neolithic farmers, who moved from the eastern end of the Mediterranean Sea towards the western edge, practiced an agriculture based exclusively on annual crops (cereals, legumes and oilseeds). This model with changes between an initial intensive production system and the transition to a later extensive agriculture (Halstead, 1987), was maintained for millennia. Later on, during the 4th/3rd millennium cal. BC, delayed-yielding crops like fruit trees were introduced in the Eastern Mediterranean (Abbo et al., 2015; Weiss, 2015; Zohary et al., 2012; Zohary and Spiegel-Roy, 1975) and from here, these spread across the western part of the basin with a significant delay with respect to the starting of cereal agriculture. Moreover, the chronological gap in the spread of fruit crops between the two extremes of the Mediterranean was also significant.

The introduction of fruit cultivation inevitably led to a profound transformation of the agricultural pace of the communities that embraced these novelties. For the first time, farmers invested significant work and time (several years) on plant species (fruit crops) that would only produce fruits several years after planting. In fact, the work initiated by one generation only saw its fruits in the next and so, agricultural practices necessarily encompassed long-term planning and dedicated management and supervision. This probably accentuated human entanglement with the land, a greater control of space and a privileged access to it that, together with greater investment, could develop land rights to tenure derived from continuity of use. Land ownership required social organization to sustain the model (McCorriston, 2009), and this appears linked to the development of processes of social complexity and/or urbanization (Fuller and Stevens, 2019; Gilman, 1981; Marston, 2017; Renfrew, 1972; Scott, 2017). On the other hand, the consumption of fruits and their derivatives enriched the diet of these communities (Miller and Wetterstrom, 2000) by adding sugar, vitamins, minerals and fibre supplements (Bouby and Ruas, 2014) but at the same time

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generated tensions between the need to produce staple calories for a growing population and the use of land for commodity crops (Fuller and Stevens, 2019).

In the eastern end of the Mediterranean the emergence of cities and complex social structures consolidated first (Rothman, 2004) allowing the rise of a new social structure necessary for implementing the initial investment, a high labor demand, and all the risks involved in growing fruit crops (Hamilakis, 1999). At the same time, these social transformations paved the way for the development of a specialized commercial agriculture. Some of the products derived from these practices, especially wine and oil, acquired a high status and became market leading products (Genz, 2003; Lovell, 2008; Sherratt, 1999; Steele, 2013), a process that is largely maintained even today.

Based on the existing archaebotanical record, the purpose of this paper is to address when and how arboriculture (grape, olive, almond, pomegranate and apple/pear) arrived into the Iberian Peninsula (Fig. 1), contextualize this process and explore its spread during the 1st millennium cal. BC.

Since the beginning of the first millennium, communities originating from the Eastern Mediterranean, mainly of Phoenician origin, settled in the south and east of the Iberian Peninsula (Aubet Semmler, 2001; López Castro et al., 2016). Later on, also Greeks linked to the colony of Massalia in the north-east (Miró & Santos, 2014) established in the area. The integration of these territories into a commercial network that encompassed the whole Mediterranean (Broodbank, 2013) accelerated a process of social and economic transformation that affected local communities in different ways (Bernabeu Aubán et al., 2013; Ruiz Rodríguez and Molinos Molinos, 2013; Sanmartí, 2004). These communities incorporated new technologies such as wheel-made pottery or the use of iron, as well as new crops such as fruit trees but the speed of transformation varied from one territory to another. At the same time, a greater social complexity is observed leading to the emergence of cities or to different forms of hierarchical rural structures.

The Iberian Peninsula is located in the most south-western corner of the Mediterranean basin, at the crossroads of this sea with the Atlantic Ocean. Iberia is characterized by a diversity of landscapes and ecological conditions, resulting in a great floral diversity. The northern coastal fringe belongs to the Euro-Siberian biogeographic region, marked by an oceanic climate with mild and wet conditions and the absence of summer drought. Most of the Iberia, however, is dominated by Mediterranean conditions with varied degrees of continentalism.

2. Material and methods

In this paper, we have decided to consider only fruit remains as they represent the most direct evidence of their consumption and presumably of their cultivation. The use of pollen and wood charcoal raises some problems. Firstly, the wild species of four of the cultivated fruit trees discussed (*Vitis vinifera*, *Olea europaea*, *Ficus carica* and *Malus* sp.) were distributed throughout prehistory across the Iberian Peninsula, and secondly, distinguishing between cultivated and wild varieties in wood charcoal and pollen is challenging. The only fruit tree species of exogenous origin that was identified in the wood charcoal assemblages of the 1st millennium BC in Andalucia (Rodríguez-Ariza, 2012) is the almond tree (*Prunus dulcis*). Its wood was identified in 8th-7th century levels which are clearly later than the presence of almond fruits in this region.

2.1. Archaeological information

In order to collect the available information on fruit species, a search was carried out to compile all published dates on cultivated fruits not only in the Iberian Peninsula but also in other areas of the Western Mediterranean (Table 1).

Our criteria to select radiometric information is based on the following protocol: a) first we selected ^{14}C made on fruit remains; b) if direct dates of fruit species did not exist, we chose those carried out on short-lived remains (mainly fauna or cultivated plants), and c) we decided to add some radiocarbon dates made on wood charcoal when radiometric information of a and b was not available. In this case, only wood charcoal related to clear archaeological contexts was used.

In order to increase the radiocarbon sample, new radiometric dates were carried out from Iberian sites where grape seeds remains were

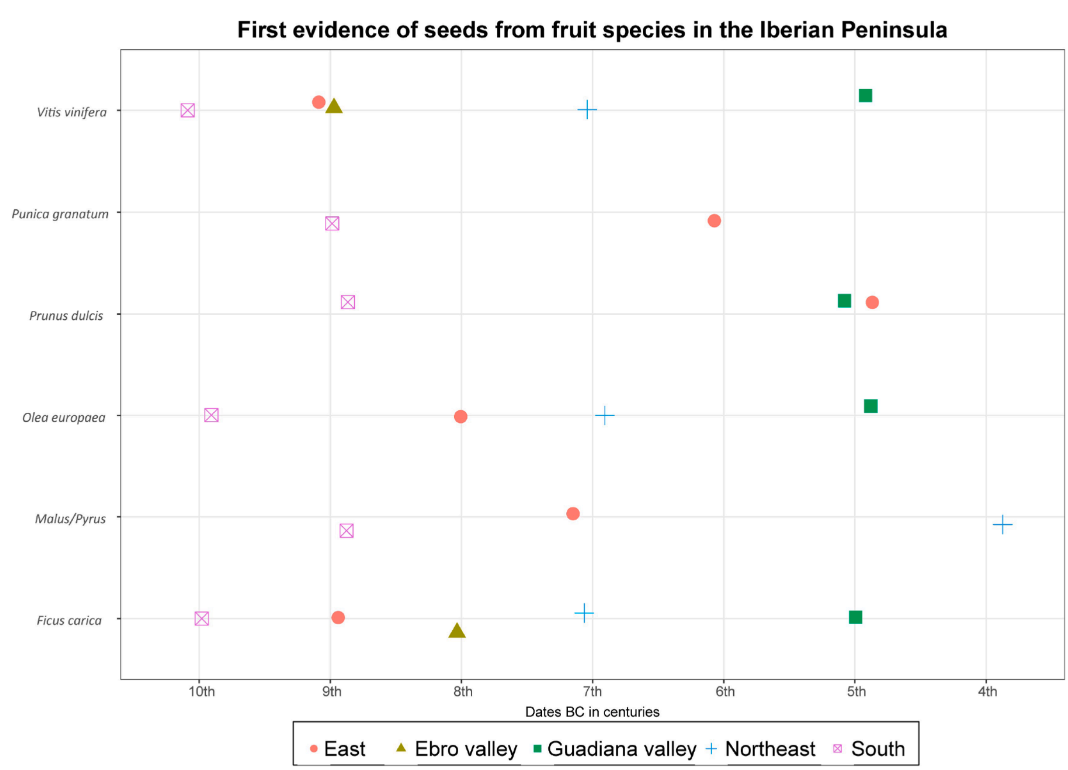

Fig. 1. Distribution of fruit species in different Iberian regions.

Table 1
Radiocarbon dates from sites with presence of fruit remains. ^{14}C dates have been calibrated using *Oxcal* software, version 4.3 (Ramsey, 2009). In order to reduce the uncertainty of the calibration, in the case that the same deposit had several dates, these have been combined and calibrated with the *R_Combine* function, as long as they are statistically equal. The asterisk remarks radiocarbon dates not used in the Bayesian models.

Site	Country	Level/ Phase	Sample	IDLab	BP	SD	1 s Max	1 s Min	2 s Max	2 s Min	Cal Mean	Cal SD	Reference
Alt de Benimaquia	Spain	SU 4004	*Vitis vinifera*	Beta-298121	2470	30	753	538	768	431	621	90	Pérez-Jordà 2013
Althiburos	Tunisia	NA1	Animal bone	Beta-262620	2790	40	1001	901	1042	836	941	52	Kallala and Sanmartí Grego, 2011
Althiburos	Tunisia	NA1	Animal bone	Beta-262619	2760	40	969	841	1002	826	906	49	Kallala and Sanmartí Grego, 2011
Althiburos	Tunisia	NA1	Animal bone	Beta-283141	2750	40	926	836	996	816	896	47	Kallala and Sanmartí Grego, 2011
Althiburos	Tunisia	NA2	Animal bone	Beta-283140	2720	40	902	827	971	804	871	38	Kallala and Sanmartí Grego, 2011
Beniteixir	Spain	33,003	*Hordeum vulgare*	Beta-322890	2590	30	804	778	820	595	780	42	Pérez-Jordà 2013
Cabezo de la Cruz	Spain	II (house 7)	Charcoal	GrN-29138*	2610	20	806	793	814	783	799	7	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	II (house 7)	*Hordeum vulgare*	GrN-29142	2590	20	802	787	806	772	791	11	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	II	Charcoal	GrN-29140*	2610	20	806	793	814	783	799	7	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	II	Coprolite	GrN-29143	2530	40	792	556	800	540	665	84	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	II	Charcoal	GrN-29863*	2520	25	781	567	792	544	663	76	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	II	Coprolite	GrN-29144	2500	60	776	541	794	430	626	100	Picazo & Rodanés 2009
Cabezo de la Cruz	Spain	III	*Vitis vinifera*	GrN-29147	2470	30	753	538	768	431	621	90	In this paper
Carthage	Tunisia	I	Animal bone	GrN-26091	2710	30	895	824	910	809	860	30	Docter et al., 2005
Carthage	Tunisia	II	Animal bone	GrN-26094	2660	30	832	801	895	794	827	25	Docter et al., 2005
Carthage	Tunisia	II	Animal bone	GrN-26090	2650	30	826	800	895	791	820	22	Docter et al., 2005
Carthage	Tunisia	II	Animal bone	GrN 26093	2640	30	823	797	893	786	814	19	Docter et al., 2005
Fonteta	Spain	I	*Stipa tenacissima*	Beta-298122	2560	20	794	772	802	594	768	47	García-Borja and Pérez-Jordà, 2012
Gadir	Spain		*Vitis vinifera*	Beta-508394	2450	30	746	431	754	411	589	103	Bernal Casasola et al., 2020
Huelva (Méndez Núñez)	Spain		*Hordeum vulgare*	Beta-406165	2800	30	996	915	1027	848	952	40	Pérez-Jordà et al. 2017
Huelva (Méndez Núñez)	Spain		*Vitis vinifera*	CNA-3773	2795	30	991	907	1043	837	946	44	González de Canales et al., 2020
Huelva (Méndez Núñez)	Spain		Animal bone	GRN-29512	2775	25	975	856	996	845	921	40	Nijboer and van der Plitch, 2006
Huelva (Méndez Núñez)	Spain		Animal bone	GRN-29511	2745	25	910	843	970	826	882	32	Nijboer and van der Plitch, 2006
Huelva (Méndez Núñez)	Spain		Animal bone	GRN-29513	2740	25	905	842	931	822	877	30	Nijboer and van der Plitch, 2006
Huelva (Méndez Núñez)	Spain		*Vitis vinifera*	Beta-295783	2640	30	823	797	893	786	814	19	Pérez-Jordà et al. 2017
Huelva (Concepción 3)	Spain		*Hordeum vulgare*	Beta-429022	2630	30	816	794	838	777	808	17	Pérez-Jordà et al. 2017
Huelva (Concepción 3)	Spain		*Vitis vinifera*	Beta-406164	2590	30	804	778	820	595	780	42	Pérez-Jordà et al. 2017
Jardín de Alá	Spain	F.A SU 10b	*Vitis vinifera*	Beta-485551	2790	30	992	904	1011	846	941	41	In this paper
Jardín de Alá	Spain	F.A SU 5	*Vitis vinifera*	Beta-485550	2720	30	896	833	918	811	866	30	In this paper
Jardín de Alá	Spain	F.J SU 7	Human bone	Beta-225409	2710	40	896	821	930	802	865	36	Hunt Ortiz and García Rivero, 2017
Kelin	Spain	I	Cereal	Beta-171910	2520	40	786	555	798	521	656	84	Pérez-Jordà 2013
Lixus	Morocco	SU 3049	*Triticum aestivum-durum*	Beta-184134	2590	40	814	763	832	553	754	73	Habibi et al. 2005
Lixus	Morocco	SU 3037	*Triticum aestivum-durum*	Beta-184133	2540	40	796	562	803	541	675	85	Habibi et al. 2005
Peña Negra	Spain	SU 7575	*Vitis vinifera*	Beta-495621	2490	30	761	546	781	511	639	78	In this paper
Peña Negra	Spain	SU 1026	*Vitis vinifera*	Beta-485547	2460	30	751	495	758	429	607	97	In this paper
Rebanadilla	Spain	IV	Charcoal		2810	40	1009	913	1073	843	965	53	Sánchez et al. 2012

(*continued on next page*)

Table 1 (*continued*)

Site	Country	Level/ Phase	Sample	IDLab	BP	SD	1 s Max	1 s Min	2 s Max	2 s Min	Cal Mean	Cal SD	Reference
				Beta-264171*									
Rebanadilla	Spain	IV	Charcoal	Beta-264170*	2780	40	996	857	1017	830	929	52	Sánchez et al. 2012
Rebanadilla	Spain	I	Charcoal	Beta-264173*	2700	40	895	812	921	801	858	35	Sánchez et al. 2012
Rebanadilla	Spain	II	*Vitis vinifera*	Beta-485543	2670	30	842	801	895	798	834	27	In this paper
Rebanadilla	Spain	I	Charcoal	Beta-264172*	2610	40	816	776	894	590	787	53	Sánchez Sánchez-Moreno et al., 2012
Sa Osa	Sardinia	Well V	*Vitis vinifera*	Beta-369366	3020	30	1372	1217	1391	1131	1272	58	Ucchesu et al. 2005
Sa Osa	Sardinia	Well U	*Vitis vinifera*	Beta-369965	3000	30	1282	1134	1377	1126	1236	58	Ucchesu et al. 2005
Sa Osa	Sardinia	Well N	*Vitis vinifera*	OxA-25106	2981	27	1260	1131	1286	1115	1202	50	Bronk-Ramsey et al. 2015
Sa Osa	Sardinia	Well N	*Vitis vinifera*	OxA-25107	2968	27	1225	1127	1276	1088	1182	47	Bronk-Ramsey et al. 2015
San Pablo	Spain	SU 11	*Vitis vinifera*	Beta-485548	2540	30	795	591	799	547	689	83	In this paper
Útica	Tunisia	SU 20,017	*Hordeum vulgare*	CNA-2403	2795	35	996	908	1027	842	947	46	López Castro et al., 2016
Útica	Tunisia	SU 20,017	*Hordeum vulgare*	CNA-2400	2790	35	996	903	1018	839	941	47	López Castro et al., 2016
Útica	Tunisia	SU 20,017	*Hordeum vulgare*	CNA-2402	2765	35	971	844	1001	832	910	46	López Castro et al., 2016

identified. In Jardín de Alá (Sevilla) (Fig. 2) we dated pips from the initial and final phase of one of the huts. In Peña Negra (Alicante), two grape seeds were dated from levels attributed to the Late Bronze phase. In Rebanadilla (Málaga) a grape seed from Phase I was dated, while in San Pablo (Málaga) a grape seed was also dated. Radiocarbon dates associated to the first fruit species identified are available in table 1.

Seeds have been determined using a binocular microscope (8-80× magnification) while the seed reference collections of the Archaeobiology Lab. of the CSIC (Madrid) and the Archaeological laboratory of the University of Valencia have been used for comparative material.

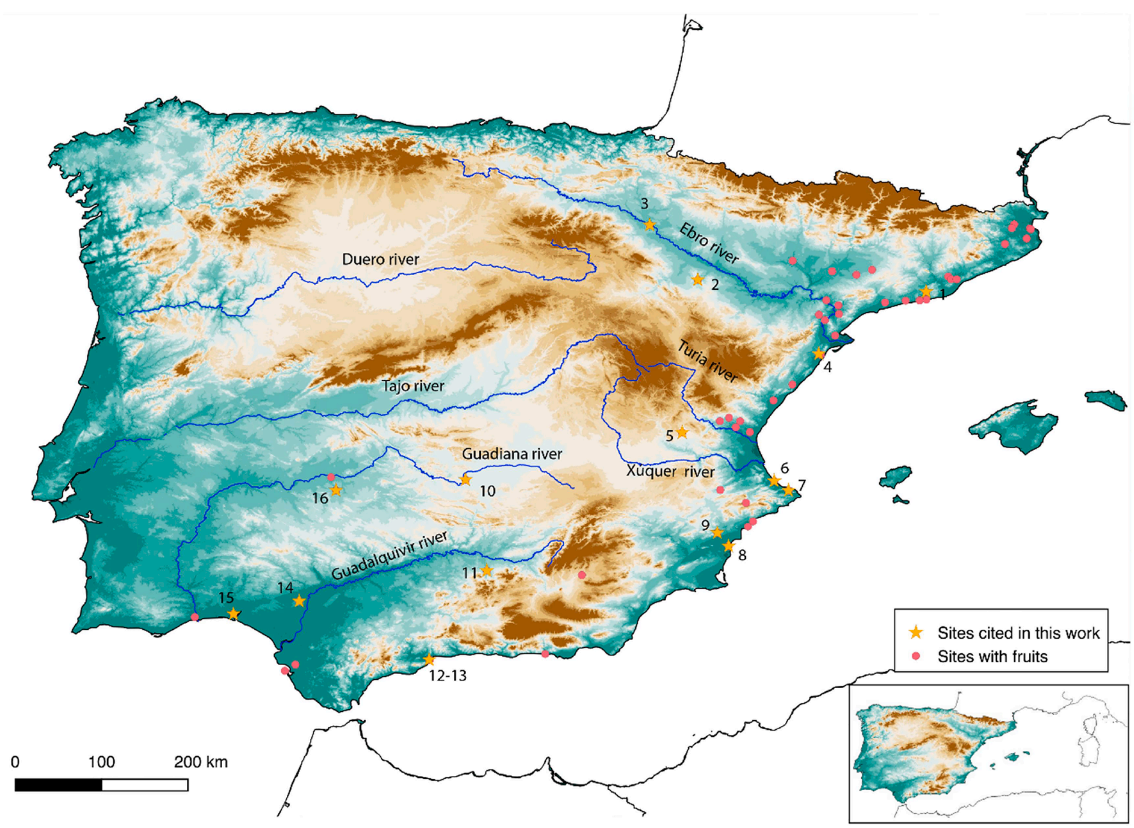

Fig. 2. Sites from the first millennium with fruit remains: 1. Turó de la Font de la Canya, 2. Cabezo de la Cruz, 3. El Castillo, 4. Sant Jaume-Mas d'en Serra, 5. Kelin, 6. Barranc de Beniteixir, 7. Alt de Benimaquia, 8. La Fonteta, 9. Peña Negra, 10. Alarcos, 11. Puente Tablas, 12. San Pablo 13. Rebanadilla, 14. Jardín de Alá, 15. Huelva, 16 La Mata.

2.2. Bayesian approach

In order to build a chronological framework of the spread of fruit trees in the Western Mediterranean, a Bayesian approach has been designed. The application of Bayesian methods in archaeology has increased notably in the last decades (Bayliss, 2015) resulting from the desire of many archaeologists of going beyond the simple *eye-balling* a set of calibration dates.

In this work we have used the software *Chronomodel v. 2.0.18* (Lanos and Dufresne, 2019) as it is more robust than *Oxcal* to build regional periodisation according to radiocarbon determinations recovered from multiple archaeological sequences (Banks et al., 2019). *Chronomodel* allows building chronological models for each site sequence where each unit (i.e., level, structure, stratigraphic unit) is defined by its radiocarbon determination and they are nested in an *event* model according to stratigraphical constrains. Later, the *event model* can be organised in a *phase* model (group of events) where each phase represents the archaeological phases considered (see Lanos and Dufresne, 2019; but see also Banks et al., 2019 appendix 1).

To have accurate chronological boundaries and precise chronological ranges between events and phases we have decided to use only ^{14}C dates carried out on short-lived samples. Also, to reduce the over-representation of dates from the same unit they have been combined using the contemporaneity test (Ward and Wilson, 1978) implemented in *Oxcal* (Ramsey, 2009). Since most of the radiocarbon determinations fall in the calibration curve plateau, known as the Hallstatt effect (Jacobsson et al., 2018), we have decided to use an alpha value of 0.01 when exploring the contemporaneity of the radiocarbon dates from the same unit. After that, we have set the *Chronomodel* parametrisation using:

a) the MCMC values consisting of 3 chains, 1500 burn iterations, 1000 batch iterations (with a maximum of 20 batches), and 200.000 acquisition interactions with a thinning interval of 10.

b) the posterior probability distribution has been calculated using the Metropolis-Hastings (*Adaptive Gaussian Random Walk)* mathematical algorithm (Hastings, 1970; Alvarado et al., 2016). It is a method to obtain a sequence based on random samples from a probability distribution where its direct sampling is hard.

3. Results

Fruits model A: Firstly, we have organised our archaeological events following Allen's temporal relations (Allen, 1983) and in those events from the same sites we have added Harris stratigraphical-temporal constrains (Dye and Buck, 2015) defined by arrows. Then, the event model has been structured in the follow phase model:

(a) Phase I: it contains the events from the site of Sa Osa (Sardinia, Italy). This phase is related to the first evidence of fruit trees in the Western Mediterranean.
(b) Phase II: it represents the moment when the first evidence of fruit trees appeared in north Africa and the south of the Iberian Peninsula. The events of this phase are Althiburos (NA-1) and Utica (stratigraphical unit 20017) from Tunisia and Jardín de Alá (FA lower level) and city of Huelva (Méndez Núñez lower level) from the southwest of the Iberian Peninsula.
(c) Phase III: it contains the events from the sites of north-western Africa such as Althiburos (NA-2) and Carthage (phase 1) whilst the events of the south of the Iberian Peninsula are the city of Huelva (Méndez Núñez upper level and Concepción 3 lower level), Jardín de Alá (FA upper level and FJ) and Rebanadilla (phase 2).
(d) Phase IV: in this phase the first evidence of fruit trees in Eastern Iberia is documented. The events nested in this phase are Carthage (phase 2) and Lixus (Morocco) (SU. 3049) from the Atlantic coast of Morocco, the city of Huelva (Concepción 3 upper level) from south-west Iberia, Fonteta (Alicante) and Beniteixir (Valencia) in eastern Iberia and Cabezo de la Cruz (phase 2) (Zaragoza) in the Ebro valley.
(e) Phase V: it is the last phase of our Bayesian model and it corresponds to the spread of fruit trees to the north of the Ebro valley. In this sense, the events considered are Lixus (SU. 3037) in the Atlantic coast of Morocco, Gadir (Cádiz) and San Pablo (Málaga) from southern Iberia, Alt de Benimaquia and Peña Negra (both in Alicante), Kelin (Valencia) (phase 1) and Cabezo de la Cruz (phase 3) from the Ebro valley.

Later on, we have created a second Bayesian model (Fruits model B) using the same phases as in model A, but adding two sites in the last phase: Turó de la Font de Canya (Barcelona) and Sant Jaume (Tarragona) located in north-eastern Iberia, dated according to relative chronology, between 650 and 575 BCE. These dates have been added to the model assuming a uniform distribution.

Event model A has an average acceptance rate of 45% while event model B has an average acceptance of 45.4%. Both models must be accepted as they fall within the threshold explained in the *chronomodel* documentation when the mathematical algorithm used to calculate the Bayesian probabilities is the Metropolis-Hastings (so-called *adapt. Gaussian Random Walk*) (but see also Roberts and Rosenthal, 2001). Detailed results such as the acceptance ratio, the HPD (Highest Posterior Density) of each radiocarbon date among others can be found in the supplementary material. Table 2 shows the mean from each phase on both models. Differences are minimal. Based on these results, we have selected model B to discuss the time of expansion of fruit trees in the Western Mediterranean. Fig. 3 depicts fruit expansion phases intervals bounded by HPD representing the start and end of each interval. According to Bayesian results, we have identified an early phase (1443 to 1061 BCE) related to the arrival of fruit trees to the Western Mediterranean. In a second moment (1103 to 795 cal BC), fruits arrived to northern Africa and the south of the Iberian Peninsula. Finally, during the period 835 to 550 cal BC, fruits spread first to eastern Iberian and after to the north of the Ebro valley. The end of this phase corresponds to the sites of Sant Jaume and Turó de la Font de la Canya (*terminus post quem* 575).

4. Discussion

4.1. Early evidence of fruit trees in the western Mediterranean.

The arrival of fruit crops to the western part of the Mediterranean is attributed to Eastern Mediterranean seafarers. In Sardinia, the first

Table 2
Modelled intervals for each arboriculture phase (calibrated calendar years BC). The beginning and the end of each phase is based on the means.

Phases of fruit spread	Bayesian Model A			Bayesian Model B		
	Modeled interval 95%		Duration (yr)	Modeled interval 95%		Duration (yr)
	Begin	End		Begin	End	
First evidences in the western Mediterranean	1317	1161	156	1317	1161	155
Arrival to north Africa & southern Iberia	1005	919	85	1005	919	86
Consolidation in north Africa & southern. Iberia	898	818	79	898	819	78
First evidences in eastern Iberia	809	751	57	809	751	57
Expansion to the north of the Ebro valley	725	571	154	724	571	153

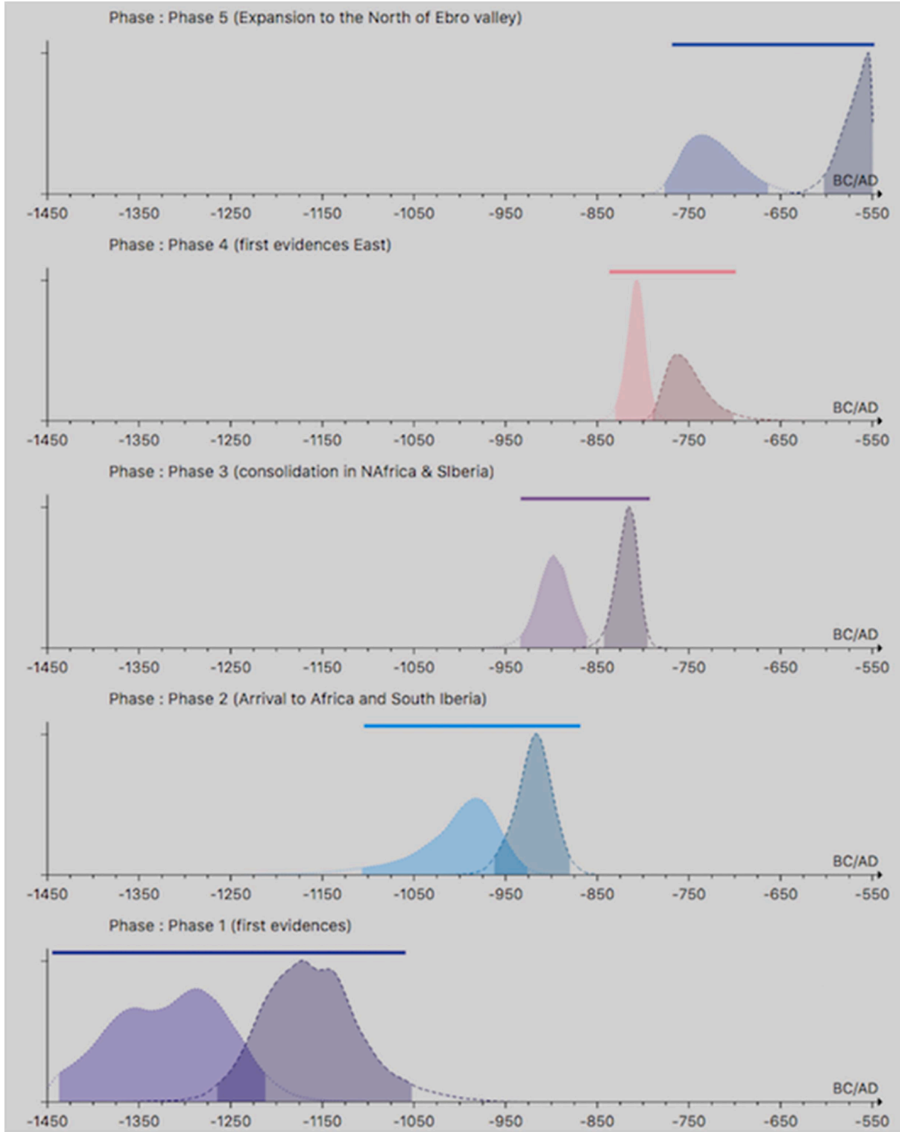

Fig. 3. Phase interval result for each expansion phase obtained in the age model. The solid bars show the shortest intervals within which fall the starting (dotted) and the ending (dashed) of a phase at 95%.

evidence of cultivated fruit crops dates back to the late second millennium (1317–1161 cal BC) (Sabato et al., 2015) when the island was involved in wide exchange networks that connected the eastern and the central Mediterranean (Lo Schiavo and Campus, 2013; Russell and Knapp, 2017). The main issue here relates to the difficulties for establishing whether the early introduction of arboriculture into the island was maintained or it merely represented an isolated event. Unfortunately, the archaeobotanical record is scarce for the period between the earliest evidence of fruit cultivation and that from the 7th-6th century BCE onwards (Pérez-Jordà et al., 2020; Sabato et al., 2018) linked to the presence of Phoenicians on the island, which impedes gaining insights into the subject. The available archaeobotanical evidence is only indirect. Nevertheless, the production of amphoras from the end of the 9th century in Sant'Imbenia (Botto, 2013; Oggiano, 2000), as well as some structures that have been interpreted as possible wine presses (Botto, 2016) suggest a local wine production, which the archaeobotanical record cannot confirm.

In Tunisia, the oldest evidence of cultivated fruit trees comes from the Numid area, particularly from the Althiburos site (Kallala and Sanmartí Grego, 2011; López and Cantero, 2016) dated to the 10th-9th century. Data from the Phoenician area is, however, unclear. In fact, archaeobotanical assemblages from Utica have been studied (López Castro et al., 2016; Montes Moya et al., 2015), but no evidence of fruit trees has been reported. Moreover, the oldest levels of the city of Carthage (Docter et al., 2005) yielded fruit remains (Kroll, 1993, 2007) but of later date (9th century BCE).

There are currently no data from either the Algerian coast and Mediterranean Morocco. The only available information from Morocco derives from the city of Lixus (Pérez-Jordà, 2001, 2005), located on the Atlantic coast, where domesticated fruit trees were found in levels dated between the end of the 9th century and the first half of the 8th century BCE (Habibi et al., 2005).

4.2. *Fruit trees in the Iberian Peninsula*

In recent years, the number of sites where archaeobotanical studies have been carried out in the Iberian Peninsula has considerably increased (Figs. 2 & 4) providing insights into the variety of plant species used by prehistoric communities. Data from several sites reveals that wild fruit tree species such as the wild olive (*Olea europaea* subsp. *oleaster*), the vine (*Vitis vinifera* subsp. *sylvestris*) and the fig tree (*Ficus carica*), were part of human subsistence not only throughout the

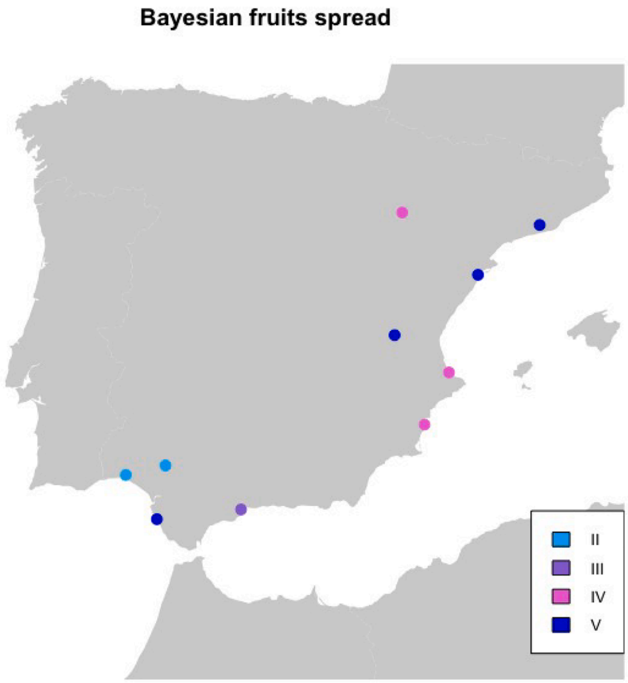

Fig. 4. Appearance of the first cultivated fruit tree species (See also Suppl. Material fig. 1).

Holocene but also in earlier periods (Carrión et al., 2010; Iriarte-Chiapusso et al., 2017; Martínez Varea and Badal García, 2018; Rivera and Walker, 1989). The archaeobotanical record suggests a limited use of fruit resources which only occurred in specific moments and particular regions. This is the case of the southeastern part of the Iberian Peninsula where plant remains point to a systematic exploitation of wild olives during the 3rd millennium cal. BC (Stika, 1999) which did not seem to have continued the following millennium (Alonso et al., 2016).

Cultural connections and exchanges between the southern Iberian Peninsula, Sardinia and the eastern Mediterranean are clearly evidenced at the end of the 2nd millennium BC and proved by the presence materials from those areas recovered in Iberia (Ruiz-Gálvez, 2015; Torres Ortiz, 2008; Valério et al., 2018), and the identification of Iberian materials in the eastern Mediterranean (Mazar, 2004; Wood et al., 2019). However, in none of these cases was there evidence of fruit tree remains. The first fruit tree species that systematically and with outstanding frequencies turned up in the archaeological record of southern Iberia occurred at the beginning of the 1st millennium cal BC (SI Fig. 1). Plant remains and fossil vineyards from the city of Huelva (Pérez-Jordà et al., 2017; Vera and Echevarría, 2013) illustrate the practice of local arboriculture between the 9th and the 8th century BCE after contact with eastern seafarers. Interestingly, the variety of species identified suggests that the arrival of fruit species into the region did not occurred gradually but in a package of several species. Together with the already known wild fruit trees that naturally thrive in the Iberian Peninsula such as the olive, the vine and the fig tree, now cultivated, the archaeobotanical record provides information on new arrivals such as the almond (*Prunus dulcis*) and the pomegranate (*Punica granatum*). From all, the vine was the most abundant and most widely spread crop.

Recently, archaeobotanical research carried out by the authors at the indigenous site of Jardín de Alá, where contacts with the colonial world are demonstrated by the presence of Phoenician pottery (Hunt Ortiz and García Rivero, 2017), has confirmed the identification of vines and olives which were abundant and recurrently present in different assemblages from a variety of structures. Grape pips were found both in the earliest levels (1011–846 cal. BC) and in more recent phases (918–811 cal. BC). These new dates anticipate the presence of domesticated vines in the Iberian Peninsula to the transition between the 10th-9th century cal. BC. The above two sites demonstrate that at least in the area of the Gulf of Cadiz domesticated fruit trees were present in chronologies similar to those from Tunisia. It is likely that the spread of fruit cultivation along the southern Mediterranean coast of Iberia occurred more or less simultaneously as it seems to suggest by the two dates of phase IV from the Phoenician site of Rebanadilla located further east (Sánchez Sánchez-Moreno et al., 2012). Both have been combined using the combination function of the Oxcal software (Ramsey, 2009) and have provided a two-sigma calibrated range (1013–851 cal. BC). However, the limited sampling of this site did not provide fruit remains until a more recent phase (895–798 cal. BC).

All radiocarbon dates allocated to the 10th- 9th century cal. BC come from the southern part of the Iberian Peninsula while evidence of spread towards the north did not occurred until the 8th century BCE (835–720 cal. BC based on Bayesian modelisation). From this point onwards, radiocarbon dating is problematic with many dates falling within the so-called Hallstatt plateau (Jacobsson et al., 2018) where calibration ranges are extremely wide. Moreover, the archaeological material (pottery, metal, etc.) from this period does not usually provide definite chronological clues. Under these limitations exploring the expansion of arboriculture remains complicated but the likely advance of arboriculture towards the north, following the Mediterranean coast, is plausible.

In fact, at a number of sites distributed along eastern Mediterranean Iberia plant remains from cultivated fruits were retrieved. In most cases these sites are located along the coast. The only exception is the site of Cabezo de la Cruz, an indigenous settlement situated in the middle Ebro valley where the presence of Phoenician material is scarce and grape remains abundant (Pérez-Jordà, 2009; Picazo Millán and Rodanés Vicente, 2009). The only date from this site shows a reduced calibration range (806–772 cal. BC) and points to the spread of vine cultivation into the Ebro valley in the transition between the 9th and the 8th century cal. BC.

Interestingly, in between the southern area of the Iberian Peninsula and Cabezo de la Cruz, there are three sites with fruit remains dated between the end of the 9th century and the first half of the 8th century BCE. All of them are situated in the coastal band. The site of La Fonteta is a Phoenician factory whose earliest levels were dated between the middle (González Prats, 2011) and the end of the 8th century BCE (Rouillard et al., 2007) according to the archaeological material. A radiocarbon date from the earliest occupation levels provided a wider chronological range (802–594 cal. BC) but it does not disprove the chronology proposed. The ubiquity of fruit trees, particularly fig and vine, at these levels was very significant (Fig. 5). The other two sites were indigenous settlements; one, San Pablo, shows the presence of Phoenician materials (Arancibia et al., 2011), and the second, Beniteixir has not provided evidence of Phoenician elements. Both of them are located by the coast and their architecture is characterized by excavated structures typical of Bronze Age Iberian indigenous sites. Unfortunately, archaeobotanical data from these two sites is very limited impeding to assess the frequency and abundance of the various taxa.

During the 767–550 cal BC (phase V of our Bayesian model), deposits with fruit remains became more frequent along the eastern coast. Sites such as Alt de Benimaquia show the first evidence of wine production. Together with a wide range of fruit tree species (Pérez Jordà, 2013), structures for producing wine are documented (Gómez Bellard et al., 1993). There is only one date coming from the abandonment levels (768–431 cal. BC) but its wide calibration range impedes establishing with accuracy the final occupation of the settlement. Nor is there any element to identify the foundation of this site where the production of wine had an outstanding importance. Further north, at sites like Sant Jaume (López Reyes et al., 2011), close to the mouth of the Ebro river, and at Turó de la Font de la Canya (López Reyes et al., 2013), similar archeobotanical assemblages were found confirming for the first time the abundant presence of fruit tree remains north of the Ebro river.

From the 5th/4th century BCE marked changes in the practice of

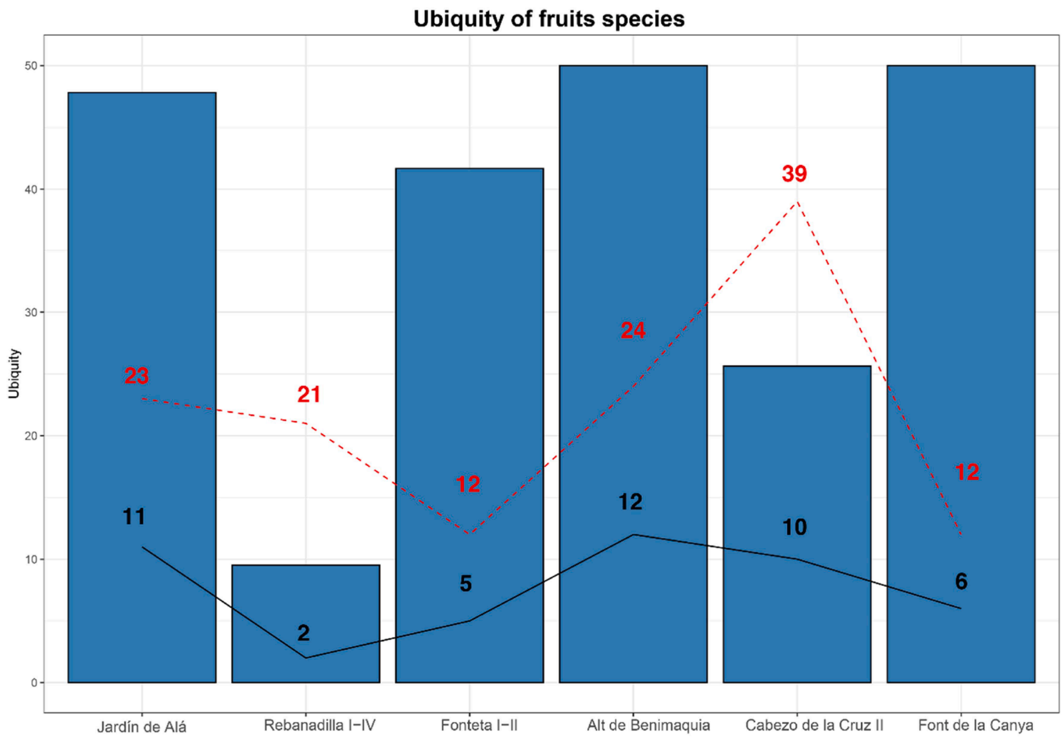

Fig. 5. Ubiquity of fruit species in the earliest sites: number of samples (red dashed line), number of samples with fruits (black line).

arboriculture are highlighted. In those territories where fruit crops had been already established, cultivation was maintained and some species such as the almond expanded. Meanwhile, arboriculture was also confirmed in the interior of the Guadiana and Guadalquivir valleys, in southern Spain. Sites such as La Mata (Badajoz) (Pérez-Jordà, 2004), Alarcos (Ciudad Real) and Puente Tablas (Jaén) (Montes Moya, 2015) show the presence of vine, almond, olive and fig (the latter absent in Puente Tablas). This gradual pattern of penetration along river valleys was also attested in the Ebro valley where fruit cultivation is attested at the necropolis of El Castillo (Navarra). In contrast, in other river valleys such as those of the Duero or Tajo rivers, or in the north of the Iberian Peninsula, cultivation did only concern plants of annual cycle (cereals and legumes) while fruit cultivation did not seem to have been practiced.

From the 5th century BCE onwards a significant difference between the Mediterranean territories located to the north and south of the river Ebro is noticed (Alonso and Pérez-Jordà, 2019). In the northern part, the ubiquity of fruit trees appeared low while the agricultural production focused on the cereals increased. This is shown by the archaeobotanical record and the presence of the so-called "*campos de silos*" (silo fields) in the Spanish archaeological literature which are concentrations of storage pits in vast areas far from the settlements. These became a significant characteristic element of this territory. To the south of the Ebro river, the ubiquity and diversity of fruit trees were much higher, equal in many cases to that of cereals. Neither silo fields, nor large structures devoted to grain storage were found while structures for wine making and oil processing appeared in a systematic way. Due to its size and capacity some of the presses documented showed a clear commercial orientation and sometimes these were associated to the production of amphorae used for packaging and marketing, especially wine but also other products deriving from fruit processing. The significant presence of species such as pomegranates and figs also points to their likely marketing.

This marked difference between these two territories was maintained until the Romans occupied the area, which in this region started right after the Second Punic War. Similarly, there was no evidence of the spread of arboriculture to new areas inner and north of the Iberian Peninsula. Here, the introduction of fruit trees did not occur until the Roman conquest (Peña-Chocarro et al., 2019).

4.3. *The development of a new agricultural model*

The 1st millennium was a period of connectivity, networks, encounters and colonisation (Broodbank, 2013; van Dommelen, 2017). The fluidity and connectedness that characterized the Mediterranean basin led to a dynamic process of Mediterraneanization (Hodos, 2009; Morris, 2003) which united the basin through shared practices and cultural mixing. These complex cross-cultural interactions and increasing mobility occurred at multiple levels and not only involved material culture but also new technologies, commodities, and crops among others. Ultimately, the multidirectional encounters among the various communities generated the emergence of new social relations (Vives-Ferrándiz Sánchez, 2015). Regarding agriculture, a significant change is observed in the western Mediterranean contributing to stop the traditional divide between the two ends of the Mediterranean Basin. In the western Mediterranean, archaeobotanical research in several settlements has shown the introduction of new crops, some considered cash-crops such as the olive and the vine. It is clear that variations observed in the Iberian archaeobotanical record result from different responses to contact.

These processes were not simple one-way unidirectional phenomena but complex multifaceted events as the archaeological record suggests. Based on the available archaeobotanical data for the period, we argue that a dual agricultural model was in practice. In some areas agriculture focused on the cultivation of annuals only, while in others the system also included fruit production. Within each of the regions adopting arboriculture differences are also observed. In fact, the communities living south and north of the river Ebro displayed different attitudes and made different choices. While in the south, a varied arboriculture developed which played a significant role in the growth of agriculture, in the north cereal production was the main focus of agriculture, with fruit trees occupying a smaller part of the overall agricultural production. The agricultural innovations and the new products, particularly wine, occupied a central place in the new economic system and became key elements in the social and economic transformation of the area. The growth of the urban phenomenon, the processes of agricultural colonisation, and the development of market-oriented agriculture (Sherratt, 1999; Van Dommelen and Gómez Bellard, 2008) were changes intimately linked to this new scenario.

The archaeological record is still limited when it comes to precisely define the spread of the new agricultural model throughout the Iberian Peninsula. As noted above, most colonial settlements and indigenous sites where arboriculture and wine production were attested are located at the southern and eastern cost. Nevertheless, the arrival of wine production to the interior of the Ebro valley in such an early date, as suggested by the Cabezo de la Cruz site, is difficult to explain as the evidence coming from the Ebro's mouth is apparently from more recent times.

Different from the north and inland regions of the Iberian Peninsula, the available archaeobotanical data highlights the consolidation of arboriculture along the eastern and southern fringe of the Iberian Peninsula from the 7th century BCE. Later on, by the 5th/4th century cal. BC, the valleys of the Guadalquivir and the Guadiana also transformed their agricultural models with the introduction of fruit tree cultivation.

The adoption of this new agricultural model based on the production of fruit products was an innovation quickly adopted by part of the communities that inhabited this territory, particularly by those with closer contact with the Mediterranean world. But at the same time, it was ignored or rejected by the groups that inhabited much of the interior and north of the Iberian Peninsula. It is clear, thus, that the new agricultural model was a long process that took place along the entire first millennium in the Iberian Peninsula. Its adoption and implementation were often associated to processes of social complexity, that took different forms, giving rise to urban societies in some cases, or the development of rural aristocracies in others. Nevertheless, this new agricultural practice became one of the defining elements of the social and economic transformations that developed in the Iberian Peninsula during the 1st millennium BC.

5. Conclusions

Using archaeobotanical data, we have presented an overview of the transition to a new agricultural model based on crops with deferred yields, fruit trees that developed in the Iberian Peninsula at the beginning of the 1st millennium BC. There is no evidence to sustain a local development of fruit tree cultivation in earlier periods despite archaeological remains such as ceramics or metallic objects suggest contacts with the eastern world at least from the end of the 2nd millennium BC.

While this agricultural transformation or revolution can be undoubtedly linked to colonial activities, the dates we have presented here allow to anticipate this process to the 10th-9th century BCE (1103–871 cal. BC) much earlier than those conventionally assumed between the 8th-7th century BCE (Buxó, 2008). Current dates of fruit seeds or of levels where these were retrieved demonstrate that the development of fruit production took place from the beginning of the establishment of colonial settlements, both in the new colonial foundations as much as in the surrounding indigenous sites with whom Phoenicians engaged. Data from southern Iberia is contemporary to that from Tunisia, highlighting the role Phoenicians had in introducing arboricultural practices into the Iberian Peninsula but also the significant role tree fruit commodities had for these communities.

CRediT authorship contribution statement

Guillem Pérez-Jordà: Conceptualization, Methodology, Funding acquisition, Writing - original draft, Writing - review & editing. **Leonor Peña-Chocarro:** Conceptualization, Methodology, Funding acquisition, Writing - original draft, Writing - review & editing. **Salvador Pardo-Gordó:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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