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ORIGINAL ARTICLE

First finds of *Prunus domestica* L. in Italy from the Phoenician and Punic periods (6th–2nd centuries BC)

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Abstract During the archaeological excavations in the Phoenician and Punic settlement of Santa Giusta (Oristano, Sardinia, Italy), dating back to the 6th–2nd centuries BC, several *Prunus* fruitstones (endocarps) inside amphorae were recovered. The exceptional state of preservation of the waterlogged remains allowed morphometric measurements to be done by image analysis and statistical comparisons made with modern cultivated and wild *Prunus* samples collected in Sardinia. Digital images of modern and archaeological *Prunus* fruitstones were acquired with a flatbed scanner and analysed by applying image analysis techniques to measure 26 morphometric features. By applying stepwise linear discriminant analysis, a morphometric comparison was made between the archaeological fruitstones of *Prunus* and the modern ones collected in Sardinia. These analyses allowed identification of 53 archaeological fruitstones as *P. spinosa* and 11 as *P. domestica*. Moreover, the archaeological samples of *P. spinosa* showed morphometric similarities in 92.5% of the cases with the modern *P. spinosa* samples currently growing near the Phoenician and Punic site. Likewise, the archaeological fruitstones identified as *P. domestica* showed similarities with the modern variety of *P. domestica* called Sanguigna di Bosa which is currently cultivated near the village of Bosa. Currently, these findings represent the first evidence of *P. domestica* in Italy during the Phoenician and Punic periods.

Keywords Archaeobotany · Image analysis · Morphometric features · *Prunus* · Sardinia

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Introduction

The genus *Prunus* L. (Rosaceae) includes about 400 species classified into five subgenera including *Prunus, Amygdalus, Cerasus, Padus* and *Laurocerasus*, which are mainly distributed in temperate regions of the boreal hemisphere (Krussman 1986; Maynard et al. 1991; Aradhya et al. 2004; Yilmaz et al. 2009). Domesticated *Prunus* includes European plum (*Prunus domestica* L.), Japanese plum (*Prunus salicina* Lindl.), peach [*Prunus persica* (L.) Batsch], apricot (*Prunus armeniaca* L.), sweet cherry [*Prunus avium* (L.) L.], sour cherry (*Prunus cerasus* L.) and almond [*Prunus dulcis* (Mill.) D.A. Webb]. With the exception of almonds, where the edible part consists of the seeds, the others are consumed for their fleshy fruits (Janick 2005).

Prunus domestica (plum) is one of the most economically important fruits in temperate regions and represents a major crop in Europe and southwest Asia (Ramming and Cociu 1991; Watkins 1995; Körber-Grohne 1996; Zohary et al. 2012). In 2013, FAOSTAT estimated that the total commercial harvest of plums was 12 million tons, cultivated from 2.5 million ha (FAOSTAT 2013).

The primary centre of plum domestication has been identified in Central Asia, with other secondary centres in East Asia, Europe and North America (Watkins 1995). However, the effective place(s) of origin and domestication of plum are still under investigation.

Crane and Lawrence (1952) and Watkins (1995) suggested that plum might be a polyploid derivative of a cross between the tetraploid *Prunus spinosa* L. and diploid *P. cerasifera* Ehrh. *P. spinosa* (sloe) is a shrub with a distribution range that extends from the western and central parts of Europe to Asia Minor; it is also present in the Caucasus region and North Africa (Hegi 1995). However, as suggested by Zohary et al. (2012), the wild relative of *P. domestica* is an autopolyploid derived from *P. cerasifera* that probably also partially contributed to two other wild species, including *P. cocomilia* Ten. and *P. brigantino* Vill. Moreover, *P. domestica* ssp. *insititia* (L.) Bonnier & Layens (damson) is considered the ancestor of modern plums (Woldring 2000; Zohary et al. 2012).

Recently, genetic studies have shown that *P. spinosa, P. domestica* ssp. *insititia* and *P. domestica* have close genetic relationships (Aradhya et al. 2004; Pollmann et al. 2005; Depypere et al. 2009; Horvath et al. 2011; Xuan et al. 2011; Milošević and Milošević 2012; Athanasiadis et al. 2013). In addition, different authors investigating genetic relatedness between modern *Prunus* species concluded that the phylogenetic reconstruction is the result of several processes of speciation derived from hybridisation that occurred during a long time span (Bouhadida et al. 2004, 2007; Katayama and Uematsu 2005; Wünsch 2009; Yilmaz et al. 2009; Horvath et al. 2011).

Archaeological evidence of *P. spinosa* fruitstones has been found in many archaeological sites in the western Mediterranean basin, dating between the Neolithic Age and Bronze Age (Woldring 2000; Zohary et al. 2012). However, in archaeological sites dating between the Bronze Age and early Iron Age, a large number of intermediate forms due to interspecific hybridisation among sloe, damson and plum have also been found (Pollmann et al. 2005). During the Roman period, the domestic plum seems to have appeared and then spread into western Europe (Janick 2005).

The earliest evidence of plum cultivation in Italy was found in a cesspit under the Temple of Fortuna in Pompeii, where a fruitstone of plum, dated to 150 BC, was found (Zech-Matterne et al. 2015). Also from Pompeii in the House of the Orchard, some painted representations of cultivated plums with yellow, blue and purple fruit dating back to 79 BC were found (Table 1; Jashemski and Meyer 2002).

Lastly, written sources provide some descriptions of cultivated plums. For example, Theophrastus mentioned the names 'Prumnon' in his *Enquiry into Plants* (*Περὶ Φυτῶν Ἱστορίας*) and Pliny described several varieties of plums with yellow, red, violet, black, white or bright coloured fruits in his *Natural History* (cited in Jashemski and Meyer 2002).

Prunus identification at the species level with traditional archaeobotanical methods is difficult due to the morphological range variation within the different taxa (Woldring 2000; Pollmann et al. 2005; Depypere et al. 2007). According to Horvath et al. (2011), the taxonomic classification of *Prunus* is generally done on the phenotypic characteristics of their flowers and fruits, and it would be better to associate both morphological characteristics and molecular markers, as the phenotypic characteristics are not always reliable due to variation that can occur due to environmental conditions. As argued by Depypere et al. (2007) and Woldring (2000), the fruitstone of *Prunus* would be the most stable of all diagnostic characters used for their identification at the species level. For this reason, in archaeobotanical studies the characteristics of the fruitstone were successfully used for their classification (Pollmann et al. 2005; Zheng et al. 2014).

During the last two decades, a significant increase in the use of image analysis applications has been highlighted in the plant biology research field, and automatized systems have the potential to replace human visual assessments. Due to the application of new image analysis technologies to plant biology, it is possible to use them on archaeobotanical material to distinguish, in an accurate, reproducible and repeatable way, wild taxa from cultivated ones (Terral et al. 2010; Bouby et al. 2013; Orrù et al. 2013; Pagnoux et al. 2015; Sabato et al. 2015; Ucchesu et al. 2015, 2016).

The recent discovery of several intact *Prunus* fruitstones recovered from inside various amphorae in the Phoenician and Punic contexts of the lagoon of Santa Giusta (Oristano, Sardinia), dated in a range between the 6th and the 2nd century BC, brings into question the spread of domesticated plums in Italy.

The present work aims to identify and characterise the *Prunus* remains from the archaeological contexts of Santa Giusta in order to investigate the domestication level of these remains by applying image analysis techniques and to explore the possible relationships among archaeological remains, traditional varieties of plum and wild populations present in Sardinia today.

Table 1 In chronological order from the earliest identifications until the 6th century AD, the major records of *P. spinosa, P. domestica* ssp. *insititia* and *P. domestica* found in archaeological contexts in western Europe and Carthage

Age	Taxon	Country	Site	References
5879–5074 cal BC	*P. domestica* ssp. *insititia* (f)	I	La Marmotta	Rottoli (1993)
5633–4372 cal BC	*P. spinosa* (f)	I	Sammardenchia	Rottoli (1999, 2005)
5400–4500 cal BC	*P. spinosa* (f)	E	La Draga	Antolín et al. (2014), Antolín and Jacomet (2015)
4500–3500 cal BC	*P. spinosa* (f)	F	Le Chenet des Pierres	Martin et al. (2008)
3500–2100 cal BC	*P. spinosa* (f)	I	Monte Covolo	Castiglioni et al. (2008)
3600–2900 cal BC	*P. spinosa* (f)	A	Kleiner Anzingerberg	Kohler-Schneider and Caneppele (2009)
1952–1778 cal BC	*P. spinosa* (f)	I	Nola	Costantini et al. (2007)
1500–1310 cal BC	*P. spinosa* (f)	I	Terramara	Mercuri et al. (2006)
1270–1190 cal BC	*P. spinosa* (f)	I	Duos Nuraghes	Bakels (2002)
1286–1115 cal BC	*P. spinosa* (f)	I	Sa Osa	Sabato et al. (2015)
1443–1116 cal BC	*P. spinosa* (f)	I	Scarceta di Manciano	Bellini et al. (2008)
1091–1031 cal BC	*P. spinosa, P. domestica* ssp. *insititia* (f)	I	Stagno	Giachi et al. (2010)
800–700 BC	*P. spinosa* (f)	I	Monte Trabocchetto	Arobba et al. (2003)
700–500 BC	*P. spinosa* (f)	I	Mokarta	Stika et al. (2008)
600/300 BC	*P. spinosa, P. domestica* (f)	I	Santa Giusta	Present work
150 BC	*P. domestica* (f)	I	Pompeii	Zech-Matterne et al. (2015)
AD 10–15	*P. spinosa, P. domestica* ssp. *insititia, P. domestica* (f)	CH	Vindonissa	Jacomet (2003)
AD 79	*P. domestica* (p)	I	Pompeii	Jashemski and Meyer (2002)
AD 100	*P. domestica* (f)	D	Neuss; Aachen	Knörzer (1967, 1970)
AD 100–200	*P. domestica* (f)	I	Casalecchio di Reno	Marchesini and Marvelli (2007)
AD 100–200	*P. domestica* ssp. *insititia*, *P. spinosa* (f)	F	Gasquinoy	Figueiral et al. (2010)
AD 100–200	*P. domestica* (f)	E	Gabia	Rodriguez-Ariza and Moya (2010)
AD 200–300	*P. domestica* (f)	F	Faulquemont	Preiss et al. (2005)
AD 200–300	*P. domestica* ssp. *insititia*, *P. domestica* (f)	F	Marseille	Bouby et al. (2011)
AD 300	*P. domestica* ssp. *insititia*, *P. domestica, P. spinosa* (f)	CH	Eschenz	Pollmann et al. (2005)
AD 300–400	*P. domestica* ssp. *insititia*, *P. domestica* (f)	B	Tienen	Cooremans (2008)
AD 600	*P. domestica* (f)	TN	Carthage	Van Zeist et al. (2001)

f fruitstones, *p* painted representations

Archaeological context

The Phoenician and Punic settlement of Santa Giusta is located in the north-central part of the Gulf of Oristano (39°51′57″N, 8°35′21″E) in Sardinia, near the former city of Othoca (Fig. 1). It has an almost circular shape, with a maximum area of 900 ha and a depth ranging from 40 to 150 cm. The site is waterlogged and has been excavated since 2005 under the supervision of the Soprintendenza per i Beni Archeologici per le province di Cagliari e Oristano and the University of Cagliari and is still in progress (Del Vais and Sanna 2009, 2012). The underwater excavation allowed for the recovery of several amphorae dating back to the Phoenician and Punic period in the 6th–2nd centuries BC (ESM 1; Del Vais and Sanna 2009). Various materials were found inside several amphorae and sediments, including animal remains such as *Ovis aries, Capra hircus, Bos taurus* (Portas et al. 2015) and macro plant remains, which were preserved in excellent condition due to the anaerobic conditions (Del Vais and Sanna 2009).

Materials and methods

Archaeological samples

A total of 64 waterlogged *Prunus* fruitstones (code PRU_SG) were analysed in this study. Nine *Prunus* fruitstones

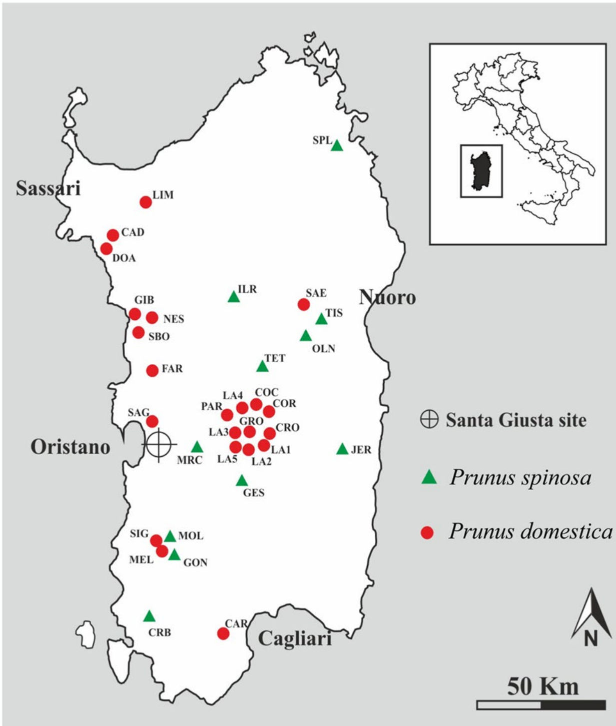

Fig. 1 Location of the Santa Giusta lagoon and distribution of modern *P. spinosa* populations and *P. domestica* varieties in Sardinia used in this study

came from four amphorae and 55 fruitstones from the layers R8, R9, R10. The remains were recovered by using the wash-over technique with a fine mesh (0.25 mm) (Kenward et al. 1980). *Prunus* remains were subsequently kept in distilled water and stored at +5 °C.

Modern samples

Modern samples of *P. spinosa* were collected from 11 different populations in Sardinia (ESM 2, Fig. 1), and fruitstones of *P. domestica*, representing 22 traditional varieties, came from different locations in Sardinia, duplicated in the field catalogue of CNR-ISPA (Nuraxinieddu, Oristano, Sardinia) (ESM 2, Fig. 1). Some of these samples were collected and selected from areas closest to the archaeological site to evaluate the potential relationships between the varieties and archaeological remains. In order to ensure the highest number of accessions, the fruit was sampled in three consecutive years, from 2012 to 2014. In addition, two accessions of *P. domestica* ssp. *insititia* (AN1 and AN2) preserved in the Sardinian Germplasm Bank (BG-SAR) were added to the study and considered as an outgroup.

Digital image analysis

Digital images of the modern and archaeological fruitstones were acquired using an Epson Perfection V550 flatbed scanner with a digital resolution of 400 dpi for a scanning area not exceeding 1024 × 1024 pixels (Bacchetta et al. 2008). Image acquisition of modern fruitstones was done after cleaning away of the pulp. To minimise shape variations, according to Depypere et al. (2007), image acquisition of the archaeological fruitstones was done on slightly dehydrated samples.

The images were processed and analysed using the software package ImageJ v. 1.49 (http://rsb.info.nih.gov/ij). A plugin, Particles 8 (Landini 2006), freely available on the official website http://www.mecourse.com/landinig/software/software.html, was used to measure 26 endocarp morphometric features (Table 2; Fig. 2). In all, 2,845 *Prunus* fruitstones were analysed.

Statistical analysis

The raw data recorded from the studied fruitstones were statistically analysed by applying the stepwise linear discriminant analysis (LDA) method, using IBM SPSS software package v. 16.0 (SPSS Inc. 2006). This method is commonly used to classify or identify unknown groups characterised by quantitative and qualitative variables (Fisher 1936, 1940; Sugiyama 2007). It allows for finding the combination of predictor variables with the aim of minimising the within-class distance and maximising the between-class distance simultaneously, thus achieving maximum class discrimination (Hastie et al. 2001; Holden et al. 2011; Alvin and William 2012; Kuhn and Johnson 2013).

On the basis of three statistical variables, *Tolerance, F-to-enter* and *F-to-remove*, the stepwise procedure selects the best features to use for the discrimination process. The *Tolerance* value indicates the proportion of a variable's variance that is not accounted for by other independent variables in the equation. A variable with extremely low *Tolerance* values provides little information to the model. The *F-to-enter* and *F-to-remove* values define the power of each variable in the model and describe what happens if a variable is either inserted or removed from the current model (Grillo et al. 2012). This method starts with a model that does not include any variables. At each step, the variable with the largest *F-to-enter* value that exceeds the selected entry criteria ($F \geq 3.84$) is added to the model. The variables omitted from the analysis at the last step have *F-to-enter* values smaller than 3.84 and are not added. The process is automatically stopped when no remaining variables are able to increase the discrimination of the method (Lo Bianco et al. 2017). Finally, a cross-validation procedure

Table 2 List of morphometric features measured on the fruitstones

Parameter	Description
Perim	Perimeter, calculated from the centres of the boundary pixels
Area	Area inside the polygon defined by the perimeter
Pixels	Number of pixels forming the endocarp image
MinR	Radius of the inscribed circle centred at the middle of mass
MaxR	Radius of the enclosing circle centred at the middle of mass
Feret	Largest axis length
Breadth	Largest axis perpendicular to the Feret
CHull	Convex hull or convex polygon calculated from pixel centres
CArea	Area of the convex hull polygon
MBCRadius	Radius of the minimal bounding circle
AspRatio	Aspect ratio = feret/breadth
Circ	Circularity = 4 π area/perimeter^2
Roundness	Roundness = 4·area/(π feret^2)
ArEquivD	Area equivalent diameter = $\sqrt{}$((4/π)·area)
PerEquivD	Perimeter equivalent diameter = area/π
EquivEllAr	Equivalent ellipse area = (π feret·breadth)/4
Compactness	Compactness = $\sqrt{}$((4/π)·area)/feret
Solidity	Solidity = area/convex_area
Concavity	Concavity = convex_area-area
Convexity	Convexity = convex_hull/perimeter
Shape	Shape = perimeter^2/area
RFactor	RFactor = convex_hull /(feret π)
ModRatio	Modification ratio = (2·minR)/feret
Sphericity	Sphericity = minR/maxR
ArBBox	Area of the bounding box along the feret diameter = feret·breadth
Rectang	Rectangularity = area/ArBBox

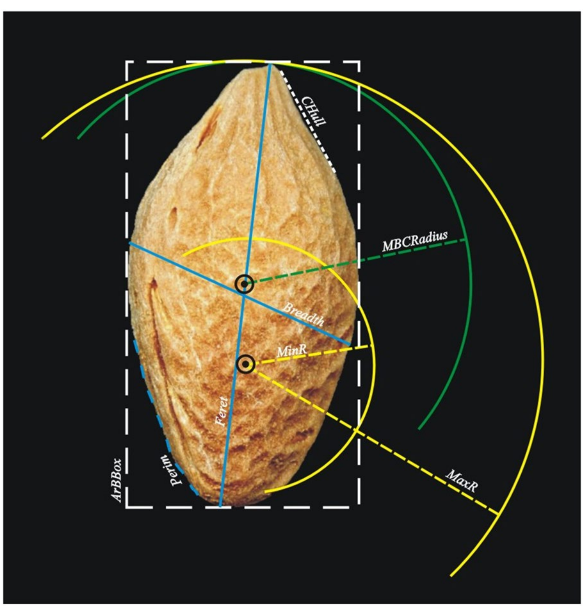

Fig. 2 Graphical representation of principal morphometric features (see Table 3) measured on each endocarp

is applied to verify the performance of the identification system by testing individual unknown cases and classifying them on the basis of all the others. This procedure, also called rotation estimation (Picard and Cook 1984; Kohavi 1995), was applied, both to evaluate the performance and to validate any classifier. The validation procedure used here is the leave-one-out cross-validation (LOOCV) (Grillo et al. 2016). It involves using a single case from the original sample set as the validation dataset and the remaining cases as the training set. Each case is classified into a group according to the classification functions computed from all the data, except the case being classified. The proportion of misclassified cases after removing the effect of each case one at a time is the leave-one-out estimate of misclassification (SPSS 2006).

All the raw data were standardized before starting any statistical calculation. Moreover, in order to evaluate the quality of the discriminant functions achieved for each statistical comparison, the Wilks' Lambda, the Eigenvalues, the percentage of explained variance, the Chi square and the Standardized Canonical Discriminant Function Coefficients (SCDFCs) were computed.

Results

To test the variability existing in *P. domestica*, a comparison among the fruitstones of the 22 modern varieties collected in Sardinia was carried out and an overall percentage of correct identification of 86.1% was reached (ESM 3).

A preliminary morphometric comparison was made among the fruitstones belonging to the three taxonomic entities (*P. spinosa, P. domestica* and *P. domestica* ssp. *insititia*) and the 64 waterlogged archaeological fruitstones from Santa Giusta (PRU_SG) were added to the classifier as an unknown group (Table 3).

An overall correct identification percentage of 94% was achieved. The fruitstones of *P. spinosa* were perfectly identified, while there were a few misidentifications among *P. domestica* and *P. domestica* ssp. *insititia*. Of the archaeological unknown fruitstones from Santa Giusta, 83% (53 fruitstones) were identified as *P. spinosa* and 17% (11 fruitstones) as *P. domestica* (Table 3). Table 4 shows the number of *Prunus* fruitstones identified from the amphorae and the layers R8, R9, R10.

No morphometric difference was observed between *Prunus* remains of differing ages (data not shown).

Table 3 Identification percentages of the archaeological fruitstones of *Prunus* (PRU_SG) from the Santa Giusta context considered as unknown specimens

	P. domestica	*P. spinosa*	*P. domestica* ssp. *insititia*	Total
P. domestica	99.9 (1,661)	0.1 (2)	–	100.0 (1,663)
P. spinosa	–	100.0 (984)	–	100.0 (984)
P. domestica subsp. *insititia*	18.0 (24)	–	82.0 (110)	100.0 (134)
PRU_SG	17.0 (11)	83.0 (53)	–	100.0 (64)
Overall				94.0% (2,845)

The numbers of fruitstones analysed are in brackets

Considering these achievements, the 11 archaeological fruitstones identified as being from *P. domestica*, one more time considered as unknown specimens, were compared with the modern varieties of plum. In this case, the archaeological samples from Santa Giusta showed most similarities with the varieties Sanguigna di Bosa (SBO) in 81.8% of cases and Di Bonarcado (FAR) in 9.1% of cases (Fig. 3). Likewise, the 53 archaeological fruitstones from Santa Giusta, identified as *P. spinosa*, were considered unknown and compared with the modern wild populations of *P. spinosa* from Sardinia. These archaeological fruitstones were very similar to those collected at Monte Arci (MRC) in 90.6% of cases (Table 5; Fig. 3).

In the evaluation of the features, the most discriminant five variables, of the 25 selected and used by the stepwise LDA, are reported. The first variable is the area of the endocarp, with a high value of *F-to-remove* (ESM 4).

Discussion

The domestication process of fruit trees remains unclear, perhaps because fruits have received much less attention than annual crop plants (Goldschmidt 2013). The identification of the place of origin of cultivated species of *Prunus* is difficult due to their long history of cultivation, to which human dispersion to different places is added (Pollmann et al. 2005). Therefore, *Prunus* species may have become naturalised, creating difficulties for the distinction between ancestrally wild populations and those which escaped from cultivation (Kole and Abbott 2012). As suggested by Pollmann et al. (2005), attribution of *Prunus* remains to a specific species is limited due to the imprecise classification of these groups.

From the results obtained through LDA, it was possible to identify correctly the unknown *Prunus* remains of the Santa Giusta context as cultivated varieties and wild species. From the 64 archaeological remains, 53 of these were classified as *P. spinosa*, while the other 11 were classified as *P. domestica*. In particular, none of these

Table 4 *Prunus* fruitstones identified and other biological remains found inside the amphorae and from layers R8, R9, R10

Context	Amphora, type	Date (cent. BC)	*P. spinosa*	*P. domestica*	Other biological remains
Area A, R8	SGT 156, T-1.2.1.2	6th	2	1	*Pinus pinea, Vitis vinifera*, animal remains
Area A, R9	SGT 97, T-1.4.4.1	5th	–	1	*P. pinea, Olea europaea, Corylus avellana*, animal remains
Area A, R8	SGT 503, T-5.2.1.3	3rd–2nd	–	4	*Prunus dulcis, C. avellana, V. vinifera*, animal remains
Area A, R9	A 119, T-5.2.2.1	3rd–2nd	1	–	*V. vinifera*, animals remains
Area A, R8	–	6th–2nd	24	3	*O. europaea, P. pinea, Quercus* sp., *Citrullus lanatus, Juglans regia, Juniperus oxycedrus, Lagenaria* sp
Area A, R9	–	–	19	2	
Area A, R10			7	–	
Total			53	11	

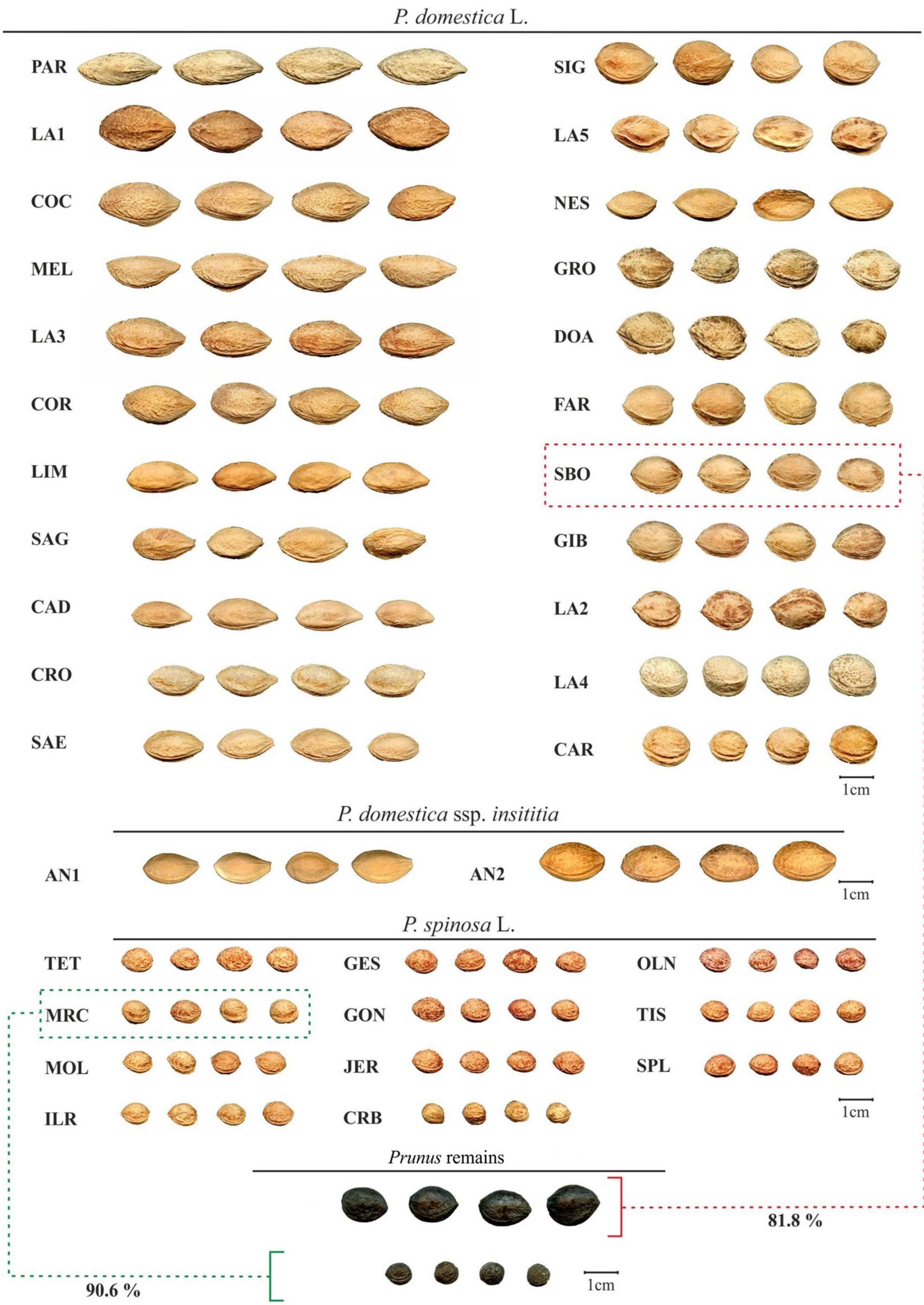

Fig. 3 Representation of the samples analysed. Below are the types of *Prunus* fruitstones identified from the Santa Giusta contexts and their relationship with the modern accession material

Table 5 Correct classification percentages in modern populations and archaeological samples of *P. spinosa*

	CRB	GON	MOL	MRC	TIS	ILR	TET	GES	JER	SPL	OLN	Total
CRB	50.9 (28)	–	1.8 (1)	30.9 (17)	1.8 (1)	10.9 (6)	–	3.6 (2)	–	–	–	100.0 (55)
GON	–	–	3.3 (2)	29.5 (18)	1.6 (1)	–	-	26.2 (16)	21.3 (13)	3.3 (2)	14.8 (9)	100.0 (61)
MOL	5.0 (5)	–	44.0 (44)	13.0 (13)	4.0 (4)	25.0 (25)	1.0 (1)	1.0 (1)	5.0 (5)	1.0 (1)	1.0 (1)	100.0 (100)
MRC	7.0 (14)	1.0 (1)	1.5 (3)	66.0 (133)	1.5 (3)	2.0 (4)	–	4.0 (8)	12.0 (24)	–	5.0 (10)	100.0 (200)
TIS	4.3 (3)	–	7.1 (5)	42.9 (30)	2.9 (2)	–	–	12.9 (9)	25.7 (18)	1.4 (1)	2.9 (2)	100.0 (70)
ILR	6.0 (6)	–	36.0 (36)	17.0 (17)	1.0 (1)	30.0 (30)	1.0 (1)	1.0 (1)	7.0 (7)	1.0 (1)	–	100.0 (100)
TET	–	–	17.4 (8)	28.3 (13)	2.2 (1)	2.2 (1)	4.3 (2)	6.5 (3)	32.6 (15)	–	6.5 (3)	100.0 (46)
GES	2.0 (2)	–	1.0 (1)	17.0 (17)	3.0 (3)	1.0 (1)	1.0 (1)	24.0 (24)	21.0 (21)	14.0 (14)	16.0 (16)	100.0 (100)
JER	1.0 (1)	–	6.0 (6)	39.0 (39)	–	3.0 (3)	2.0 (2)	14.0 (14)	30.0 (30)	–	5.0 (5)	100.0 (100)
SPL	–	1.9 (1)	–	5.8 (3)	–	–	1.9 (1)	26.9 (14)	5.8 (3)	42.3 (22)	15.4 (8)	100.0 (52)
OLN	1.0 (1)	–	3.0 (3)	32.0 (32)	1.0 (1)	1.0 (1)	–	14.0 (14)	12.0 (12)	11.0 (11)	25.0 (25)	100.0 (100)
P. spinosa remains	–	–	–	90.6 (48)	3.8 (2)	–	–	–	3.8 (2)	1.9 (1)	–	100.0 (53)
Overall												38.1% (1,037)

fruitstones were attributed to *P. domestica* ssp. *insititia*, the wild form at the origin of the domestic plum. Based on these achievements, it can be assumed that the earliest plum cultivation may have occurred in Sardinia at least since the 6th century BC, during the Archaic Period. However, the place of origin of these cultivated fruit trees is still unknown. There are more finds of domesticated fruitstones of plum in waterlogged contexts of the Roman period, suggesting that the Romans contributed to the spread of several varieties of plums into western Europe (Pollmann et al. 2005; Zohary et al. 2012). A further result of this study is that the archaeological remains from Santa Giusta which were identified as *P. domestica*, are similar to a traditional variety that is cultivated in the territory of Bosa, in northwestern Sardinia.

The close relationship shown by the comparative analysis between the archaeological and modern samples of *P. spinosa* allow us to hypothesise that the wild fruit found in the Santa Giusta amphorae might have been gathered on the slopes of Monte Arci which is located just 10 km from the Santa Giusta archaeological site. This massif is a volcanic complex rich in obsidian materials which were exploited for millennia by the Neolithic community. In addition, it is probable that during the Phoenician and Punic period this was an important area for the exploitation of natural resources, as shown by the gathered wild fruit found in the amphorae of Santa Giusta.

Possible hypotheses about the use of this wild fruit can be made using ethnobotanical research. The uses of sloes are varied; ethnobotanical literature indicates their use principally for food and medicine (Parada et al. 2009; Ţiţă et al. 2009; Łuczaj 2012; Pardo-de-Santayana et al. 2013; Pieroni and Quave 2014). In Sardinia, the consumption of sloes as food and as medicine is well documented, as a liquid extract of flowers or fruit for the treatment of coughs, in addition to their traditional use for dyeing wool (Atzei 2003; Campanini 2009).

Other uses may be related to religious rituals: in some Punic tombs, charcoal remains of sloe could represent firewood for human body cremation or ritual offerings (Gómez Bellard et al. 1990). In addition, in Roman cemeteries, the use of fresh fruit of sloe, damson and plum as ritual offerings is well known (Preiss et al. 2005; Cooremans 2008; Bouby et al. 2011; Rottoli and Castiglioni 2011).

In the case of Santa Giusta, the presence of *P. spinosa* and *P. domestica* together with animal remains could represent their use as food or could be linked to food preservation methods. This practice is well known for Phoenician and Punic Sardinia (Del Vais and Sanna 2012).

Conclusions

The discovery of well-preserved waterlogged fruitstones of *P. domestica* in the Phoenician and Punic contexts of Santa Giusta could be evidence that the introduction of primitive cultivated forms of plums in Sardinia was started by the Phoenician people in the Archaic period. Therefore, these fruitstones represent the first cultivated plum finds in Sardinia and the oldest evidence of cultivated plums in Italy. We hope for future investigations to better understand the history of the beginning of domestication of fruit trees in the Mediterranean basin.

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