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Cultivated and wild plant exploitation during the Phoenician and Punic period in Sardinia: the contribution of the waterlogged finds

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Summary

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Abstract

The project focuses on the study of the exploitation of the vegetal species in Sardinia during the Archaic and Punic period, analysing vegetal macroremains recovered on archaeological sites dated from the 7th to the 3rd century BC. It centres in particular on seeds and fruits which proceed from coastal and underwater sites, where the special environment enabled an optimal preservation of those organic materials. The sites selected for the study were the Mistras Lagoon, in Central-West Sardinia, identified as the harbour of Tharros during the 7th-3rd century BC; the Santa Giusta Lagoon, also in central-west Sardinia, interested by the presence of an underwater site of uncertain interpretation, connected with the neighbouring city of Othoca, and the coast of Nora-Pula in South Sardinia.

The vegetal macroremains found during different archaeological excavations on the Mistras Lagoon, thanks to the systematic sampling of the stratigraphic units, were subject to archaeobotanical analysis. They were selected and studied at the stereomicroscope, identifying the *taxa* thanks to modern reference collections and botanical atlases. The study put in evidence the great presence of many cultivated species, starting from cereals and pulses, continuing with extremely high percentages of grapevine and fig, and a variety of other plants as olive, plum, pomegranate, melon, different types of nuts, and the unprecedented finding of aromatic plants as the coriander and the dill. The spontaneous vegetation recorded depicts from one side the presence of species typical of wetlands, as well as other characteristics of the Mediterranean *maquis*; more importantly the abundance of ruderal plants is attested, indicating an environment highly influenced by human activities, and in particular by the presence of pastures and cultivations. All the data seem to point to a pretty intensive development of the agriculture in the area during that period, characterised by a diversification of the cultures.

From the Santa Giusta Lagoon was analysed the content of a transport amphora, dating to the Archaic period. Abundant grape pips were found from the sieving of the sediment, in association with animal bones, presumably of ovicaprid. This type of content is well known from past findings from the same lagoon and from other underwater sites of the Island; the most accepted hypothesis interprets them as the evidence of some sort of preservation of the meat in a by-product of the grapevine. The great novelty of the new finding analysed in the present study is that abundant remains of coriander were also

found in the content; the spice, attested here and in Mistras for the first time in a Sardinian context, could have been used as an ingredient for the peculiar meat product.

The archaeobotanical analysis were integrated by the morphometric study of the endocarps of *Olea europaea* L. and of the pips of *Vitis vinifera* L. The digital images obtained from the scanning of the olive endocarps found in Mistras and Santa Giusta were compared to the images of modern endocarp samples, pertaining to the wild and the cultivated subspecies. The morphometric and statistical analysis revealed the presence of wild morphotypes in the Santa Giusta Lagoon, and of a mixture of wild and domesticated ones in Mistras. In addition, the endocarps from Mistras attributable to the domesticated subspecies, found a great affinity with some of the most typical cultivar actually grown in the Island.

Analogously, the grape pips selected in Mistras, in Santa Giusta, and in Nora, were compared thanks to morphometric analysis to modern samples of wild and domesticated grapevine. Each one of the archaeological groups revealed a predominant presence of domesticated morphotypes. Moreover, the existence of different varieties in the assemblages was proved, corroborating the hypothesis on the high degree of development reached by the viticulture in the period under study.

Introduction

State of knowledge on the rural exploitation of Archaic and Punic Sardinia (8th-7th to 3rd century BC).

The data on the relationship between man and the vegetal system during the Archaic and Punic period in Sardinia are at the moment few and quite fragmentary. They do not enable a paleoenvironmental reconstruction on a large scale, or an exhaustive knowledge on the vegetal species cultivated and exploited by man. However, valuable information can be recollected from several archaeological researches held during the past decades, which focus in different ways on the rural exploitation.

The archaeobotanical field of research is the one which gives the most direct information on vegetal species exploited or influenced by man behaviour. This approach concerns the study of vegetal microremains as pollen and phytoliths, the analysis of wood and charcoal, included in the subdisciplines of xylology and anthracology, and the carpology, which takes into considerations all other type of vegetal macroremains, such as seeds, fruits and leaves (for an overview on archaeobotanical procedures see Pearsall 2015).

The first report on vegetal remains found in a Sardinian Punic site comes from the Santa Gilla lagoon, near Cagliari. At the end of the 19th century two excavation campaigns were held inside the lagoon, in the locality called Su Mogoru (Vivanet 1892; 1893; Levi 1937). The excavations revealed the presence of an area in which were dispersed different types of materials, comprising manufactured wood, interpreted as the remains of a palisade, Punic transport amphorae, bones of ovine and bovids in part contained into the amphorae, in part scattered in the area, clay figures of presumed deities, humans, animals, and anatomic parts as hands and feet, interpreted as *ex voto* (Vivanet 1892; 1893; Moscati et al. 1991). The wood of the presumed palisade was analysed by Patrizio Gennari, Professor of the University of Cagliari and director of the Botanic Garden of the University, and recognised as *Ulmus glutinosa* (Vivanet 1893). Another archaeobotanical data was given by the amphorae content; some of the ones which contained animal bones were full of nuts, recognised as *Corilus avellana*, as well as pinecones identified as *Pinus laricia* and *Pinus silvestris*, according to the 19th c. classification and terminology; the pinecones were sometimes used as stoppers (Vivanet 1892; 1893). The same area of the lagoon was investigated also during more recent years, when more wood elements, clay figures and transport amphorae were found (Zucca 1993; Solinas & Orrù 2005).

Another site of great interest is the maritime context investigated in front of the ancient Nora, in the municipality of Pula in southern Sardinia, between the Seventies and Eighties of the 20th century by a French mission authorised by the Cagliari Archaeological Superintendence (the reports of the investigations have recently been collected and published in Bonetto 2014). During the different excavation campaigns were recovered hundreds of transport amphorae and other materials of different age, although predominantly Punic (Bertelli 2014). The numerous archaic and Punic transport amphorae found contained in many cases animal remains attributed to ovicaprids and bovids (Poplin 2014). Moreover, inside of some of the containers, the animal remains were in association with grape pips, pertinent to *Vitis vinifera* ssp. *vinifera* (Marinval & Cassien 2001); the peculiar finding inspired the hypothesis of an original content constituted by salted meat, confectioned with the concurrence of a by-product of the grapevine, with a procedure similar to that described in the much later byzantine agronomical text *Geoponica* (XIX, 9) (Poplin 1980; Marinval & Cassien 2001).

Sporadic findings of vegetal macroremains proceed from a variegated selection of contexts. In the necropolis of Monte Sirai, inside a feminine incineration tomb dated around the 580 BC, was found a ceramic pastry board; the print of some grape pips was observed in the surface of this domestic object, presumably produced involuntarily during its fabrication (Bartoloni 1988). The presence of grape pips, attributed to ssp. *sylvestris*, was also recorded in the Punic phase of the nuraghe Ortu Comidu in Sardara (Bakels 2002). In the underwater context of the port of Olbia were found Late-Punic transport amphorae, some of which contained nuts and pinecones (Pallarés 1987).

More recent excavations were held on two Punic sites in the hinterland of Terralba, as a part of an ample project of landscape archaeology focused on the rural exploitation of the territory (van Dommelen et al. 2010; 2012; van Dommelen & Gómez 2012). The sites excavated, Pauli Stincus and Truncu ’e Molas, revealed the presence of two rural farms. In particular, the site of Truncu ’e Molas provided interesting data from an archaeobotanical point of view. In fact the site, occupied from the 5th to the 2nd century BC, has been interpreted as a settlement specialised in the cultivation of the grapevine and the production of wine on a large scale, thanks to the documentation of a pressing structure in which interior were still present some grape pips; moreover, two pruning knifes, apt for working on the grapevine, were found (Pérez-Jordà et al. 2010; van Dommelen et al. 2010; 2012; van Dommelen & Gómez 2012). Apart from the findings related to the viticulture and vinification, the analysis revealed the presence of macroremains of ruderal plants as *Beta vulgaris*, *Lolium* sp., *Galium* sp. and *Gypsophila* sp., while no cereals were attested, supporting the hypothesis of the specialisation of the site in practices more related to other agricultural activities (Pérez-Jordà et al. 2010; van Dommelen et al. 2010; 2012; van Dommelen & Gómez 2012). Between the species that were identified thanks to anthracological analysis, several trees and shrubs are attested, in great part attributed to *Erica* sp., *Pistacia lentiscus*, *Olea europaea*, and in minor proportions to *Salix* sp., *Arbutus unedo*, *Pistacia terebinthus*, *Pinus halepensis* and *Cistus* sp.; it is assumed that these species do not necessarily represent the vegetation of the immediate surroundings of the site, as the wood, transported to the settlement to be used for several purposes, could have also been collected from a certain distance (Pérez-Jordà et al. 2010; van Dommelen et al. 2012). Additional data on the intense agricultural exploitation of the hinterland of Terralba during the Middle-Punic and Late-Punic period come from the excavation of Pauli Stincus, and from territorial geomorphological and pedological analysis, that revealed the presence of plowed lands in different areas (van Dommelen & Gómez 2012).

Going to the central part of the gulf of Oristano, important data come from the waterlogged site of the Santa Giusta lagoon, which presents important analogies with the discoveries of the Santa Gilla lagoon already cited. Inside the Santa Giusta lagoon, large areas are characterised by the presence of scattered archaeological remains, the most evident being transport amphorae and manufactured wood; two main phases of formation of the site were recognised, one dating to the 6th-beginning 5th century BC and the other to the 3rd-2nd century BC (Del Vais & Sanna 2009; 2012). In addition to the cited wood elements, that at least in part could be attributed to boats, the anoxic conditions, created by the waterlogging and by the fact that the materials are englobed in a thick layer of mud, enabled the preservation of other organic remains such as seeds and fruits (Del Vais & Sanna 2009; 2012). A great amount of these vegetal macroremains were found inside the transport amphorae, but also in the sediment outside them, perhaps as a consequence of the fact that the vessels were not sealed or had lost the lids, and in many cases presented fractures (Del Vais & Sanna 2009; 2012; Sabato et al. 2019). *Vitis vinifera* seeds were recovered in all the samples that were analysed, and were frequently associated inside the amphorae with bones of ovicaprids and bovids (Del Vais & Sanna 2009; 2012), as in the case of Nora (Marinval & Cassien 2001). The detail of the carpological analysis already published, and of the results proceeding from new findings, will be discussed in detail in the chapters of the present work, but we can for now point out the presence of pinecones, of several types of nuts, and of cultivated and wild fruits (Del Vais & Sanna 2009; 2012; Sabato et al. 2019).

Variegated data proceed from the excavations of Tharros, in the northern part of the gulf of Oristano, and from the surveys in its hinterland. During the excavations held in the Eighties and Nineties in the *tofet* of the city, a typical Punic sanctuary in which were deposed urns containing incinerated remains of infants, several types of archaeobotanical analysis were held; they comprised palynological, phytoliths, and anthracological analysis; the study was also integrated by the observation of the contemporary vegetation and characteristics of the hinterland, enabling a first assessment on the potentiality of the territory, in order to make more founded hypothesis on the possible evolution of the landscape in time (Nisbet 1980; Fedele 1979; 1980; 1983; Palmieri & Lentini 1994; Acquaro et al. 2001; Lentini 1993; 1995; 2014). The phytoliths and the charcoal found on the cinerary urns revealed the use in the funerary pyres of herbaceous species, presumably proceeding from the immediate surroundings of the city, of shrubs typical of the Mediterranean maquis, also at disposition in the area, as *O. europaea* and *P. lentiscus*, as well as the presence of *Quercus* sp. (Nisbet 1980). The palynological analysis, held not only in the area of the *tofet* but also in different locations on the hinterland, enabled a reconstruction of the vegetal environment of the area and of its evolution; the changes, attributed mainly to human factors, would have started already from the Iron Age, in the 9^{th} century BC, increasing significantly from the 5^{th} century BC, when the data point to a relevant loss of arboreal species and an increment of herbaceous ones (Acquaro et al. 2001; Lentini 2014). Indicators such as the substitution of *Quercus ilex* with *Quercus coccifera* were moreover interpreted as a sign of deforestation, possibly produced to open new areas to cultivation (Palmieri & Lentini 1994; Lentini 1993; 1995; 2014). However, the Punic era do not show tendencies to extensive monocultures; on the contrary a wide variety of cultivated, or at least cultivable species, was registered, as *V. vinifera*, *O. europaea*, *Prunus* sp. and so on (Acquaro et al. 2001). On the other side, it is true that after the end of the 4^{th} century BC the situation continues to change progressively, until an absolute predominance of cereals during the following Roman era (Acquaro et al. 2001; Palmieri & Lentini 1994; Lentini 1993; 1995; 2014). More recent palynological analysis were executed on coring samples extracted in the area of Mistras, the lagoon adjacent to Tharros, recognised as its harbour during the Archaic and Punic period (Pascucci et al. 2018; Del Vais et al. 2020); they also suggest an incrementation of the fires and of anthropic activities during the Punic period (Di Rita & Melis 2013). The harbour context of the Mistras lagoon has been investigated with multiannual archaeological and geomorphological surveys and excavations (Pascucci et al. 2018; Del Vais et al. 2008; 2010; 2020), and the extremely relevant archaeobotanical results of these campaigns will be discussed in the following chapters.

Recent acquisitions come from the study of the 1st millennium occupation phases of the site of S'Urachi, once again in Central-West Sardinia (van Dommelen et al. 2018; Pérez-Jordà et al. 2020). The carpological analysis is revealing the presence of a broad range of cultivated plants; between them the cereals are represented by *Triticum aestivum/durum*, *Hordeum vulgare* ssp. *vulgare* and in fewer quantities by *Panicum miliaceum*, and the legumes by *Vicia faba*, *Lens culinaris* and *Pisum* cf. *sativum*; *Vitis vinifera* seems the most attested among the fruit species, in association with *Ficus carica* and *Olea europaea*; also attested is the presence of *Punica granatum* since the Iron Age, of *Cucumis melo*, and of *Linum usitatissimum* (van Dommelen et al. 2018; Pérez-Jordà et al. 2020). Between the wild species were recorded remains of *Pistacia lentiscus* and *Prunus spinosa*, as well as herbaceous species pertaining to the Cyperaceae and Polygonaceae families, and invasive plants as *Lolium temulentum* (van Dommelen et al. 2018; Pérez-Jordà et al. 2020).

The analysis of the residual content of transport amphorae is equally important in the reconstruction of the uses of plants. Chemical analysis held on a transport amphora of Sant'Imbenia type, found on the Iron Age II phase of the settlement of Cungiau 'e Funtà, therefore pertinent to the final Nuragic phase dated to the second half of the 8th century BC, revealed the presence of white wine (Del Vais et al. 2016/2017). A Punic amphora from Nora, produced locally and pertinent to the Ramon T-4.1.1.4., dated between the end of the 5th and the first part of the 4th century BC (Ramon Torres 1995), contained olive oil (Bordignon et al. 2005). Other vessels can also reveal useful information, as in the case of a Punic funeral vase dated to the 5th century BC, found in the necropolis of Monte Sirai, that contained the residue of a product derived from *Citrus* sp. (Frère et al. 2012).

Finally, in the reconstruction of the rural aspects of Punic Sardinia, some other researches focusing on landscape archaeology should be mentioned. The interest of scholars on these aspects started since the Sixties, with the important action of Ferruccio Barreca (Barreca 1988), followed in more recent years by the work of several research groups operating in different areas of the Island. Extensive researches on rural sites and on the organisation of the landscape were and are being held in the hinterland of Tharros (Tore & Stiglitz

1987; Tore 1991; Stiglitz 2011; Del Vais 2014), in the already cited territory of Terralba (Zucca 1991; Artudi & Perra 1994; 1997; Annis 1998; Roppa 2008; van Dommelen et al. 2006; 2010; 2012; van Dommelen & Gómez 2012), in the Sulcis on the South-West portion of the Island (Finocchi 2007), in the area of Nora (Botto & Rendeli 1998 ; Botto et al. 2003; Finocchi 2000; 2002; Botto 2011) and in the Cagliari hinterland (Tronchetti 2004; Roppa 2013), revealing an intensive rural penetration, linked to agrarian activities, and characterised by a high density of small rural settlements, especially from the 5th century BC (van Dommelen & Gomez Bellard 2008; van Dommelen & Finocchi 2008; Roppa & van Dommelen 2012; Del Vais 2014; Roppa 2014).

The rural exploitation has been frequently put in relation with the influence of the North-African city of Carthage, that exercised a hegemonic role on the Punic areas of central Mediterranean (Barreca 1988; Manfredi 1993; Moscati et al. 1997; Bernardini 2009; Bechtold 2013b; Del Vais 2014; Secci 2016). Besides, Punic transport amphorae of Sardinian production are frequently found in Carthaginian contexts (Bechtold 2013a), but this does not exclude that the great part of the rural production was destined to the local consumption of the same Sardinian territories.

The archaeobotanical data presented in the following chapters will provide new information, that will add more elements to the reconstruction of cultivated or exploitable plants present in Sardinia during the Archaic and Punic period, as well as on wild vegetation and on the evolution of the landscape. The main focus of the study is on some of the most remarkable sites already cited, the Santa Giusta and the Mistras lagoons, both waterlogged sites in which the state of preservation of the organic elements is optimal.

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Chapter 1

Plant exploitation and environmental indicators during the Archaic and Punic period in Sardinia (Italy): new data from the harbour of Tharros (Mistras Lagoon, Cabras)

Introduction

The interest about the agrarian aspects in the regions of the central and western Mediterranean Basin interested by the presence of the Phoenicians and Punics during the 1st millennium BC started several decades ago (Isserlin 1983; Barreca 1988; Lancel 1992; Moscati et al. 1997; Krings 2000; Morel 2000). In the last decades, a renewed effort on territorial investigations put into light different aspects of the exploitation of the territory in various regions, as in the Iberian Peninsula (Carretero Pobrete 2007; López Castro 2007 2008), in the island of Ibiza (Gómez Bellard 2008), in North Africa (Fentress & Docter 2008), Sicily and Malta (Spanò Giammellaro et al. 2008; Docter et al. 2012). Researchers working in Sardinia were between the first scholars to produce investigations on the subject, focusing on the ruralisation process that involved the hinterland of the major coastal settlements, and that seemed to reveal an intense agricultural exploitation of the territory (Barreca 1988). In Sardinia, the efforts to get light on the rural penetration and the agricultural production have been and are particularly evident, as proved by several research programs involving nearly all the areas interested by the Phoenician and Punic presence, as well as various synthesis on the subject (Finocchi 2007; Botto 2011; Roppa & van Dommelen 2012; van Dommelen et al. 2012; Roppa 2013; 2014; Del Vais 2014; Secci 2016).

The increasing use of the archaeobotanical approach is of great help in giving a more complete vision of the exploitation of plants during this period, and of the impact of human communities on the environment. Particularly interesting are in this sense the carpological studies, involving the analysis of plant macroremains such as seeds and fruits. Nowadays, even if the number of archaeological contexts in Sardinia investigated under this point of view is still not enormous, we have at disposition some valuable information, starting from the findings of the underwater contexts of Nora, in the South-West (Marinval & Cassien 2001), of Olbia in the North-East (Pallarès 1987) and of the Punic phases of the Nuraghe Orto Comidu of Sardara in South Sardinia (Bakels 2002). More systematic investigations are being held in several sites on the central-western part of the Island, as in S'Urachi-San Vero Milis (van Dommelen et al. 2018; Pérez-Jordà et al. 2020), in the Santa Giusta Lagoon (Del Vais & Sanna 2009; 2012; Ucchesu et al. 2017; Sabato et al. 2019b), and in Truncu 'e Molas-Terralba (Pérez-Jordà et al. 2010; van Dommelen et al. 2010; 2012).

The present work focuses on the analysis of the plant macroremains found in the Mistras Lagoon, in the northern part of the gulf of Oristano in Central-West Sardinia (Fig. 1). The lagoon has been recognised as the harbour of the city of Tharros during the Archaic and Punic period, from the 7th to the 3rd century BC (Del Vais et al. 2020). The study gives new and in-depth information about the presence of domesticated plants, some of which first recorded on this site for what concerns Sardinia, and about human impact on the vegetation of the region.

Fig. 1 – The Mistras Lagoon (in the red rectangle), Central-West Sardinia.

The archaeological context

The Mistras Lagoon has been systematically investigated with an interdisciplinary approach since 2003 by the University of Cagliari, in collaboration with the Archaeological Superintendence of Cagliari, the University of Sassari and the Consiglio Nazionale delle Richerche – CNR; the main purpose of the research was to verify the possible use of the area as a harbour during the past, hypothesis confirmed by the archaeological and geomorphological investigations (Pascucci 2018; Del Vais et al. 2008; 2010; 2020).

The plant macroremains here presented were recovered during the stratigraphic excavations held in 2014 and 2015 in the central area of the lagoon (Fig. 2), characterised by the presence of a sandy barrier, formerly a palaeobeach (Pascucci et al. 2018).

Fig. 2 – On the left, the position of the two stratigraphic excavations on the sandy barrier inside the Mistras lagoon. On the right, the 2014 excavation.

The excavations, situated at approximately 500 m of distance one from the other, put into light a natural stratigraphy revealing the gradual formation of the palaeobeach (Pascucci et al. 2018; Del Vais et al. 2020). The stratigraphy, characterised by an alternation of sand and *Posidonia oceanica* (L.) Delile, was rich in archaeological materials such as ceramics, zooarchaeological remains, wood and other plant macroremains (Del Vais et al. 2020; Mureddu et al. 2020). As understandable for a harbour site (Sadori et al. 2015), the findings may represent materials accumulated on the palaeoshore as a consequence of human activities such as transhipment operations, but also of natural transport of materials and sedimentation processes. The study of the findings, which is at a preliminary stage, accompanied by a series of radiocarbon dating, revealed the presence of materials datable from the 7th to the 3rd century BC for the 2014 excavation, and from the 5th to the 3rd century BC for the 2015 campaign (Pascucci et al. 2018; Del Vais et al. 2020). The waterlogged conditions enabled the preservation of the organic materials in the lower layers of the stratigraphy corresponding to the shoreface deposits (Pascucci et al. 2018), where the prevailing presence of *P. oceanica* contributed to the creation of stable and anoxic conditions.

Materials and methods

During the excavations, the systematic sampling of the different stratigraphic units was put in place. Taking into regard the exceptionality of the context, and the possibility to recover completely new information, the choice was to produce several samples for stratigraphic unit, going from 2 l up to 20 l of volume, for a total of 117 samples. The presence of carpological remains was so patent that a lot of specimens were also recovered during the excavations. The sediment samples were sieved by wash-over in the laboratories of the BG-SAR-HBK (Sardinian Germplasm Bank – Hortus Botanicus Karalitanus, University of Cagliari) (Porceddu et al. 2017), using different mesh sizes from 1 mm until the mesh fraction of 0,25 mm. The sediment resulting from the sieving was carefully examined at the stereomicroscope for the recovery of plant macroremains and other small materials. At the present moment all the samples have been sieved, and a significant part of them have been screened for the recovery of the materials.

The recovered plant macroremains were stored in deionised water at 5°C in the facilities of the BG-SAR. They were identified thanks to the modern reference collection of the BG-SAR and of the Laboratory of Archaeology of the University Paul Valéry-Montpellier 3; furthermore, specific botanical atlases for the identification of seeds and fruits were used (Bercht 1941; Beijerinck 1976; Berggren 1969; 1981; Anderberg 1994; Jacomet 2006; Knapp 2006; Knorzer 2007; Cappers et al. 2009; 2012; Cappers & Neef 2012; Neef et al. 2012; Cappers & Bekker 2013). The characteristics of the identified *taxa*, and the likability of their presence in the region during the period under consideration, were verified thanks to modern plant references and checklists (Mabberley 2017; Bartolucci et al. 2018; Pignatti 2017-2019) and taking into consideration the actual characteristics of the flora of the microregion in which the site is placed (Fenu & Bacchetta 2008).

As the complete study of the site and the other findings is still under process, a precise evaluation of the formation processes and chronology of the different stratigraphic units is possible only in general terms at the moment; therefore, also a comparison between layers from the archaeobotanical point of view seems still premature. For this reason, we will present in detail in this work only the results of some of the most relevant stratigraphic units (named US – Unità Stratigrafica, according to the acronym used in the documentation of excavations), providing a general overview of the carpological results. These US are the lower ones, pertaining to shoreface deposits, the US28, US32 and US34 of the 2014 excavation, and the US24, US25 and US26 of the 2015 excavation (Table 1). The two campaigns are from now on indicated as MIS14 and MIS15.

A precise counting of the litres processed in the case of the MIS14 stratigraphic units is not possible, as the data add macroremains directly recovered during the excavation, in order to achieve a complete representation of all the individuated *taxa*. On the contrary, more precise indications about the MIS15 sampled and monitored volumes is available; in this case we considered only samples of 20 l, completely sieved and checked in search of the macroremains. The use of large volumes was useful in the sense that it enabled the recovery not only of important quantities of domesticated and economically valuable plant remains, but most of all because a large amount of wild herbaceous *taxa* would have probably gone unobserved with lower quantities of sediments; they are in fact always present in very small numbers, but representing a wide variety of genus and species.

The macroremains were counted considering for most species an entire element as a unit, while all the fragmented specimens were considered as fragments, with the exception of *Ficus carica* L. and *Vitis vinifera* L. *F. carica* is in fact represented on the site by achenes remains in such large quantities that a precise counting would have been impossible: for this reason, only a small portion of the achenes, occupying a predetermined volume, was actually counted, and the whole quantities were estimated according to the number of analogous volumes occupied. The number of seeds in the case of *V. vinifera* was counted taking into account the seed remains, entire or fragmented, in which the stalk was preserved in its entirety, while all the specimens without stalk or with a fragmentary one were considered as fragments.

Results

A total of 52.333 plant macroremains have been recovered at the moment, representing 130 *taxa*, identified in most cases at species level (Tab. 1).

		Site	MIS14			MIS15			Total N.
		Stratigraphic unit	US 28	US 32	US 34	US 24	US 25	US 26	
		Soil volume	>20 l	>40 l	ca. 20 l	20 l	20 l	20 l	
Taxa	**Plant part**	**Preservation**							
Cereals									
Hordeum vulgare L. subsp. *vulgare*	fruit	C	1	8 *2	*3	3	4		16 *5
Hordeum vulgare L. subsp. *vulgare* var. *nudum*	fruit	C	1	4			1		6
Triticeae	fruit	C	*11		*2	*9			*22
Triticum aestivum/durum	fruit	C	2	3 *1	1	1		1	8 *1
Triticum aestivum/durum/turgidum type *compactum*	fruit	C		2	3	2	1		8
Pulses									
Lens culinaris Medik.	seed	C	*1	2 *2	2			1	5 *3
Pisum sativum L.	seed	C		1			1		2
Vicia faba L.	seed	C		1					1
Oil and fiber plants									
Linum usitatissimum L. cf. subsp. *usitatissimum*	fruit	C	*9	14		*1			14 *10
		W	*498	*815	*104			*293	*1710
Linum usitatissimum L. subsp. *usitatissimum*	seed	C		3	1				4
		W	4 *9	15 *22	*2			8 *7	27 *40
Fruits and nuts									
Corylus avellana L.	fruit	W	*2	*8	*3	*6	1 *9		1 *28
Cucumis melo L.	seed	W	1 *5				3 *1	1 *2	5 *8
Ficus carica L.	fruit	W	4500	12000	325	2200	2350	3625	25000
Malus Mill.	seed	W		3					3
Morus nigra L.	fruit	W		1	1		1		3
Olea europaea L.	endocarp	C	*1	*1					*2
		W	*1	23 *20	4 *5	7 *16	34 *8	27 *15	95 *65
Pinus pinea L.	seed	W	*1	*6	*5	*12	*8	1 *5	1 *37
	cone scale	W				2			2
Prunus avium (L.) L.	endocarp	W					1		1
Prunus domestica L.	endocarp	W				1	1		2
Prunus dulcis (Mill.) D.Webb	endocarp	W	*2	*16	*6	*40	5 *60	1 *13	6 *137
Prunus spinosa L.	endocarp	W	1 *3	13 *17	3 *3	*4	7 *6	3 *6	27 *39
Punica granatum L.	seed	W	6 *30	53 *75	11 *26	5 *22	14 *18	6 *2	95 *173
Vitis vinifera L.	fruit	W		1		1	5		7

	pedicel	W	92	125	35	29	41	51	373
	seed	C	1	3 *2	1				5 *2
		W	431 *1391	4885 *3830	1225 *1462	559 *630	502 *250	561 *183	8163 *7746
	undeveloped fruit	W	10	35	7	4	1	11	68
	undeveloped seed	W	34	179	53	17	17	22	322
Aromatic plants									
Anethum graveolens L.	fruitlet	W		3			1	6	10
Coriandrum sativum L.	mericarp	C	1						1
		W	8 *35	6 *5	*21	1 *2	1	*34	16 *97
	fruit	W		3					3
Shrubs									
Ilex aquifolium L.	seed	W		3					3
Juniperus oxycedrus L.	seed	W		10			3		13
Juniperus turbinata Guss.	leave	W	*1	*10					*11
Myrtus communis L.	seed	C	4						4
		W	28	164	53	4	6	76	331
Pistacia lentiscus L.	fruit and seed	C		8 *1					8 *1
		W	6 *8	92 *29	14	19 *23	20 *12	15 *3	166 *75
Rubus ulmifolius Schott	fruitlet	C	2	3	2		2	1	10
		W	407 *67	875 *86	74 *15	21 *12	42 *26	302 *59	1721 *265
Sambucus nigra L.	endocarp	W					2		2
Thymelaea hirsuta (L.) Endl.	seed	W	17 *31	63 *88	5 *6	7 *9	10 *25	23 *39	125 *198
Herbaceous plants									
Adonis cfr. *aestivalis* L.	fruitlet	W	1		1		1	1	4
Ajuga iva (L.) Schreb.	fruitlet	W	4	2 *1	1	1	4		12 *1
Ammi majus L.	fruitlet	W						1	1
Anthemis cf. *arvensis* L.	fruit	W	3						3
Anthemis L.	fruit	W		1	2	4			7
Apiaceae	fruitlet	W	1						1
Atriplex Tourn. ex L./*Chenopodium* Tourn. ex L.	fruit	W	17	29	2	19	28	9	56
Atriplex Tourn. ex L.	fruit with exocarp	W	2				3	1	6
Avena fatua L.	fruit	C	1			1			2
Beta vulgaris L.	compound fruit	W		5 *5					5 *5
	fruit	W	1	6	1		5	1	14
Boraginaceae	fruit	W	1 *9	1 *2			*1		2 *12
Brassicaceae	seed	W	1			1			2

Bromus cfr. *hordeaceus* L.	fruit	C			2				2
Bryonia L.	seed	W	2	1	1 *2				4 *2
Calendula arvensis (Vaill.) L.	fruit	W	8 *1	6			1		15 *1
Calepina irregularis (Asso) Thell.	fruit	W			1			*4	1 *4
Carduus nutans L.	fruit	W	1	1					2
Carduus Vaill. ex L.	fruit	W		1		1			2
Carex cf. *divulsa* Stokes	fruit	W		3		2		1	6
Carex cf. *flacca* Schreb.	fruit	W				2			2
Carex L.	fruit	W	1	2	1		*1		4 *1
Cerastium L.	seed	W					5 *2	1	6 *2
Chenopodium murale L.	seed	W	40 *5	61 *9		73 *19	50	10 *2	234 *35
Chenopodium Tourn. ex L.	fruit with exocarp	W						1	1
Circaea lutetiana L.	fruit	W						1	1
Clematis Dill. ex L.	fruitlet	W					1		1
Cucurbitaceae	seed	W		1					1
Cyperaceae	exocarp	W	1						1
Digitaria cf. *sanguinalis* (L.) Scop.	fruit	C		1			1		2
Daucus carota L.	fruitlet	W	6	1					7
Ecballium elaterium (L.) A.Rich.	seed	W	4 *72	5 *16	1 *4	*20	3 *26	6 *64	19 *202
Echium cf. *vulgare* L.	fruitlet	W				2			2
Echium Tourn. ex L.	fruitlet	W		*3	2 *1		1		3 *4
Euphorbia helioscopia L.	seed	W	10 *31	16 *75	3 *4	7 *40	13 *59	8 *24	57 *233
Euphorbia peplus L.	seed	W	1			2	2		5
Fabaceae	seed	W				1			1
Fallopia convolvolus (L.) À.Löve	fruit	W		11	10				21
Festuca L.	fruit	C		5					5
Fumaria Tourn. ex L.	fruit	C					*1		*1
		W	26 *73	58 *123	27 *30	4 *31	11 *46	7 *49	133 *352
Galium L.	fruitlet	W						1	1
Glaucium corniculatum (L.) Rudolph	seed	W		1		4	3	6	14
Glaucium flavum Crantz	seed	W	17	19	3		3 *1	2	44 *1
Glebionis segetum (L.) Fourr.	fruit	C	1	1			1		3
		W	43 *16	168 *30	23 *4	22 *8	27 *16	10 *3	293 *77
Heliotropium europaeum L.	mericarp	W	6	7 *3		1	2 *1	6	22 *4
Hyoscyamus niger L.	seed	W	3			3	3		9
Lamiaceae	seed	W		2					2

Lepidium coronopus (L.) Al-Shehbaz	fruit	W	*2	*2		1	1	2	4 *4
	seed	W	2						2
Leucanthemum Mill.	fruit	W				1			1
Linum usitatissimum L. subsp. *angustifolium* (Huds.) Tell.	seed	W		1					1
Lolium cf. *temulentum* L.	fruit	C	1	5	9 *2	1		1	17 *2
Lolium L.	fruit	C	1						1
Malva cf. *sylvestris* L.	fruitlet	C	2	1					3
		W	1 *8	*4		3 *8	2 *13	*9	6 *42
	seed	W		1		2	1		4
Mercurialis annua L.	seed	W	*2	1		*1			1 *3
Muscari cf. *comosum* (L.) Mill.	seed	W	28 *2	73 *4	25 *12		10	36	172 *64
Onopordum cf. *macracanthum* Schousb.	fruit	W		1 *1	*2				1 *3
Ornithopus compressus L.	fruitlet	W	1 *1	3	3		1		8 *1
Papaver dubium L./*rhoeas* L.	seed	W	20	8		38	10	4	80
	stigmatic disk	C		1					1
		W	1	4	2		1	2	10
Plantago cf. *lanceolata* L.	seed	C						1	1
Poa L.	fruit	C		2					2
Poaceae	fruit	C	5	10					15
Portulaca oleracea L.	seed	W	3	1		8	2		14
Ranunculus sardous Crantz	fruitlet	W	1	3	3 *3		4	2	13 *3
Ranunculus trilobus Desf.	fruitlet	W	18 *1	17 *1	1 *2	1	8	12*4	57 *8
Raphanus raphanistrum L.	fruitlet	C				1	1		2
		W	1 *2	2 *2	1	8 *22	8 *14	1	21 *40
Rapistrum rugosum (L.) All.	fruit	C		1		4	3		8
		W	69 *112	120 *55	43 *20	10 *17	12 *22	58 *71	312 *297
Reseda luteola L.	seed	W	3	2		30	13		48
Rumex crispus L.	fruit	W	47 *4	92 *6	9 *1	7	5		160 *11
	fruit with perianth	W	1		2			41 *3	44 *3
Sagina apetala Ard.	seed	W				23	2		25
Silene gallica L.	seed	C		1					1
		W	7	4	2	18	8		39
Silene latifolia Poir.	seed	W	1			1 *1			2 *1
Silybum marianum (L.) Gaertn.	fruit	W	*3	8 *5	*13			1 *1	9 *22
Spergularia cf. *marina* (L.) Besser	seed	W				1			1
Stellaria media (L.) Vill.	seed	W	2	1		3	1	1	8

Stellaria cf. *pallida* (Dumort.) Crép.	seed	W				3	2	1	6
Trifolium Tourn. ex L.	exocarp	W		*1		*1	*1		*3
Urtica dioica L.	fruit	W	2	3			2	2	9
Urtica urens L.	fruit	W				5	3		8
Valeriana officinalis L.	fruit	W		1			2		3
Valerianella dentata (L.) Pollich	fruit	C		1					1
		W	5	7		1	6	2	21
Veronica cf. *agrestis* L.	seed	C				3			3
		W				1		3	4
Veronica Tourn. ex L.	seed	C	2						2
		W	2	5		2	2		11
Viola Tourn. ex L.	seed	W		1					1
Wetland plants									
Bolboschoenus maritimus (L.) Palla	fruit	W	48 *18	174	14	17	19 *7	67	339 *25
Glyceria cf. *máxima* (Hartm.) Holmb.	fruit	C		1					1
Cladium mariscus (L.) Pohl	fruit	W		1			2	1	4
	fruit with exocarp	W		2			1		3
Cyperus capitatus Vand./*longus* L.	fruit	W				25	13		38
Eleocharis cf. *palustris* (L.) Roem. & Schult.	fruit	W					1		1
Juncus Tourn. ex L.	fruit	C	3 *1	7	1	*1	1		12 *2
	seed	C				1			1
		W	3			72	23		98
Medicago cf. *littoralis* Loisel.	fruit	W	2	2 *4	2 *7		2	2	10 *11
Silene canescens Ten./*colorata* Poir.	seed	W	1	2					3
Typha cf. *angustifolia* L.	fruit	W	12			292	93		397
Aquatic plants									
Potamogeton Tourn. ex L.	fruitlet	W		1					1
Cymodocea nodosa (Ucria) Asch.	seed	W	1 *6	8 *8	4 *2	2 *13	34 *19	7 *2	56 *50
Potamogeton cf. *natans* L./*nodosum* Poir.	fruitlet	W			1			2	3
Potamogeton Tourn. ex L.	fruitlet	W		1					1
Ruppia maritima L.	fruitlet	W	6 *1	9	2	2	4	2	25 *1
Stuckenia pectinata (L.) Börner	fruitlet	W		3	1	1			5
Indet.			32	30	16	36	27	20	161
N. of charred remains			51	98	29	28	17	5	228

N. of waterlogged remains	8521	24940	3785	4670	4211	5978	52105
Total N. remains	8572	25038	3814	4698	4228	5983	52333
Total N. det. Taxa	78	91	55	69	80	59	130

Table 1 - Plant macroremains from the excavations of Mistras 2014 (MIS14) and Mistras 2015 (MIS15) (C = charred; W = waterlogged; *n = fragments).

From each stratigraphic unit proceed several thousands of macroremains. In the case of the MIS15 layers, we can evaluate an average concentration of more than 200 specimens per litre of sediment. This high concentration of findings is in part due to the numerosity of specimens reached by some species, particularly *Ficus carica* and *Vitis vinifera*.

The prevailing preservation condition is waterlogging, as the charred macroremains represent only the 0,44% of the total of the counted material. Most of those charred remains are represented by cereals and pulses, that are also the only ones not present under waterlogged conditions. Some other sporadic specimens between the fruit crops and the wild plant remains is preserved under charred conditions, as some *Linum usitatissimum* L. subsp. *usitatissimum* remains, *V. vinifera* seed, and taxa referred to herbaceous vascular plants. Also patent is the presence in all the layers of approximately the same range of taxa.

Between the crops recognised (Fig. 3), the cereals are represented by 27 specimens attributable to barley (*Hordeum vulgare* L. subsp. *vulgare*), 17 to wheat (*Triticum aestivum*/*durum* and *Triticum aestivum*/*durum*/*turgidum* type *compactum*), plus 22 cereal fragments of uncertain attribution; the pulses are present in very low numbers, but all the same attesting the presence of lentils in number of 8 charred remains (*Lens culinaris* Medik), 2 peas (*Pisum sativum* L.) and 1 faba bean (*Vicia faba* L.).

Between the annual crops the presence of flax (*L. usitatissimum* subsp. *usitatissimum*) is also registered; 71 seed remains seem safely attributable to the cultivated flax; on the contrary the attribution of more than 1700 fruit fragments to *L. usitatissimum* subsp. *usitatissimum* is only hypothetic; in fact their attribution to wild or domesticated types is more uncertain, and the presence of at least one seed attributed to the wild narrowleaf flax (*L. usitatissimum* L. subsp. *angustifolium* (Huds.) Tell.), was also registered.

The horticulture, together with the exploitation of wild fruits, is testified by a variety of vascular plants (Fig. 3). Particularly numerous are the remains of fig (*F. carica*), counting some 25000 achenes. Grapevine (*V. vinifera*) is the second most represented species, as more than 8000 seeds and almost the same number of seed fragments were counted, plus seven berries and 373 pedicels; furthermore 322 undeveloped seeds were counted, as well as 68 undeveloped fruits. Also attested are melon (*Cucumis melo* L.) with 5 entire seeds and 8 fragments; 3 seeds attributed to apple (*Malus* Mill.); 3 remains of black mulberry (*Morus nigra* L.); 95 olive endocarps (*Olea europaea* L.) and more than 60 fragments. Between the fruits pertaining to *Prunus* Tourn. ex L. genus are attested wild cherry (*Prunus avium* L.) with at least 1 endocarp, plum (*Prunus domestica* L.) with 2 endocarps, and blackthorn (*Prunus spinosa* L.) with 27 entire endocarps and 39 fragments. Pomegranate (*Punica granatum* L.) is quite well represented, as more than 90 seeds, and more than 170 seed fragments, were attributed to this fruit. A variety of nuts is attested, in particular hazelnuts (*Corylus avellana* L.), counting 1 entire fruit, which presents clear signs of the action of some rodent, and 28 fragments; pine nuts (*Pinus pinea* L.), represented by 1 entire seed and 37 fragments and 2 cone scales; almonds (*Prunus dulcis* (Mill.) D. Webb.) are well testified by 6 endocarps and 137 fragments.

The seeds of *V. vinifera* and the endocarps of *O. europaea* are being analysed thanks to morphometric analysis, that are revealing the attribution of large number of the remains to the domesticated crops, *V. vinifera* subsp. *vinifera* and *O. europaea* var. *europaea*.

Mericarps of the aromatic plant of coriander (*Coriandrum sativum* L.) were also registered: 3 entire fruits were counted, and 16 mericarps, plus a certain number of fragments. Between the aromatic plants were also counted 10 remains of *Anethum graveolens* L.

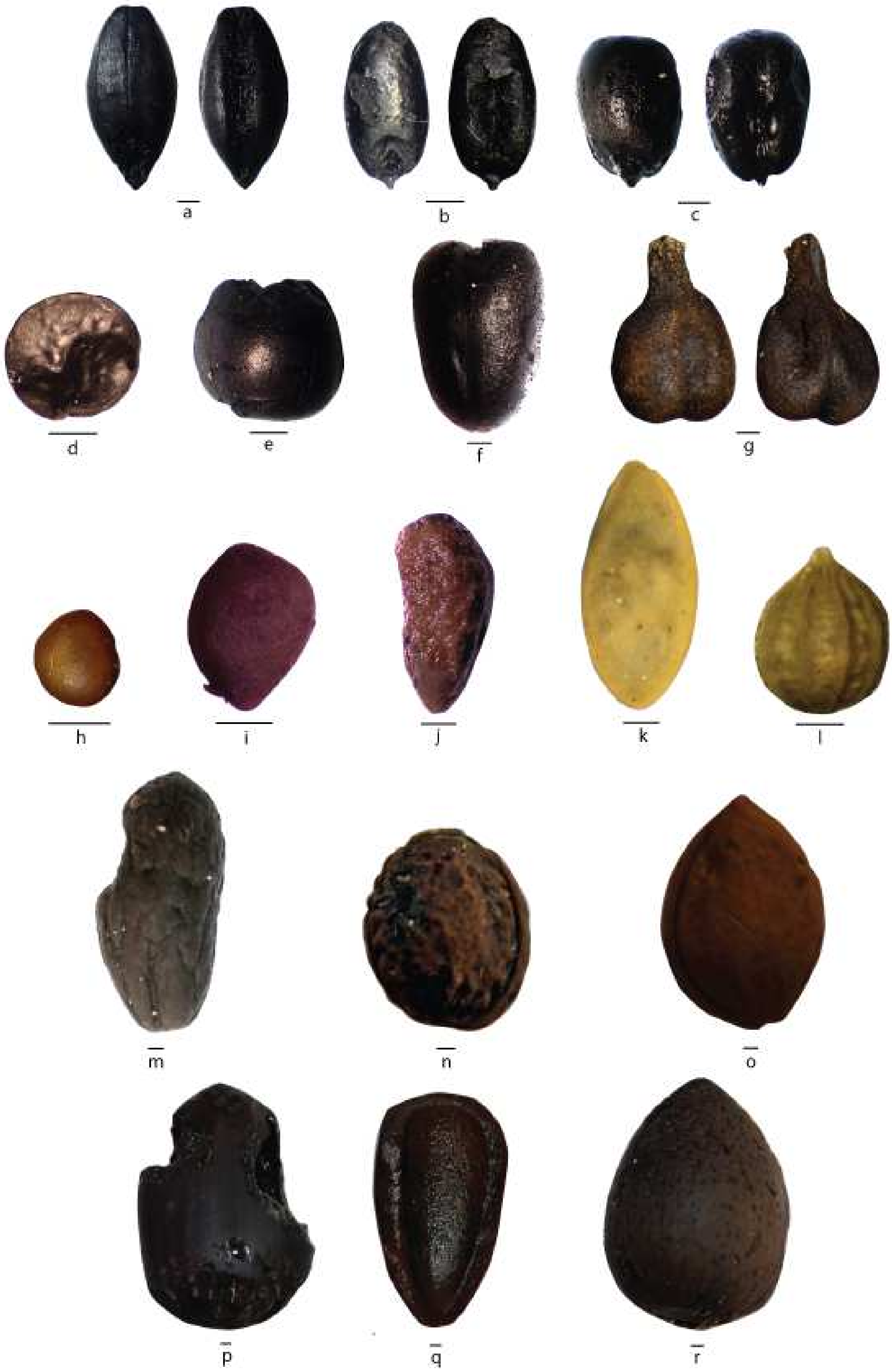

Fig. 3 – Carpological remains of annual crops, cultivated and gathered fruits and nuts. a) *Hordeum vulgare* L. subsp. *vulgare*; b) *Triticum aestivum/durum*; c) *Triticum aestivum/durum/turgidum* type *compactum*; d) *Lens culinaris* Medik.; e) *Pisum sativum* L.; f) *Vicia faba* L.; g) *Vitis vinifera* L. subsp. *vinifera*; h) *Ficus carica* L.; i) *Morus nigra* L.; j) *Punica granatum* L.; k) *Cucumis melo* L.; l) *Coriandrum sativum* L.; m) *Olea europaea* L. var. *europaea*; n) *Prunus spinosa* L.; o) *Prunus domestica* L.; p) *Corylus avellana* L.; q) *Pinus pinea* L.; r) *Prunus dulcis* (Mill.) D.Webb. Scale bar = 1mm.

The data about plants representative of spontaneous vegetation, that could give palaeoenvironmental indications, are extremely abundant, as a high number of *taxa* attributed to different types of environments was recognised; elements of the maquis vegetation, coastal, wetland and aquatic plants were identified, and most of all synanthropic herbaceous plants (Fig. 4).

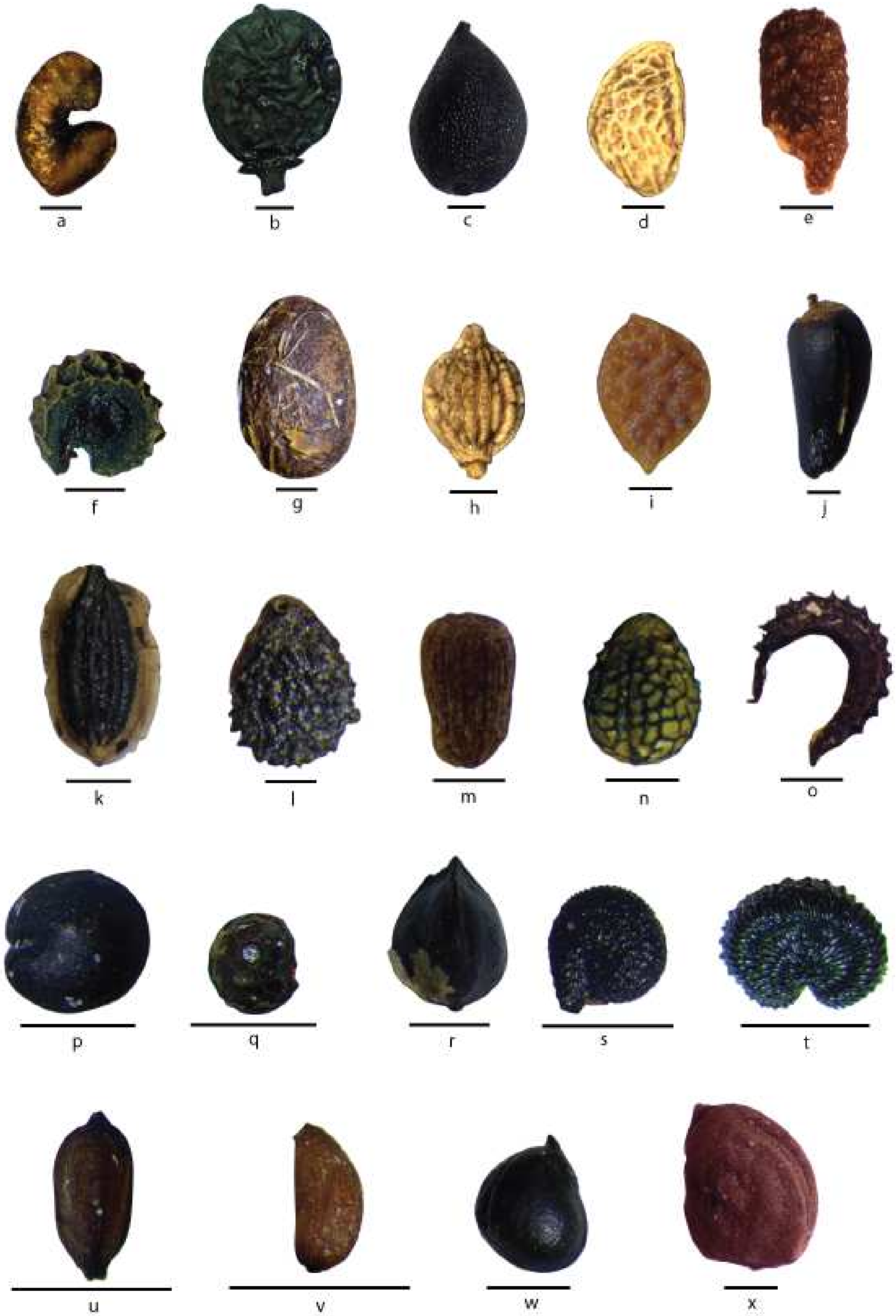

Fig. 4 – Carpological remains of spontaneous vegetation. a) *Myrtus communis* L.; b) *Pistacia lentiscus* L.; c) *Thymelaea hirsuta* (L.) Endl.; d) *Rubus ulmifolius* Schott; e) *Sambucus nigra* L.; f) *Malva* cf. *sylvestris* L.; g) *Ecballium elaterium* (L.) A.Rich.; h) *Rapistrum rugosum* (L.) All.; i) *Ranunculus sardous* Crantz; j) *Silybum marianum* (L.) Gaertn.; k) *Anethum graveolens* L.; l) *Heliotropium europaeum* L.; m) *Glebionis segetum* (L.) Fourr.; n) *Euphorbia helioscopia* L.; o) *Calendula arvensis* (Vaill.) L.; p) *Chenopodium murale* L.; q) *Papaver dubium* L./*rhoeas* L.; r) *Rumex crispus* L.; s) *Portulaca oleracea* L.; t) *Silene gallica* L.; u) *Cyperus capitatus*

Vand./*longus* L.; v) *Juncus* Tourn. ex L.; w) *Ruppia maritima* L.; x) *Stuckenia pectinata* (L.) Börner. Scale bar = 1 mm.

Discussion

The plant assemblage recovered in the harbour site of Mistras is an important source of information on domesticated and gathered plants, as well as on spontaneous vegetation. The economic valuable plants can represent in large part products of the hinterland of Tharros, lost during transhipment operations and destined to the same city or to the exportation; some of them could also be representative of imported products. The role of natural currents in the transportation and deposition of the macroremains, in particular in the case of the taxa representative of the spontaneous vegetation, should not be underestimated, as various studies, concerning different environments and types of waterlogged archaeological sites, correctly pointed out (Cappers 1993; Antolín et al. 2017; Steiner et al. 2020).

Between the cultivated crops cereals and pulses are perhaps underrepresented, as, differently from other plants, they are not well preserved in wet conditions (Jacomet 2013), and only charred remains were found. The presence of all the detected species is well known from the preceding periods in Sardinia (Bakels 2002; Ucchesu et al. 2015), except for the variety *Triticum aestivum*/*durum*/*turgidum* type *compactum*. For the period under consideration, the presence of the same range of cereals and pulses has already been recorded in the terrestrial site of S'Urachi (van Dommelen et al. 2018; Pérez-Jordà et al. 2020), while they seem absent in the rural context of Truncu 'e Molas, a fact that has been attributed to a specialisation of the site to other agricultural activities (Pérez-Jordà et al. 2010). At this regard it has to be considered how in past decades Punic Sardinia was considered as an important source of cereal provisions for the North African metropolis of Carthage (Barreca 1988; Manfredi 1993; Moscati et al. 1997), a vision that is now being partially resized as new data about the diversification of agriculture emerge (van Dommelen et al. 2012; 2018; Del Vais et al. 2020; Pérez-Jordà et al. 2010; 2020). In any case, even when not present in large numbers in the archaeobotanical record, it seems safe to assume that cereals and pulses should have been basic elements of the alimentation.

Linum usitatissimum L. subsp. *usitatissimum* is another species present since previous times on the Island, and the use of flax to produce oil and fibres is usually associated with the spread of Neolithic agriculture (Zohary et al. 2012). Remains of *L.* cf. *usitatissimum* were recognised in the Bronze Age site of Sa Osa (Sabato et al. 2015), and *L. usitatissimum* was detected in S'Urachi (van Dommelen et al. 2018; Pérez-Jordà et al. 2020).

The presence of fruits, domesticated and gathered wild fruits, is extremely important. Between them the three species usually considered as the most classical fruit plants of the Mediterranean, *Vitis vinifera* L., *Ficus carica* L. and *Olea europaea* L., have a particular prominence; after being collected for long time from the wild, they were presumably the first fruit plants to be domesticated (Zohary et al. 2012). In particular for what concerns *V. vinifera* the findings of Mistras confirm the importance of this crop in Sardinia. Thousands of grape pips, pedicels and also some raisins were found on the site; the pips were analysed with morphometric analysis that revealed the pertinence of a great majority of them to domesticated morphotypes; besides, the presence of undeveloped pips may give an ulterior indication on the attribution of the Mistras remains to domesticated varieties, as only the berries of the *V. vinifera* subsp. *vinifera* usually contain partly developed pips together with the developed ones (Zohary et al. 2012). In Sardinia, the cultivation of the grapevine was already established since the Bronze Age, when with high probability secondary domestication events took place (Ucchesu et al. 2015). At the same time several findings prove how the Nuragics, the autochthonous population of Sardinia of the Bronze and Iron Age, were already involved in the production of wine (Perra et al. 2015; Damasco et al. 2020), presumably also as a response to the influence coming from the constant contact with different agents of the eastern Mediterranean (Botto 2016). The 1st millennium BC was certainly a period of great development for the cultivation of this plant not only in Sardinia, but in general in the western Mediterranean. In the Italian Peninsula the cultivation of grapevine probably started during the Bronze Age (Marvelli et al. 2013), but the production of wine gradually augmented in quantity and importance, as proved by the increasing production and diffusion of transport amphorae of western Greek tradition dedicated to the wine (Sourisseau 2009). On the other side in the most western regions, France and Iberian Peninsula, this still appears as the millennium during which viticulture was introduced, as a consequence of the establishment of respectively Greek and Etruscan settlements on the one side (McGovern et al. 2013; Bouby et al. 2014), and Phoenician settlements on the other (Buxó 2008; Prados Martínez 2011; Pérez-Jordà et al. 2017; 2021). On the southern side of the western Mediterranean the presence of *V. vinifera* remains in archaeological contexts is well attested in Punic Carthage (van Zeist et al. 2001; Kroll 2007). The influence of Phoenician people was probably important also in what regards the ulterior development of viticulture in Sardinia; the findings of *V. vinifera* remains for what concerns the Archaic and Punic period are in fact relatively numerous. In several sites were found transport amphorae of local production and Phoenician and Punic tradition containing grape pips, frequently in association with animal remains, a content that seem to indicate some sort of conditioning of the meat with a by-product of the grapevine. This is the case of Nora (Marinval & Cassien 2001) and of Santa Giusta (Del Vais & Sanna 2009; 2012; Sabato et al. 2019b). Other attestations come from the central-western part of the Island: a transport amphora of Sant'Imbenia type and of local production, found in the settlement of Su Cungiau 'e Funtà, contained white wine, as revealed thanks to chemical analysis (Del Vais et al. 2016-2017); in the site of S'Urachi the ongoing investigations documented the presence of grapevine remains (van Dommelen et al. 2018; Pérez et al. 2020); the rural settlement of Truncu 'e Molas was probably dedicated to specialised activities of viticulture and wine production during the Punic period (van Dommelen et al. 2012). In the same hinterland of Tharros the signs of an increased cultivation of the grapevine come not only from the Mistras findings, but also from different palynological analysis held in the area, that show a clear increment of the pollen of this plant around the 5^{th} and 4^{th} century BC (Acquaro et al. 2001; Di Rita & Melis 2013).

As for *O. europaea*, the endocarps of Mistras were also classified thanks to morphometric analysis, and the data point to a presence of both wild and domesticated morphotypes. The endocarps recognised as wild can derive from the local vegetation, while the domesticated ones can reveal the first evidence of the presence of the cultivated olive. Olive remains in Archaic and Punic sites of Sardinia were already registered in Santa Giusta (Del Vais & Sanna 2009; 2012; Sabato et al. 2019b) and S'Urachi (van Dommelen et al. 2018; Pérez-Jordà et al. 2020).

Concerning *F. carica*, this fruit is represented by extremely high numbers of achenes; this is quite understandable, as each compound fruit can contain hundreds of them. Fig remains were documented on several archaeobotanical assemblages of the western Mediterranean, with remarkable numbers in Sardinian Bronze Age sites (Ucchesu et al. 2014; Sabato et al. 2015), and a constant presence, when the carpological data is at disposition, in Archaic and Punic sites of Sardinia (van Dommelen et al. 2018; Pérez-Jordà et al. 2020) and of other regions, as in several settlements of the Iberian Peninsula (Pérez-Jordà 2020), in Lixus on the Atlantic coast of Morocco (Pérez-Jordà 2005), and of course in Carthage in North Africa, well known during the Antiquity for its fig cultivations (van Zeist et al. 2001; Kroll 2007).

Not only the attestation of *V. vinifera* and *O. europaea* find a good parallel in the findings of the Santa Giusta lagoon (Del Vais & Sanna 2009; 2012; Sabato et al. 2019b), but also the majority of the other fruit species attested in the Mistras lagoon. This is the case of *Prunus spinosa* L., *Prunus avium* (L.) L., presumably gathered from wild trees, and of *Prunus domestica* L.. The presence of the cultivated *P. domestica* is particularly important: as Mistras and Santa Giusta provided the older documentation of this fruit in Sardinia, the major role of Phoenician people in the introduction of the plum on the Island is confirmed at the state of the research (Ucchesu et al. 2017).

The finding of nuts, in particular *Corylus avellana* L., *Pinus pinea* L. and *Prunus dulcis* (Mill.) D. Webb, also correspond to the data at disposition for Santa Giusta (Del Vais & Sanna 2009; 2012; Sabato et al. 2019b). Hazelnuts and pinecones were also found in the Late-Punic underwater site of the harbour of Olbia (Pallarès 1987), and in the Santa Gilla lagoon (Vivanet 1892; 1893) as content of some transport amphorae.

The few *Malus* Mill. seeds at the moment have no parallel findings in earlier or contemporaneous sites of Sardinia, and it cannot be specified if we are dealing with remains of wild or domesticated apples.

Extremely important seems the attestation of *Punica granatum* L., which seeds are present in almost all the layers; until very recently this fruit had not been recorded in the archaeobotanical register of Archaic and Punic Sardinia (Perotti & Secci 2016-2017), and only recent investigations in S'Urachi gave evidence of its presence (Pérez-Jordà et al. 2020). Phoenician people seemingly played a major role in the spread of pomegranate, which wild ancestor is localised in the Caspian belt (Zohary et al. 2012), from the eastern to the western Mediterranean (Perotti & Secci 2016-2017; Torres Gomáriz 2017; Nigro & Spagnoli 2018). Outside Sardinia the findings usually concern sites interested by the presence of Phoenicians. An exception seems to be the case of Malta, where it is well attested during the 1st millennium BC, althought the first evidences are far more ancient (Fiorentino et al. 2012). In Carthage remains of pomegranate were found both in the harbour and in urban contexts (van Zeist et al. 2001; Kroll 2007); in Sicily remains of this fruit were found in Mozia (Nigro & Spagnoli 2018); in the Iberian Peninsula it is already attested during the Archaic phases of Huelva (Pérez-Jordà et al. 2017), and different findings come from slightly more recent sites (Pérez-Jordà 2020); on the Atlantic side of

North Africa pomegranate seeds are attested in the Archaic and Punic levels of Lixus (Pérez-Jordà 2005).

The presence, between the cited fruits and nuts found in Mistras, of imported goods cannot be ruled out in total, either from other areas of Sardinia or from outside the region; nevertheless, it seems useful to point out that the palynological analysis, a part from the already cited data on *V. vinifera*, suggest a very slight increment of *O. europaea*, and the presence of essences like *Prunus* sp. and *C. avellana* in the area; on the contrary no pollen of *P. granatum* was registered (Acquaro et al. 2001; Di Rita & Melis 2013).

Another important finding is that of the seeds of *Cucumis melo* L. The oldest attestation of melon in the western Mediterranean was found in the Bronze Age site of Sa Osa (Sabato et al. 2015); the seeds of Sa Osa, which were studied thanks to molecular and morphometric analysis, showed closer affinities with non-sweet varieties (Sabato et al. 2019a). Remains of this vegetable are once again attested in Archaic Huelva (Pérez-Jordà et al. 2017) and Punic Carthage (van Zeist et al. 2001).

The seeds of *Morus nigra* L. confirm an early presence of the black mulberry in the western Mediterranean and in particular in Sardinia, as already proved by the findings of Sa Osa (Sabato et al. 2015). The investigations in the harbour of Carthage also provided some remains of *M. nigra* dating to Punic times (van Zeist 2001), while at the actual state of knowledge other evidences in the western Mediterranean are slightly more recent, as is the case of southern France, where the oldest attestations are dated to the 1st century BC (Durand et al. 2016).

The presence of important numbers of mericarps, and sometimes the entire fruit, of *Coriandrum sativum* L., one of the oldest aromatic crops (Zohary et al. 2012), is also significant. Coriander appears in the archaeobotanical record of the western Mediterranean during the 1st millennium BC, as many other horticultural species. It is attested in Punic Carthage both from the harbour site (van Zeist 2001) and in urban contexts (Kroll 2007); in Sicily it is present in indigenous Elymian sites of the western coast, dating to the 7th and 6th century BC (Stika et al. 2008), and in the Iberian Peninsula its unique attestation for the period is at the moment that of Castro Marim in Portugal, dating to the 5th century BC (Queiroz et al. 2006; Pérez-Jordà 2020). The study of the content of a transport amphora recently recovered in the Santa Giusta Lagoon, dated to the Archaic phase, suggests its use in the conditioning of the meat contained in the transport amphorae, in association with the already well-known element of grape (Del Vais & Sanna 2009; 2012; Sabato et al. 2019b). Another noteworthy element is the finding of the aromatic *Anethum graveolens* L., once again a first attestation of a cultivated plant in Ancient Sardinia; seeds of *A. graveolens*, a plant native of the eastern Mediterranean, were found in the Punic levels of Carthage (Van Zeist et al. 2001). The same Punic Carthage could have had a major role in the spread of these aromatic plants, and more specifically of their use in culinary habits, analogously to many other aspects of culture and economy in the regions under its influence.

Between the wild plants which fruits could have been gathered and used are some species typical of the maquis vegetation, as myrtle (*Myrtus communis* L.) and lentisk (*Pistacia lentiscus* L.), and shrub species such as thornless blackberry (*Rubus ulmifolius* Schott); due to the nature of the site, it does not seem possible to attribute with certainty their presence to human activities, as they could also have been dispersed by natural factors.

One of the main results of the carpological analysis here presented, which will be object of deepest analysis in the prosecution of the study, are the data on the wild plants, which could give a contribution to the reconstruction of the palaeoenvironment of the area; this is the first archaeobotanical study of a Sardinian context were such a variegated and abundant assemblage of plant macroremains attributed to wild species was recorded. As already underlined, in examining the materials they should not be considered as representatives only of the immediate proximities of the sites, but of a broader area, as some of the remains could have been transported by natural agents from the hinterland or from other parts of the coast.

Between the wild species attested a certain number of *taxa* indicate the presence of maquis vegetation, as cade (*Juniperus oxycedrus* L.), myrtle (*M. communis*), lentisk (*P. lentiscus*), of coastlands and wetlands, as sea clubrush (*Bolboschoenus maritimus* (L.) Palla) and rush (*Juncus* Tourn. ex L.), all vegetation types that correspond to environments still characteristics of the area (Bacchetta et al. 2009). Remains of aquatic plants, namely pondweeds as *Stuckenia pectinata* (L.) Börner and sea grasses like *Cymodocea nodosa* (Ucria) Asch., were also registered.

More eloquent for what concerns the correlation between man and the landscape is the high presence of synanthropic species; almost all the herbaceous species identified are in fact typical of cultivated areas and pastures, and more in general associated to ruderal areas interested by a strong human impact. Between them are the milk thistle (*Silybum marianum* (L.) Gaertn.), the corn marigold (*Glebionis segetum* (L.) Fourr.), the field marigold (*Calendula arvensis* (Vaill.) L.), the turnipweed (*Rapistrum rugosum* (L.) All.), the sowbane (*Chenopodium murale* L.), the curly dock (*Rumex crispus* L.), the sun spurge

(*Euphorbia helioscopia* L.) and the common poppy (*Papaver dubium* L./*rhoeas* L.), to cite only a few of them.

The data on the spontaneous vegetation seems to coincide with other palaeoenvironmental analysis available for the area, which indicate an exploitation of the landscape that is already evident during the 2nd millennium BC, and that progressively increases during the Archaic and Punic phases, in particular from the 5th century BC (Fedele 1979; 1980; 1983; Nisbet 1980; Acquaro et al. 2001; Di Rita & Melis 2013; Lentini 1994; 1995; 2014). Nevertheless, a certain amount of arboreal coverture is still attested during the great part of the 1st millennium BC, as well as a certain variety of the cultures; on the contrary during the following Roman phase the vegetation seems reduced in terms of variability and the culture of cereals is much more predominant than what attested before (Acquaro et al. 2001; Di Rita & Melis 2013; Lentini 2014).

Conclusions

The archaeological excavations held in the Mistras Lagoon, harbour of Tharros during the Archaic and Punic period (7th-3rd century BC), provides archaeobotanical information in great part new for Sardinia, as it provides the oldest attestations in the Island of many cultivated plants, and unprecedented information on the spontaneous vegetation. The study contributes to the reconstruction of the agricultural, commercial and environmental aspects of the Island during the 1st millennium BC.

The traditional crops, as cereals and pulses, are accompanied by a variety of cultivated and gathered fruits and nuts, between which stands out the important role of the grapevine, but also the attestation of fruits only recently documented on Sardinian sites of the period, as the plum and the pomegranate, and the first evidences of the presence of aromatic plants as coriander and dill.

Furthermore, the exhaustive information on wild plants helps in the reconstruction of the palaeoenvironment, that appears extremely interested by anthropic activities, in accordance with the data on the progressive ruralisation held in Sardinia in particular during the second half of the millennium.

The archaeobotanical study on the Mistras Lagoon are far from concluded; the complete analysis of the plant macroremains found in the different stratigraphic units is still going on, accompanied by statistical comparisons between samples of known volume; once completed a more precise evaluation of the plant assemblages will be possible. Hopefully new archaeobotanical data will also proceed from the surrounding areas, in particular the same Tharros and its hinterland, contributing to a more complete and integrated interpretation.

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Chapter 2

The Santa Giusta lagoon (Sardinia, Italy): new archaeobotanical data from an Archaic transport amphora

Introduction

The Santa Giusta Lagoon, situated in the central part of the gulf of Oristano (Central-West Sardinia), contains one of the most intriguing archaeological sites of Archaic and Punic Sardinia (Fig. 1). The lagoon is situated near to the modern city of Santa Giusta, which insists on a previous settlement identified as Othoca, cited in ancient literary sources (Del Vais 2010).

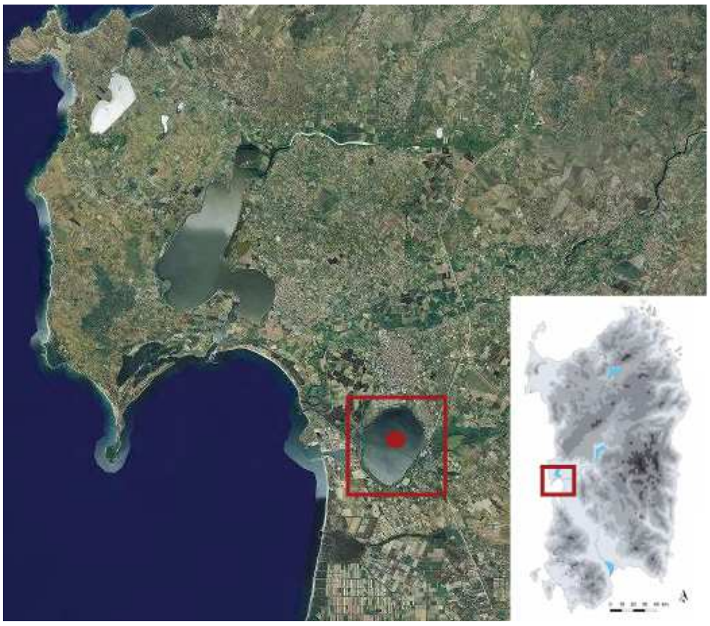

Fig. 1 – The Santa Giusta Lagoon in Central-West Sardinia, with the location of the archaeological site.

The first archaeological investigations inside the lagoon were held during the years Seventies and Eighties of the 20th century (Tore & Zucca 1983; Fanari 1988; Mastino et al. 2005; Del Vais 2010; Del Vais & Sanna 2019). Since 2005 systematic surveys and excavation campaigns, conducted by the Archaeological Superintendence of Cagliari and the University of Cagliari, put in evidence the existence of a large dispersion area of archaeological materials of Archaic and Punic period in the north-eastern part of the lagoon, covering a time span going from the 7th to the 3rd-2nd century BC (Fig. 2-3) (Del Vais & Sanna 2009; 2012).

Fig. 2 - The underwater excavation area at Santa Giusta, showing scattered ceramics and wood (Del Vais 2010).

Fig. 3 – An archaic transport amphora recovered during the 2005 campaign (Del Vais 2010).

The site, which interpretation is still uncertain, is constituted by a deposit of scattered remains, mainly transport amphorae of Sardinian production, together with other ceramic vessels, and by manufactured wood, that could at least in some measure represent elements of ships (Del Vais & Sanna 2009; 2012). Many of the transport amphorae contained animal bones, between which were recognised rests of bovids and ovicaprids, as well as carpological remains, represented by seeds and fruits; the plant materials are preserved thanks to the waterlogged and anoxic conditions of the stratigraphy (Del Vais & Sanna 2009; 2012; Sabato et al. 2019). The carpological remains recognised by previous analysis comprise different nuts, in particular *Corylus avellana* L., *Juglans regia* L., *Prunus dulcis* (Mill) D.Webb.; cones of *Pinus halepensis* Mill. and *Pinus pinea* L.; cucurbits as *Citrullus lanatus* (Thunb.) Matsum. & Nakai and *Lagenaria siceraria* (Molina) Standl.; fruits as *Olea europaea* L., *Vitis vinifera* L., *Prunus spinosa* L. and *Prunus domestica* L.; between the wild plants *Juniperus oxycedrus* L. and *Quercus* Tourn. *ex* L. remains were identified, and a high presence of the aquatic *Potamogeton* Tourn. *ex* L. (Sabato et al. 2019). Particularly interesting was the finding of *Prunus domestica* endocarps, probably introduced in Sardinia during the Punic era (Ucchesu et al. 2017). The carpological remains were partially contained into the transport amphorae, but they were also largely present in the sediment, perhaps as a result of the loss of content from the same vessels, that were not sealed and frequently presented fractures (Del Vais & Sanna 2009; 2012; Sabato et al. 2019). In particular the *V. vinifera* remains, seeds and pedicels, have been frequently found in association with the animal bones as a content of the amphorae (Del Vais & Sanna 2009; 2012; Sabato et al. 2019).

In this work are presented the archaeobotanical results coming from the analysis of the content of an Archaic/Middle Punic transport amphora previously unpublished, found in the lagoon during a survey operation of the Archaeological Superintendence of Cagliari; the amphora, in addition to the carpological remains, contained animal bones that at a first sight seem pertinent to ovicaprids. The amphora, that for its macroscopic characteristics seems attributable to a local production, in analogy with other containers from the site which were object of archaeometric analysis (Del Vais & Sanna 2009; 2012; Amadori et al. 2017), can be generally dated to the 6^{th}-5^{th} century BC, but a more specific typological study is required to assign it to a precise type and better define its chronology; it was unsealed and presented fractures on the body.

Materials and methods

The sediment which filled the amphora, from now on called Anf. T-01, was extracted from the vessel and sieved by wash-over in the laboratories of the HBK-Hortus Botanicus Karalitanus (University of Cagliari). The entire sediment was processed using a sieve mesh size of 0,25 mm, in order to retain the maximum amount of remains. The result of the sieving was then examined at the stereomicroscope to separate the carpological findings from other types of remains, as ceramic and bone fragments, and from residues of the sediment. Once detected and separated, the carpological remains were identified thanks to the modern reference collection of the BG-SAR-Sardinian Germplasm Bank (Porceddu et al. 2017), to botanical atlases for the identification of seeds and fruits (Cappers et al. 2012), and to digital resources (https://www.actaplantarum.org/), and their characteristics, as well as the likability of their presence, were defined with updated plant references and checklists (Mabberley 2017; Bartolucci et al. 2018). The carpological remains were then stored in deionised water at 5°C in the facilities of the BG-SAR.

Results

A total of 3957 specimens was counted, including carpological remains and other plant elements as charcoal and wood fragments which at the moment have not been analysed; between the carpological remains, 24 *taxa* were identified (Tab. 1), and are here discussed.

Taxa	**Plant part**	**N. remains**
Cultivated plants		
Coriandrum sativum L.	mericarp	289 *293
	seed	65 *29
Ficus carica L.	fruit (achene)	376
Vitis vinifera L.	seed	1973 *7
	undev. seed	54
	undev. fruit	29 *11
	pedicel	48
Ruderal plants		
Apiaceae	fruit	1
Asphodelus Tourn. ex L.	seed	59
Brassicaceae	seed	1
Clematis Dill. ex L.	fruitlet	1
Cyperaceae	fruit	1

Fallopia convolvolus (L.) Á. Löve	fruit	1
Fumaria Tourn. ex L.	fruit	3
Galium L.	mericarp	1
Medicago cf. *minima* (L.) L.	fruit	1
Papaver dubium L./*rhoeas* L.	seed	79 *7
Ranunculus sardous Crantz	fruit	1
Rubus ulmifolius Schott	fruitlet	*1
Rumex crispus L.	fruit	5
Rumex L.	tepal	6
Trifolium Tourn. ex L.	perianth	7
Wetland and acuatic plants		
Aquatic plants/algae indet.		*19
Bolboscheonus maritimus (L.) Palla	fruit	2
Najas L.	fruit	2 *7
	seed	2
Posidonia oceanica (L.) Delile	leave	*1
Ruppia maritima L.	fruit	25
Stuckenia pectinata (L.) Börner	fruitlet	149
	circumscissile	31
Zannichellia palustris L.	fruit	219
Indeterminated		
Charcoal		18
Leave		*1
Pedicel		121
Wood		11
Total specimens		3957
Total taxa		24

Table 1 – Carpological and other vegetal macroremains found in the Archaic/Middle Punic (6th-5th century BC) transport amphora Anf. T-01 from the Santa Giusta lagoon. *n=fragments.

All the carpological remains are preserved by waterlogging. The highest numbers in the counting of the remains is given by those species, cultivated or gathered, that most likely represent part of the content of the amphora. Between them 1973 *Vitis vinifera* L. seeds were counted, together with seed fragments, undeveloped seeds and fruits, and pedicels (Fig. 4). Extremely abundant is *Coriandrum sativum* L., as hundreds of entire and fragmented mericarps were found (Fig. 5); the presence of seeds separated from the mericarps seems attributable to post-depositional processes that could have damaged the remains. Also remarkable is the presence of *Ficus carica* L., attested by the finding of 376 achenes.

Fig. 4. *Vitis vinifera* L. remains: seed, undeveloped seed, pedicel (scale 5 mm).

Fig. 5. *Coriandrum sativum* L. mericarps (scale 5 mm).

The wild plants are represented by synanthropic species as *Asphodelus* Tourn. ex L., *Fallopia convolvolus* (L.) Á.Löve, *Fumaria* Tourn. ex L., *Papaver dubium* L./*rhoeas* L., *Ranunculus sardous* Crantz and *Rumex crispus* L. All these taxa are present with low numbers of remains, usually inferior to 10, with the exception of *Asphodelus* sp. and *P. dubium*/*rhoeas*, which count respectively 59 and 86 specimens. Wetland plants are restricted to some *Bolboschoenus maritimus* (L.) Palla remains, while more represented are aquatic plants, mostly typical of fresh and brackish water as *Najas* L., *Ruppia maritima* L., *Stuckenia pectinata* (L.) Börner, *Zannichellia palustris* L. The remains of these last two species are particularly abundant, as around two hundred specimens were counted for both of them. One leaf of seagrass, the *Posidonia oceanica* (L.) Delile, was also detected.

Discussions

The importance of *Vitis vinifera* L. as a content of Anf. T-01 is patent, as more than 2000 specimens of this species were counted. For this reason, it seems probable that grapes, fresh, dried or resulting from some other processing, were put purposely inside the amphora, so that their presence is not the result of casual infiltrations during the post-depositional process. Morphometric analysis on the seeds are underway, and are attributing the great part, if not all, of the seeds to *V. vinifera* subsp. *vinifera*; the presence of cultivated grapes seems confirmed by the attestation of undeveloped seeds, usually typical only of domesticated grapevine (Zohary et al. 2012). Besides, the importance of viticulture in ancient Sardinia is not a novelty, as the first signs of this agricultural practice, together with proves of secondary domestication processes held on the Island, date to the Bronze Age (Ucchesu et al. 2015). During the 1st millennium BC the cultivation of the grapevine must have continued and perhaps grown in importance, as proved by the findings of *V. vinifera* remains in all those Archaic and Punic contexts where archaeobotanical analysis were held (Marinval & Cassien 2001; Bakels 2002; van Dommelen & Gómez Bellard 2012; van Dommelen et al. 2010; 2012; 2018; Del Vais et al. 2020; Pérez-Jordà et al. 2020).

A real novelty of this finding is the presence of *Coriandrum sativum* L. At the present moment the only other documentation of coriander fruits on archaeological Sardinian sites comes from the Mistras Lagoon, in the northern part of the gulf of Oristano, from a waterlogged context recognised as the harbour of the Archaic and Punic city of Tharros (Del Vais et al. 2020). Coriander is one of the most ancient aromatic plants used in the Mediterranean; in South-West Asia there are evidences of its presence in Neolithic sites, and clear signs of a well-affirmed domestication come from 2nd millennium BC sites of Egypt and Greece (Megaloudi 2005; Zohary et al. 2012). Its introduction to the western Mediterranean for the moment seems to date to the 1st millennium BC, when it is documented in Punic Carthage (van Zeist et al. 2001; Kroll 2007), in Sicily (Stika et al. 2008) and in the Iberian Peninsula (Pérez-Jordà 2020). In Santa Giusta its presence in association with presumed remains of salted meat and grapevine seems particularly interesting, as it could have constituted an important aromatic ingredient.

As for the fig achenes found inside of the amphora, they could be either attributed to a voluntary introduction of figs in the vessel, or to casual intrusions, as their number is important but not particularly striking, considering that one single compound fruit of fig can contain hundreds of achenes (Zohary et al. 2012).

The transport amphorae contents documented in the underwater context of the Santa Giusta Lagoon, not only those here examined, but also the already known from previous results (Del Vais & Sanna 2009; 2012; Sabato et al. 2019) find several parallels in the Punic world, especially evident in other underwater Sardinian contexts. The first attestation of the presence of animal bones inside Punic transport amphorae come from the Santa Gilla lagoon near Cagliari, where the first excavations took place at the end of the 19th century, followed by several interventions during the past century (Vivanet 1982; 1893; Moscati 1991; Solinas-Orrù 2005); here some vessels also contained nuts of *Corylus avellana* L., while others were full of pinecones, recognised at the time of the first intervention as *Pinus pinaster* Aiton and *Pinus sylvestris* L. (Vivanet 1983). The underwater excavations conducted by a Franco-Italian mission in front of Nora, also in the South of the Island, documented the presence of animal remains in association with *V. vinifera* seeds inside Punic amphorae (Marinval & Cassien 2001; Poplin 1980; 2014). In the Mistras lagoon the ongoing studies of the University of Cagliari are revealing the copresence of Punic Sardinian transport amphorae, all in fragmentary state, animal bones and a variety of cultivated and wild carpological remains (Del Vais et al. 2020). In the North some evidences come from the port of Olbia, where Late-Punic amphorae found during underwater excavations contained nuts, presumably of *C. avellana*, and pinecones, as well as animal bones (Pallarès 1987). Concerning the presence of animal bones inside Punic transport amphorae, this was also documented in other underwater sites as the port of Cagliari (Sanna et al. 2010), and outside Sardinia in the anchorage of Torre la Sal in the Iberian Peninsula, inside an archaic amphora of central Mediterranean provenance (Wagner 1978; Ramon Torres 1986; 1995). In these contexts, the presence of carpological remains was not documented, but it should be considered the possibility that a specific archaeobotanical approach was not undertaken.

The prevailing hypothesis regarding the several cases in which animal remains were found inside transport amphorae, in association with carpological remains and in particular grape seeds, is that of the existence of an industry dedicated to the production of salted meat, processed thanks to a by-product of the grapevine (Marinval & Cassien 2001; Poplin 1980; 2014; Del Vais & Sanna 2019; Sabato et al. 2019). In this sense the copresence of *C. sativum* attested in the present study could be significant. However it should not be forgotten that in some cases was also conjectured the pertinence of the osteological remains to meat that had already been consumed (Vivanet 1892; Poplin 1980); a more complex and complete approach to the study of the transport amphorae and their content will give further information and keys for the interpretation. What seems in any case undeniable is the importance of the agricultural compartment in the economy of Punic Sardinia. The existence of a developed agricultural and pastoral system is proved by several studies focusing on rural landscapes and sites (van Dommelen & Gómez Bellard 2008; 2012; van Dommelen et al. 2010; 2012; Roppa & van Dommelen 2012; Del Vais 2014; Roppa 2014), and the products attested in the Santa Giusta lagoon give additional evidences on the subject.

As for the wild species documented inside Anf. T-01, it seems possible to hypothesise for the majority of them an introduction inside the unsealed amphora after their deposition on the site. This is certainly the case for the wetland and aquatic plants; the copresence of plants typical of fresh and brackish water environments, as *Ruppia maritima* L., *Stuckenia pectinata* (L.) Börner and *Zannichellia palustris* L., and of the marine plant *Posidonia oceanica* (L.) Delile, could attest different moments of the post-depositional process, during which the coastline was evolving from an ancient conformation to the actual lagoon system. It seems premature at the state of knowledge to make firm assessments on this subject; a few attempts of reconstruction of the ancient coastline were undertaken in previous studies, supposing the existence of a bay during the Punic times at the place of the actual lagoon (Stiglitz 2004; Bernardini et al. 2014). Accurate geomorphological analyses are being held thanks to the ongoing project of research *Interazioni tra uomo e ambiente nell'evoluzione del paesaggio costiero antico della Sardegna*, financed by the RAS, Assessorato della Programmazione, Bilancio, Credito e Assetto del Territorio (*Progetto di ricerca fondamentale o di base*, L.R. 7 agosto 2007, n. 7, Bando 2013, 23 settembre 2015 – 23 settembre 2018), and coordinated by Carla Del Vais; they will hopefully give reliable information on the evolution of the coastline and of the lagoon.

As for the synanthropic species found in the sediment of Anf. T-01, they could have been transported from the land by water currents, but it cannot be excluded the possibility of their presence as intrusion in the original content of the amphorae, due to a casual recollection together with the harvested products.

Conclusions

The data from the archaic amphora found in the Santa Giusta lagoon is in line with previous evidences coming from Archaic and Punic sites of Sardinia, where the copresence of animal bones and grapevine as remains of the content of transport amphorae is attested. However, this finding gives a new and interesting information, as

an unprecedented association with the aromatic fruits of coriander is attested. Further studies will eventually help in defining the nature of these attestations, that apparently proves the existence of a system of preservation of meats thanks to a by-product of the grapevine, in this case implemented with the use of an aromatic ingredient.
Furthermore, the study provides information on the wild plants, attesting the presence of synanthropic species, but also of aquatic plants, presumably included in the sediment during the post-depositional process.

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Chapter 3

Characterisation of archaeological olive endocarps from Archaic and Punic period (7^{th}-3^{rd} century BC) of Sardinia (Italy)

Introduction

The genus *Olea* L. includes several species distributed over tropical and southern Africa, southern Asia and China, as well as Australia, New Caledonia and New Zealand (Mabberley 2017). Only *Olea europaea* L. is present in the Mediterranean Basin, in a various wild [var. *sylvestris* (Mill.) Lehr], domesticated (var. *europaea*) and feral forms (Mulas 2013). As proved by different studies the wild form, the so-called oleaster, is the only ancestor of the domesticated olive (Angiolillo et al. 1999; Lumaret et al. 2004; Breton et al. 2006; 2009; Zohary et al. 2012; Besnard et al. 2016; 2018). The wild form naturally spreads in a great part of the Mediterranean Basin. Its distribution range coincides with the thermo-mesomediterranean belt with dry-subhumid ombrotypes, being one of the main constituents of the scrublands (Bacchetta et al. 2003; Carrion et al. 2010). The domesticated form covers a wider area, extending also to the northern regions of the Mediterranean Basin (Carrion et al. 2010; Zohary et al. 2012).

As shown from archaeological data both from the eastern and the western Mediterranean, human populations exploited the wild olive before its domestication, since the Palaeolithic and Neolithic eras, for its fruits and as a source of wood and forage (Costantini 1989; Kislev et al. 1992; Buxó i Capdevila 1997; Terral 2000; Rodríguez-Ariza, Montes Moya 2005; Weiss 2009; Kaniewski et al. 2012; Besnard et al. 2018).

The first signs of domestication were found in Chalcolithic South-West Asia, in different archaeological sites; this makes the olive one of the first fruit tree to be domesticated (Zohary et al. 2012). The most ancient find is that of Tuleilat Ghassul, at North of the Dead Sea; in this site a considerable amount of olive endocarps, attributed to the domesticated variety, has been dated 6.800-5.800 BP (Zohary, Spiegel Roy 1975; Lovell et al. 2010; Zohary et al. 2012; Weiss 2015). Nevertheless, the origin of its domestication is still under debate. Some studies hypothesise that during the Bronze Age, especially the Middle and Late Bronze Age, the domestication process fully developed in South-West Asia and it gradually spreads to the Aegean and then to the western Mediterranean (Terral et al. 2009; Zohary et al. 2012; Pérez-Jordà et al. 2017; Breton et al. 2018; Valamoti et al. 2018).

As for the spread of the cultivation of this plant to the western Mediterranean, it is certain that Phoenicians and Greeks played an important role, taking to the West domesticated olives from the eastern Mediterranean, together with cultivation techniques (Zohary et al. 2012). Nevertheless, it seems nowadays that the domestication process in this area has been more complicated, and it is not yet completely clear. Genetic and morphometric analysis have been adopted to understand the complex phenomenon that undertook to the actual olive varieties and cultivars and to characterise them (Baldoni et al. 2006; Breton et al. 2006; 2009; Belaj et al. 2011; Muzzalupo et al. 2014; Besnard et al. 2016). The studies suggest that the cultivated variety was introduced to the western Mediterranean from South-West Asia (Besnard et al. 2018). However, it could be that at least secondary domestication events took place, as there seem to be signs of an early domestication in the Iberian Peninsula since the Bronze Age (Terral et al. 2009), as well as in the Italian Peninsula (D'Auria et al. 2016). Numerous crosses between introduced plants and local oleasters followed in different regions during the millennia, in what is a still ongoing process (Breton et al. 2009; Newton et al. 2014; Besnard et al. 2018). Anyway, during the first millennium BC domesticated olives should have spread in almost all parts of the Mediterranean Basin (Zohary et al. 2012). Later, during the Roman Empire the cultivation and the trade of olive products gradually increased, at the point that at its highest the production of olive oil in the Roman world could have reached up to 1 billion litres per year (van der Veen 2018).

Olive growing is nowadays not only one of the most important features of Italian agriculture, but also one of the most ancient (Caracuta 2020). In Sardinia the oleaster is spontaneously present (Bacchetta el al. 2003), and the domesticated olive is widely cultivated (Piras & Lovicu 2013; Bandino & Sedda 2013; Chessa 2013). Different episodes of introduction of allochthonous domesticated plants from different parts of the Mediterranean could have happened during history, due to its central position that could have favoured contacts from different areas, and to the multiple colonisation and conquest events (Erre et al. 2010; Cossu 2013; De Santis 2013; Ferrante 2013).

At the moment, according to the FAO Olive Germplasm Plant Production and Protection Division, the world olive germplasm contains some 2.600 cultivars, many of which need a better identification and characterisation (FAO 2010). The presence of homonyms and synonyms, and the different state of research according to different regions, can generate misunderstanding in their classification (Ganino et al. 2006; Díez et al. 2012; Muzzalupo 2014; Belaj et al. 2016). A continuous improvement of the classifications is necessary for better exploitation, selection and propagation choices.

Morphometric features involving the different characteristics of the fruits are currently used to define the cultivars (Ganino et al. 2006). Computerised image analysis on olive endocarps is particularly suitable, as the endocarps do not seem to undergo through significant variations according to different environmental conditions and cultivation techniques, reducing the confounding factors that could influence the measurements (Terral et al. 2004; Belaj et al. 2016). Therefore, their morphometric analysis can be used to compare the archaeobotanical remains with modern specimens, with the great advantage of using a low-cost and non-destructive method (Newton et al. 2006; 2014; Terral et al. 2009).

Different approaches have already been used in the study of the olive germplasm (Bronzini de Caraffa et al. 2002; Baldoni et al. 2006; Erre et al. 2010; Muzzalupo et al. 2014). The recent study of Piras et al. (2016) on Sardinian olive successfully applied morpho-colorimetric techniques that has also proved its usefulness on the analysis of other plant species, such as *Vitis vinifera* L. (Orrù et al. 2013; Ucchesu et al. 2015), *Prunus domestica* L. (Sarigu et al. 2017; Frigau et al. 2020) and *Malus domestica* Borkh. (Sau et al. 2018; 2019).

This work studies archaeological olive endocarps found in the archaeological contexts of the Santa Giusta and Mistras lagoons in Sardinia, dated to the Archaic and Punic period, covering a time span which goes from the 7th century BC to the 3rd century BC. Thanks to digital image analysis the morphometric characteristics of the olive endocarps are extrapolated, and the archaeological ones are compared to endocarps from wild and cultivated plants by Linear discriminant analysis (LDA). The aims are to obtain information about the state of domestication of the olive during the Archaic and Punic period in Sardinia and to find possible similarities with modern cultivars that could give hints about the origins of these last ones.

Archaeological contexts

The Santa Giusta Lagoon and the Mistras Lagoon are located respectively in the central and in the northern part of the gulf of Oristano (Fig. 1).

Fig. 1 - Location of the excavation areas in the Santa Giusta and Mistras lagoons, Central-West Sardinia.

The Santa Giusta lagoon is situated next to the ancient city of Othoca, one of the most important settlements during the Archaic and Punic period in Sardinia (Del Vais 2010). The lagoon, deep from 40 to 150 cm, has an approximately circular shape and an extension that in winter reaches the 900 ha. The Soprintendenza Archeologica per le Province di Cagliari e Oristano and the University of Cagliari investigated the site since 2005 through underwater surveys, coring of the sediments and stratigraphic excavations that enabled a good reconstruction of the deposition sequences (Del Vais & Sanna 2009; 2012). The investigations documented the presence in the middle of the lagoon of a large dispersion area of archaeological material, the most evident being wood remains and transport amphorae (Del Vais & Sanna 2009; 2012; Del Vais 2018). A certain number of amphorae were recovered during the excavations and the sediment inside them was sieved to recover content remains (Sabato et al. 2019).

The Mistras lagoon has been identified as the harbour of the city of Tharros since the 7th century BC until the 3rd century BC (Pascucci et al. 2018; Del Vais et al. 2020). The lagoon, elongated in shape and parallel to the shore, is partially closed by a coastal barrier system. In 2009, the same Soprintendenza and University as in the case of Santa Giusta undertook a survey inside the lagoon to investigate a submerged structure; the study of different materials found in the area gave for the context a broad range of dating which goes from the late Punic period to the first centuries of the Roman era (Pascucci et al. 2018). However, the carpological remains were found in association with materials dating to the 3rd-2nd century BC (Del Vais et al. 2020); this seems their most probable chronological collocation, in good correlation with the radiocarbon dating executed on other organic elements found in the area (Pascucci et al. 2018). During 2014 and 2015, the University of Cagliari excavated in two different areas of the sandy barrier located inside the lagoon, formerly a palaeobeach; according to preliminary results the stratigraphic units from which the materials for the present study were sampled contain materials dating from the 7th to the 4th century BC (Pascucci at al. 2018); however, as many of the elements found during the excavation campaigns are still under study, the dating of the sites is not unequivocally established to the day. The archaeological material found on the three sites investigated in Mistras is represented by ceramic fragments, especially transport amphorae, and by animal bones, wood and vegetal macroremains.

Materials and methods

The olives are stone fruits composed of different layers: the outer and middle ones called epicarp and mesocarp, and the inner layer called endocarp, which encloses the seed (Cappers and Bekker 2013). The endocarp represents almost the only type of olive's remain found on archaeological excavations; as a consequence, it is also the most useful element in archaeobotanical studies concerning this plant.

Archaeological samples

Olive endocarps, well preserved thanks to the waterlogged and anaerobic conditions of the sites, were found both in the Santa Giusta and Mistras lagoons. The endocarps from Santa Giusta come from four transport amphorae, which types are typical of the Sardinian Phoenician and Punic tradition (Ramon Torres 1995). The most ancient ones are the A158 and the A97; the typological study enabled an attribution for the A158 to the Ramon T-1.2.1.2. (Del Vais & Sanna 2012), dated to the first two thirds of the 6th century BC (Ramon Torres 1995), while the A97 was attributed to the T-1.4.4.1. (Del Vais & Sanna 2012), dated to the 5th century BC (Ramon Torres 1995). According to previous analysis the A97 also contained one *Prunus domestica* L. fruitstone, *Pinus pinea* L. and *Corylus avellana* L. remains, as well as animal remains (Ucchesu et al. 2017). The other two amphorae, A153 and A230, can be attributed to the elongated type T-5.2.1.3., dated to the

3^{rd}-2^{nd} century BC (Ramon Torres 1995; Del Vais & Sanna 2012). The dating is also corroborated by the deposition history, reconstructed thanks to the stratigraphic investigation of the context (Del Vais & Sanna 2009; 2012). A total of 14 olive endocarps were found inside the Santa Giusta amphorae.

In the Mistras site, 44 and 53 endocarps respectively from the 2014 and 2015 campaigns were found thanks to the sampling and sieving of the sediment. The finds come from different layers (US 26, US 31, US 32, US 34, US 35 of the 2014 excavation, and US 24, US 25 and US 26 of the 2015 excavation). Other 29 olive endocarps were recovered during the 2009 Mistras underwater excavation.

In order to maintain the good preservation of the endocarps, after the recovery they were stored in de-ionized water at 5°C in the Sardinian Germplasm Bank (BG-SAR) (Porceddu et al. 2017).

A total of 139 archaeological endocarps were analysed (Table 1).

Context	Amphora/Stratigraphic Unit	Group code	Date (century BC)	N. of endocarps
Santa Giusta	SGT-ST ANF 158	SGT-ST A	6th-5th	3
	SGT-ST ANF 97			3
	SGT-ST ANF 230	SGT-ST B	3rd-2nd	4
	SGT-ST ANF 153			4
Mistras 2014	MIS14 Section	MIS14	7th-5th	4
	MIS14 US26			3
	MIS14 US31			11
	MIS14 US32			9
	MIS14 US34			7
	MIS14 US35			6
Mistras 2015	MIS15 US24	MIS15	6th-4th	8
	MIS15 US25			23
	MIS15 US26			22
Mistras 2009	MIS09	MIS09	3rd-2nd	29

Table 1 - Archaeological endocarps lot details from Santa Giusta and Mistras lagoons. A broad datation range is given according to preliminary results, as the whole data coming from the sites is still under study.

Modern samples

Modern olive endocarps used in this study were sampled from ancient trees, wild populations, and from cultivars (Fig. 2; ESM 1).

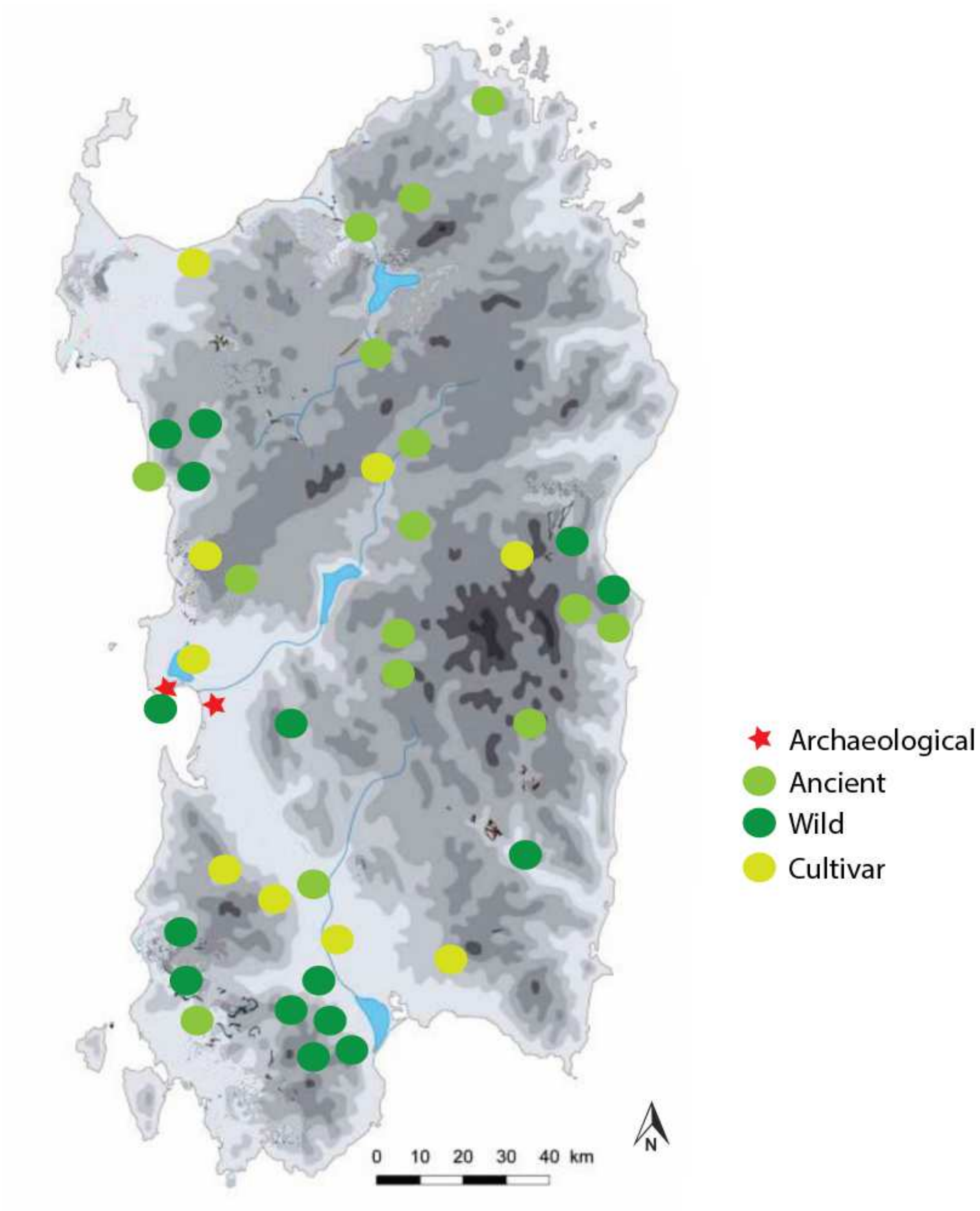

Fig. 2 - Sampling locations of archaeological, ancient trees, wild and cultivated olive endocarps.

The samples collected from ancient trees come from 15 different locations, where the trees for the collection were chosen taking into consideration their monumental dimensions (from 3 m to 12,6 m of circumference measured at 1,3 m from the ground) (Fig. 2; ESM 1). According to their location and dimension, they can be considered wild olives of old age, excluding an attribution to feral forms (Piras et al. 2016). Fruits of *O. europaea* var. *sylvestris* were collected from 18 wild populations isolated from cultivated areas, to avoid possible hybrids (Fig. 2). Furthermore, olives coming from 62 cultivars were sampled during different years in the field collections of Agris Sardegna

(Agricultural Research Agency of Sardinia), and in fields in the main growing areas. The cultivars sampled as comparison material are representative of the olive diversity of the entire Mediterranean Basin, as the main cultivars from Spain, France, Italy, Tunisia, Greece and Turkey were analysed (ESM 1). The Sardinian germplasm in particular is represented by 23 cultivars, enabling a more in depth analysis. The cultivars were grouped according to their pertinence to the same varietal groups, certified by genetic affinities (Erre 2010; Bandino & Sedda 2013; Chessa 2013; http://www.oleadb.it) (ESM 2).

Fruits were picked up from different trees of the same population for the wild olives and of the same variety for the cultivars, to ensure the greatest morphological variability; they were sampled in autumn, at the full ripeness of the fruit, to ensure the complete morphological development of the endocarps. Then the exocarps and mesocarps were removed and the endocarps perfectly cleaned. In total 10.919 modern olive endocarps were included in the analysis.

Image analysis

Digital images of all the archaeological and modern endocarps were acquired using a flatbed scanner (Epson Perfection V550), with a resolution of 400 dpi, on a scanning area not exceeding 1.024 × 1.024 pixels. Each accession was scanned twice, with a white background and then a black background (Bacchetta et al. 2008).

The images were then processed and the morphometric parameters of each endocarp were extrapolated with the open-source software ImageJ v. 1.52 (htto://rsb.info.nih.gov/ij).

The plugin Particles8 (http://www.mecourse.com/landinig/software/software.html) was used to measure 26 morphometric variables. In addition, 80 Elliptic Fourier Descriptors (EFDs), which describe the contour shape, were extrapolated thanks to another specific plugin (Diaz 2017), as described by Sau et al. (2019). An overall number of 106 morphometric variables were measured on each endocarp.

Statistical analysis

All the morphometric parameters were used to build a database of the descriptive features. Then statistical analysis was applied to compare the archaeological endocarps, considered as unknown cases, to the modern ones. The stepwise Linear Discriminant Analysis (LDA) was applied using the SPSS software (Statistical Package for the Social Sciences) release 27.0.1.0 (SPSS Inc. for Windows, Chicago, Illinois). The LDA is a method useful to identify or classify unknown groups characterised by quantitative and qualitative parameters (Fisher 1936; 1940; Sugiyama 2007); it allows to minimize the between-class distance and maximise the within-class distance, achieving the maximum class discrimination (Hastie et al. 2002; Holden et al. 2011; Rencher & Christensen 2012; Kuhn-Johnson 2013). The stepwise method selects the most significant parameters for each endocarp, using the statistical parameters Tolerance, which indicates the proportion of a variable variance not accounted by other independent variables in the equation, and F-to-enter and F-to-remove, which determinate the influence of each variable on the model and describe what happens when a variable is inserted or removed (Bacchetta et al. 2010). The stepwise method starts with a model with no variables, and includes them step by step; at each step the predictor with the largest F-to-enter value exceeding the entry criteria ($F \geq 3.84$) is added to the model. When no more variables are useful to increase the discrimination ability, the process is automatically stopped (Venora et al. 2009). Then a cross-validation procedure verifies the performance of the validation system.

Results

A first analysis on the archaeological endocarps from the different archaeological sites, to determine differences and similarities between the finds from the different contexts, was executed (Table 2). The analysis of the endocarps found in the transport amphorae of Santa Giusta perfectly classified them according to their provenance (ESM 3) as well as to their chronology (Table 2).

	SGT-ST A	SGT-ST B	Total
SGT-ST A	**100.0 (6)**	-	100.0 (6)
SGT-ST B	-	**100.0 (12)**	100.0 (8)
Overall			100.0 % (14)

Table 2 - Correct classification percentages of archaeological olive endocarps from Santa Giusta lagoon according to their chronology. The number of endocarps is given in parenthesis.

The endocarps from the excavations of MIS14 and MIS15 were compared according to their context and to their stratigraphic unit (ESM 4). The correct classification percentage reached an overall classification of 34,0%, and the higher correct classification was reached by the sample MIS14 US32, with the high percentage of 84,6%. However, crossed identifications between stratigraphic units and from one site to the other were frequent. For this reason, and for the affinity of the archaeological contexts, the endocarps from these two sites are considered as a unique group in the following analysis with the modern samples.

The different groups of archaeological endocarps were then compared to the modern samples. As a first step, to verify the level of correctness in the discrimination between cultivars and wild olive endocarps, only the modern samples, divided into ancient trees, wild olives and cultivars, were analysed (Table 4). The number of misattributions was very low, confirming the reliability of the classification. Only the endocarps from ancient trees were distributed in almost equal parts between ancient trees and wild olives.

	A	W	C	Total
A	**40.4 (227)**	47.3 (266)	12.3 (69)	100.0 (562)
W	12.7 (278)	**78.1 (1711)**	9.2 (201)	100.0 (2190)
C	0.7 (58)	2.4 (193)	**96.9 (7916)**	100.0 (8167)
Overall				90.2% (10.919)

Table 4 – Correct classification percentages of modern olive endocarps: A = Ancient tree, W = Wild population, C = Cultivar. The number of endocarps is given in parenthesis.

The four groups of archaeological endocarps, considered as unknown, were compared to the ancient trees, wild olives and cultivars (Table 5). The LDA analyses identified the endocarps from Santa Giusta (STG-ST A, SGT-ST B) almost completely as wild, classifying them on both ancient trees (50,0%) and wild olive populations (87,5%) (Table 5). In the case of Mistras a significant number of endocarps was identified as cultivated, with a percentage respectively of 47,4% in the MIS14 MIS15 group, and of 75,9% in the MIS09 sample.

	A	W	C	Total
SGT-ST A	**50.0 (3)**	33.3 (2)	16.7 (1)	100.0 (6)
SGT-ST B	12.5 (1)	**87.5 (7)**	-	100.0 (8)
MIS14 MIS15	20.6 (20)	32.0 (31)	**47.4 (46)**	100.0 (97)
MIS09	17.2 (5)	6.9 (2)	**75.9 (22)**	100.0 (29)

Table 5 - Correct classification percentages among archaeological and modern endocarps: A = Ancient tree, W = Wild population, C = Cultivar. The number of endocarps is given in parenthesis.

The archaeological endocarps identified as wild were then considered in relation to the accessions coming from the ancient trees and the wild populations, and the ones identified as cultivated were compared to the different cultivar groups in the database. A previous analysis on the modern samples was executed to establish their correct classification percentages; then the modern samples with classification percentages below 5,0% were excluded to avoid further misattributions (ESM 5; ESM 6).

The highest percentages of attribution reached by the archaeological wild endocarps are those of the group SGT-ST A, and of MIS09. They classify respectively to the 80,0% and the 42,9% in the accession of the ancient trees of SS_M. The fruit-stones from SGT-ST B are attributed with the 16,7% to several accessions, VI_M, AR, PAW, VI (Table 6). In the case of the fruit-stones from MIS14 MIS15 the highest percentage goes to the accession of PAW with the 17,6%. Lower percentages of the archaeological groups are attributed to other accessions pertaining to both ancient trees and modern wild populations (Table 6).

	Correct classification of modern samples	Archaeological endocarps classification			
		SGT_ST A (5)	SGT-ST B (12)	MIS14 MIS15 (51)	MIS09 (7)
BA_M (12)	83,3 (10)	-	-	-	-
GP_M (36)	19,4 (7)	-	-	-	-
CU_M (12)	33,3 (4)	-	-	5,9 (3)	14,3 (1)
OZ_M (11)	9,1 (1)	-	-	-	14,3 (1)
PA_M (12)	41,7 (5)	-	-	-	-
US_M (12)	8,3 (1)	-	-	-	-
LU_M (12)	8,3 (1)	-	-	-	-
SS_M (228)	48,2 (110)	**80,0** (4)	-	13,7 (7)	**42,9** (3)
SA_M (36)	30,6 (11)	-	-	-	-
SE_M (36)	11,1 (4)	-	-	-	-
VI_M (23)	34,8 (8)	-	**16,7** (2)	7,8 (4)	-
MN_M (60)	26,7 (16)	-	8,3 (1)	3,9 (2)	-
AR (120)	42,5 (51)	-	**16,7** (2)	11,8 (6)	14,3 (1)
CD (144)	19,4 (28)	-	-	3,9 (2)	-
CL (126)	19,0 (24)	-	-	5,9 (3)	-
GP (120)	17,5 (21)	-	-	2,0 (1)	-
SP (108)	25,9 (28)	-	-	2,0 (1)	14,3 (1)
IC (117)	29,9 (35)	-	8,3 (1)	2,0 (1)	-
MA (119)	25,2 (30)	-	-	2,0 (1)	-
MF (120)	16,7 (20)	-	-	-	-
PS (119)	25,2 (30)	-	-	-	-

SM (120)	82,5 (99)	-	-	2,0 (1)	-
SN (120)	20,8 (25)	-	-	-	-
CS (119)	16,8 (20)	-	-	-	-
TE (83)	14,5 (12)	-	8,3 (1)	-	-
TR (131)	21,4 (28)	-	8,3 (1)	9,8 (5)	-
PAW (195)	30,8 (60)	20,0 (1)	**16,7** (2)	**17,6** (9)	-
VI (92)	57,6 (53)	-	**16,7** (2)	9,8 (5)	-
Overall 30,4 % (2443)					

Table 6 - Correct classification percentages among wild olives endocarps and archaeological ones identified as *O. europaea* var. *sylvestris* from Mistras and Santa Giusta. The number of endocarps is given in parenthesis.

Finally, the cultivated archaeological endocarps were analysed to find possible similarities with modern cultivars (Table 7). They were attributed with different classification percentages to several accessions. Not taking into consideration the SGT-ST A result, as only one seed was involved in this step, the highest rate of identification with some of the modern groups of cultivars was reached by the endocarps of MIS14 MIS15, with 39,1% on G4, followed by MIS09 with 22,7% on the same group (Table 7).

Modern cultivar samples	Correct classification of modern samples	Archaeological endocarps classification		
		SGT_ST A (1)	MIS14 MIS15 (46)	MIS09 (22)
G1 (418)	41,1 (172)	-	-	4,5 (1)
CA (220)	14,1 (31)	-	4,3 (2)	-
G2 (445)	48,7 (169)	-	-	-
GI (216)	31,9 (69)	-	-	-
G3 (217)	9,7 (21)	-	-	4,5 (1)
HB (215)	61,9 (133)	-	-	4,5 (1)
KA (220)	53,6 (118)	-	-	9,1 (2)
KO (218)	59,2 (129)	-	-	-
LE (217)	23,0 (50)	-	8,7 (4)	9,1 (1)
MAN (220)	36,4 (80)	-	4,3 (2)	4,5 (1)
MO (216)	36,1 (78)	-	-	-

G4 (767)	63,1 (484)	-	**39,1** (18)	**22,7** (5)
NB (219)	52,5 (115)	-	-	-
G5 (902)	55,2 (498)	-	4,3 (2)	-
NE (220)	45,0 (99)	-	-	-
PE (118)	58,5 (69)	-	6,5 (3)	-
PI (220)	52,3 (115)	-	-	-
G6 (231)	45,9 (106)	-	-	-
SEM (219)	39,7 (87)	-	-	-
SV (214)	46,7 (100)	-	2,2 (1)	-
AS (99)	18,2 (18)	-	-	-
BC (85)	58,8 (50)	-	-	-
BS (100)	35,0 (35)	-	2,2 (1)	-
CAR (100)	72,0 (72)	-	-	-
CAS (98)	80,6 (79)	-	6,5 (3)	13,6 (3)
KON (99)	10,1 (10)	-	-	-
COR (100)	46,0 (46)	-	-	-
CU (99)	22,2 (22)	-	-	9,1 (2)
ER (100)	30,0 (30)	-	-	-
LEU (100)	48,0 (48)	-	6,5 (3)	-
LU (99)	9,1 (9)	-	-	-
MAI (100)	20,0 (20)	-	2,2 (1)	4,5 (1)
MAU (104)	31,7 (33)	**100,0** (1)	6,5 (3)	4,5 (1)
MEM (99)	53,5 (53)	-	-	-
NM (94)	14,9 (14)	-	-	-
NO (95)	51,6 (49)	-	-	-
NU (99)	29,3 (29)	-	-	9,1 (2)
OL (25)	52,0 (13)	-	-	-
PAS (44)	13,6 (6)	-	-	-
PIC (99)	21,2 (21)	-	2,2 (1)	-
SF (100)	59,0 (59)	-	2,2 (1)	-
TI (100)	26,0 (26)	-	2,2 (1)	-
UP (96)	55,2 (53)	-	-	-

Overall 44,2 % (7968)

Table 7 – Correct classification percentages among cultivars and archaeological endocarps identified as *O. europaea* var. *europaea* from Mistras. The cultivars are grouped according to their genetic affinities. The number of endocarps is given in parenthesis.

Discussion

The comparison between the olive endocarps found on the archaeological sites of Santa Giusta and Mistras with modern samples collected on ancient trees, wild olive populations and cultivars, permits to elaborate different considerations on the presence of the olive during the Archaic and Punic period in Sardinia. In the case of the samples coming from the Archaic and Punic site of Santa Giusta, the statistical analysis revealed how the samples SGT-ST A and SGT-ST B, dating respectively to the 6^{th}-5^{th} century BC and to the 3^{rd}-2^{nd} century BC, when compared to one another, clearly separate in two distinct groups according to their chronology. Both groups were recognised as wild olives, except one endocarp from SGT-ST A, which was classified as cultivated. The SGT-ST A endocarps recognised as wild found the best classification with the modern accession SS_M, that represents the ancient trees of San Sisinnio (Villacidro, SW Sardinia), a locality in the Middle Campidano plain distant some 50 km from the archaeological sites; the trees of San Sisinnio, possibly millennials, pertain to the most extensive aggregation of wild olives of old age in Sardinia (Chessa 2013). On the other side the SGT-ST B sample resembles to several accessions, with the highest percentages on the accession of VI_M from Giagazzu, Viddalba, situated at more than 100 km from the site, in the northern part of Sardinia, on AR, from Armungia, a quite isolated population at some 80 km of distance from Santa Giusta, and on the wild population of of PAW and VI; in these two last cases the wild populations are situated in the territory of Pau and Villaverde in the Monte Arci, at less than 20 km from the site.

The endocarps from the different excavations held in the Mistras lagoon provided some different results. The comparison between the groups MIS14 and MIS15, dated to the Archaic and Punic period (7^{th}-4^{th} century BC), and MIS09, coming from a slightly more recent context (3^{rd}-2^{nd} century BC), showed a certain similarity. If the chronological overlap is present, although low, the collection area of the olives could perhaps have been similar.

In the analysis with the modern sample, MIS14 MIS15 endocarps were classified half as wild olives and half as cultivars, while most of the findings of MIS09 were attributed to cultivated olives. However, the result of the more specific analysis was similar, particularly in the case of the endocarps recognised as domesticated, as both groups found a resemblance to the same modern accession. The archaeological olive endocarps with wild features were attributed predominantly to PAW, and secondarily to SS_M, in the case of MIS14 MIS15, while a greater part of MIS09 endocarps with wild morphotype was reconducted to SS_M. On the other side, the ones recognised as cultivated were in both cases similar to the modern sample G4. This result is quite remarkable; in fact, G4 is a group that includes the cultivars Nera di Gonnos, Confetto, Maiorca, Sivigliana da mensa, Manna and Tonda di Cagliari, which pertain to the same varietal group, and show genetic affinities revealed by molecular analysis (Erre et al. 2010; Chessa 2013). They are all traditional Sardinian cultivars, cultivated nowadays in the Central-West and South-West part of the Island, especially in the Campidano of Oristano, the Middle Campidano, the Trexenta and the Parteolla (Bandino & Sedda 2013). At the same time, they have no genetic affinities with any other registered cultivars (Chessa 2013).

Even if the low number of the archaeological endocarps considered does not allow strong assessments, it is at least possible to underline some results that seem significant. The resemblance of the archaeological samples recognised as wild olives to the ancient trees of SS_M, and secondly to isolated modern wild populations, can be explained with the sharing of archaic characteristics; this seems more reasonable than an affinity due to the collection of wild olives in those same areas during the antiquity. Nevertheless, this possibility cannot be excluded for the populations of the Monte Arci, situated between 10 and 20 km from the archaeological sites; it can also be noted how previous analysis on *Prunus spinosa* archaeological endocarps found in the Santa Giusta lagoon found the best resemblances with *P. spinosa* modern samples collected in the Monte Arci (Ucchesu et al. 2017).

Even more interesting is the closeness of the archaeological endocarps recognised as cultivated with a group of cultivars typical of Sardinian traditional olive-growing, especially because the genetic data at disposition point to an autochthonous origin for them. Without going as far as to claim an identity, the morphometric results presented, in addition to the genetic analysis, reinforce the hypothesis of a local and ancient origin of these typical Sardinian cultivars.

From the archaeological point of view, we shouldn’t forget that both sites are in some degree related to the transport of goods and, in the case of Mistras, recognised as possible harbours; therefore, the presence of imported materials is possible. However, all the exposed data suggest a local provenance for the olive endocarps found in Santa Giusta and Mistras. In any case the presence of cultivated olives is a clear fact. As already stated (Sabato et al. 2019), the association of olive endocarps with transport amphorae could be a hint indicating their transport as fruits, or their use as ingredients of elaborated food products. On the contrary, as the contexts are clearly not production sites, it is not possible to advance hypothesis on the production of olive oil.

In the last decades, thanks to archaeobotanical research, our knowledge on the state of agriculture and exploitation of plants in the Ancient world grow considerably. In the case of Sardinia several studies already underlined the importance of fruit trees in the local agriculture since the Bronze Age, as is the case of *Vitis vinifera* (Ucchesu et al. 2015), and from the Phoenician and Punic period in the case of *Prunus domestica* (Ucchesu et al. 2017) and a variety of other fruits between which the presence of *O. europaea* has been underlined (Del Vais & Sanna 2009; 2012; van Dommelen et al. 2018; Sabato et al. 2019). Moreover, the presence of *O. europaea* in the area of Tharros, and in the same Mistras area is already known thanks to palynological, anthracological and xylological analysis, even if these procedures cannot enable a distinction between wild and domesticated olive (Nisbet 1980; Lentini 1997; Acquaro et al. 2001; Di Rita & Melis 2013; Mureddu et al. 2020). At the same time a growing number of scholars is concentrating the efforts on the investigation of the agricultural exploitation in the different regions interested by the Phoenician and Punic presence; the studies are revealing the intensity of the agrarian penetration, but also a variegated panorama of agricultural activities and products (van Dommelen & Gómez Bellard 2008; 2012; Pérez et al. 2010; Roppa & van Dommelen 2012; Del Vais 2014; Roppa 2014; Secci 2016). The results here presented add now significant information for what concerns *O. europaea*, a fruit tree which still has great agricultural and economic value at world scale.

Conclusions

The morphometric analysis on the olive endocarps found in the Santa Giusta and Mistras lagoons was helpful in clarifying the state of olive domestication in Sardinia during the Archaic and Punic period. The use, or at least the presence, of wild olives in the two contexts was recognised, and a high percentage of domesticated olives was found in the Mistras contexts. These domesticated archaeological olive endocarps showed a clear resemblance with a group of Sardinian cultivars. The results prove the presence of domesticated olives in Sardinia at least since the Archaic and Punic period. Furthermore, it seems possible to hypothesise an ancient origin for some of the traditional cultivars still grown on the Island. Further analysis, and an improvement of the archaeological and modern olive fruit-stones database, will be useful in future investigations for a better reconstruction of the history of olive domestication, and for the detection of the origins of the modern cultivars.

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Additional material

Sample code	Type	Cultivar	Sampling area	Main areas of cultivation	N. endocarps
AT_M	A	_	Quaddoru - Atzara	_	48
BA_M	A	_	Barbusi - Carbonia	_	12
GP_M	A	_	Golgo San Pietro - Baunei	_	36
BO_M	A	_	S'Orculana - Bottida	_	12
CU_M	A	_	Tanca Manna - Cuglieri	_	12
LA_M	A	_	Grumu orgiastru - Laconi	_	12
OZ_M	A	_	Meleu - Ozieri	_	11
PA_M	A	_	Stazzareddu - Palau	_	12
US_M	A	_	Niala - Ussassai	_	12
LU_M	A	_	Santu Baltolu di Carana - Luras	_	12
SS_M	A	_	San Sisinnio - Villacidro	_	228
SA_M	A	_	Valeri - Sarule	_	36
SE_M	A	_	Sedduri - Bosa	_	36
VI_M	A	_	Giagazzu - Viddalba	_	23
MN_M	A	_	Santa Maria Navarrese - Baunei	_	60
AR	W	_	Sa Pala ’e Steri - Armungia	_	120
BO	W	_	Tangone - Bosa	_	120
CD	W	_	Cala Domestica - Buggerru	_	144
CL	W	_	Cala Luna - Baunei	_	126
GP	W	_	Golgo is Piscinas - Baunei	_	120
SP	W	_	Golgo San Pietro - Baunei	_	108
IC	W	_	Is Cioffus - Assemini	_	117
MA	W	_	Capo Marrargiu - Bosa	_	119
MF	W	_	Mitza Fanebas - Assemini	_	120
PS	W	_	Perdu Secci - Assemini	_	119
SM	W	_	Capo San Marco - Cabras	_	120
SN	W	_	San Nicolò - Buggerru	_	120
SE	W	_	Sedduri - Bosa	_	117
CS	W	_	Su Campu Santu de is Orrù - Assemini	_	119
TE	W	_	Agro di Teulada - Teulada	_	83
TR	W	_	Trunconi - Assemini	_	131
PAW	W	_	Agro di Pau - Pau	_	195

VI	W	_	Agro di Villaverde-Villaverde	_	92
BOS	C	Bosana	Cuglieri + Villasor AGRIS	Sardinia	220
CA	C	Carolea	Villasor AGRIS	Italy	220
CO	C	Corsicana da olio	Villasor AGRIS	Sardinia	228
FR	C	Frantoio	Villasor AGRIS	Italy	119
GI	C	Giarraffa	Illorai AGRIS + Villasor AGRIS	Sicily	216
GO	C	Gordales	Sassari AGRIS	Spain	118
HB	C	Hojiblanca	Sassari AGRIS + Villasor AGRIS	Spain	215
KA	C	Kalamata	Villasor AGRIS	Greece	220
KO	C	Koroneiki	Villasor AGRIS	Greece	218
LE	C	Leccino	Villasor AGRIS	Italy	217
MAN	C	Manzanilla	Illorai AGRIS + Villasor AGRIS	Spain	220
MO	C	Moresca	Illorai AGRIS + Villasor AGRIS	Sicily	216
NG	C	Nera di Gonnos	Gonnosfanadiga	Sardinia	120
NV	C	Nera/Tonda di Villacidro	Villacidro + Villasor AGRIS	Sardinia	218
NB	C	Nocellara del Belice	Illorai AGRIS + Villasor AGRIS	Sicily	219
NE	C	Nocellara etnea	Illorai AGRIS + Villasor AGRIS	Sicily	220
PE	C	Pendolino	Villasor AGRIS	Italy	118
PI	C	Picholine	Villasor AGRIS	France	220
PC	C	Pitz'e Carroga	Dolianova + Villasor AGRIS	Sardinia	217
SEM	C	Semidana	Cabras + Villasor AGRIS	Sardinia	219
SV	C	Sivigliana da olio	Villasor AGRIS	Sardinia	214
TC	C	Tonda di Cagliari	Dolianova + Villasor AGRIS	Sardinia	208
AS	C	Ascolana semitenera	Villasor AGRIS	Italy	99
BC	C	Bella di Cerignola	Villasor AGRIS	Italy	85
BS	C	Bella di Spagna	Villasor AGRIS	Italy	100
CAR	C	Cariasina	Villasor AGRIS	Sardinia	100
CAS	C	Cassanese	Villasor AGRIS	Italy	98
CON	C	Confetto	Villasor AGRIS	Sardinia	99
KON	C	Conservolia	Villasor AGRIS	Greece	99
COR	C	Coratina	Villasor AGRIS	Italy	100

COM	C	Corsicana da mensa	Villasor AGRIS	Sardinia	99
CU	C	Cucco	Villasor AGRIS	Italy	99
ER	C	Erkence	Villasor AGRIS	Turkey	100
GR	C	Grossane	Villasor AGRIS	France	99
IT	C	Itrana	Villasor AGRIS	Italy	107
LEU	C	Leucocarpa	Villasor AGRIS	Italy	100
LU	C	Lucques	Villasor AGRIS	France	99
MAI	C	Maiatica	Villasor AGRIS	Italy	100
MAJ	C	Maiorca	Villasor AGRIS	Sardinia	70
MN	C	Manna	Villasor AGRIS	Sardinia	86
MAU	C	Maurino	Villasor AGRIS	Italy	104
MEM	C	Memecik	Villasor AGRIS	Turkey	99
NM	C	Nocellara messinese	Villasor AGRIS	Sicily	94
NO	C	Nociara	Villasor AGRIS	Italy	95
NR	C	Nostrale di Rigali	Villasor AGRIS	Italy	100
NU	C	Nucalia	Villasor AGRIS	Italy	99
OG	C	Ogliastrina	Villasor AGRIS	Sardinia	92
OD	C	Olia durci	Villasor AGRIS	Sardinia	14
OL	C	Olia longa	Villasor AGRIS	Sardinia	25
OLA	C	Olianedda	Villasor AGRIS	Sardinia	94
OLU	C	Olieddu	Villasor AGRIS	Sardinia	98
PA	C	Paschixedda	Villasor AGRIS	Sardinia	100
PAS	C	Passulunara	Villasor AGRIS	Sicily	44
PIB	C	Pibireddu	Villasor AGRIS	Sardinia	100
PIC	C	Picual	Villasor AGRIS	Spain	99
SF	C	San Felice	Villasor AGRIS	Italy	100
SC	C	Santa Caterina	Villasor AGRIS	Italy	99
SVM	C	Sivigliana da mensa	Villasor AGRIS	Sardinia	184
TG	C	Terza grande	Villasor AGRIS	Sardinia	100
TP	C	Terza piccola	Villasor AGRIS	Sardinia	92
TI	C	Tonda iblea	Villasor AGRIS	Sicily	100
UP	C	Uovo di Piccione	Villasor AGRIS	Tunisia	96

ESM 1 - Modern endocarps lot details. A = Ancient olives; W = Wild populations; C = Cultivars.

Sample code	Cultivar samples	Varietal group code	Total endocarps
BOS OLU PIB	Bosana Olieddu Pibireddu	SG1	418
CA	Carolea	CA	220
FR CO	Frantoio Corsicana da olio	SG2	445
GI	Giarraffa	GI	216
GO SC	Gordales Santa Caterina	SG3	217
HB	Hojiblanca	HB	215
KA	Kalamata	KA	220
KO	Koroneiki	KO	218
LE	Leccino	LE	217
MAN	Manzanilla	MAN	220
MO	Moresca	MO	216
NG CON MAJ SVM MN TC	Nera di Gonnos Confetto Maiorca Sivigliana da mensa Manna Tonda di Cagliari	SG4	767
NB	Nocellara del Belice	NB	219
OG NV OLA IT COM TG TP PA	Ogliastrina Nera/Tonda di Villacidro Olianedda Itrana Corsicana da mensa Terza grande Terza piccola Paschixedda	SG5	902
NE	Nocellara etnea	NE	220
PE	Pendolino	PE	118
PI	Picholine	PI	220
PC OD	Pitz'e Carroga Olia durci	SG6	231
SEM	Semidana	SEM	219
SV	Sivigliana da olio	SV	214
AS	Ascolana semitenera	AS	99
BC	Bella di Cerignola	BC	85
BS	Bella di Spagna	BS	100
CAR	Cariasina	CAR	100
CAS	Cassanese	CAS	98
KON	Conservolia	KON	99
COR	Coratina	COR	100
CU	Cucco	CU	99
ER	Erkence	ER	100

GR	Grossanne	GR	99
LEU	Leucocarpa	LEU	100
LU	Lucques	LU	99
MAI	Maiatica	MAI	100
MAU	Maurino	MAU	104
MEM	Memecik	MEM	99
NM	Nocellara messinese	NM	94
NO	Nociara	NO	95
NR	Nostrale di Rigali	NR	100
NU	Nucalia	NU	99
OL	Olia longa	OL	25
PAS	Passulunara	PAS	44
PIC	Picual	PIC	99
SF	San Felice	SF	100
TI	Tonda Iblea	TI	100
UP	Uovo di piccione	UP	96

ESM 2 – Grouping of the cultivars according to previously detected synonyms (Erre 2010; Bandino, Sedda 2013; Chessa 2013; http://www.oleadb.it).

	SGT-ST A		SGT-ST B		
	ANF158	ANF97	ANF230	ANF153	Total
ANF158	**100.0** (3)	-	-	-	100.0 (3)
ANF97	-	**100.0** (3)	-	-	100.0 (3)
ANF230	-	-	**100.0** (4)	-	100.0 (4)
ANF153	-	-	-	**100.0** (4)	100.0 (4)
Overall					100.0 (14)

ESM 3 - Correct classification percentages of archaeological olive endocarps from Santa Giusta lagoon according to their pertinence to different transport amphorae. The number of endocarps is given in parenthesis.

		MIS14						MIS15			
		SEZ	US26	US31	US32	US34	US35	US24	US25	US26	Total
MIS14	SEZ	-	-	-	25.0 (1)	-	-	-	75.0 (3)	-	100.0 (4)
	US26	-	**33.3 (1)**	-	-	-	-	-	33.3 (1)	33.3 (1)	100.0 (3)
	US31	-	-	-	36.4 (4)	-	-	-	36.4 (4)	27.3 (3)	100.0 (11)
	US32	-	-	-	**84.6 (11)**	-	-	-	15.4 (2)	-	100.0 (13)
	US34	-	-		57.1 (4)	-	-		42.9 (3)	-	100.0 (7)
	US35	-	-	-	16.7 (1)	-	-	-	16.7 (1)	66.7 (4)	100.0 (6)
MIS15	US24	-	-		12.5 (1)	-	-	-	62.5 (5)	25.0 (2)	100.0 (8)
	US25	-	-	-	17.4 (4)	-	-	-	**39.1 (9)**	43.5 (10)	100.0 (23)
	US26	-	-	-	9.1 (2)	-			36.4 (8)	**54.5 (12)**	100.0 (22)
Overall											34.0 (97)

ESM 4 - Correct classification percentages of archaeological olive endocarps from Mistras 2014 and 2015 excavations according to their pertinence to different stratigraphic units. The number of endocarps is given in parenthesis.

Sample code	Correct classification percentage 1st step	Correct classification percentage 2nd step	Correct classification percentage 3rd step
AT_M (48)	0.0 (0)	-	-
BA_M (12)	75.0 (9)	83.3 (10)	83.3 (10)
GP_M (36)	16.7 (6)	19.4 (7)	19.4 (7)
BO_M (12)	0.0 (0)	-	-
CU_M (12)	25.0 (3)	33.3 (4)	33.3 (4)
LA_M (12)	0.0 (0)	-	-
OZ_M (11)	9.1 (1)	9.1 (1)	9.1 (1)
PA_M (12)	50.0 (6)	41.7 (5)	41.7 (5)
US_M (12)	8.3 (1)	8.3 (1)	8.3 (1)
LU_M (12)	8.3 (1)	8.3 (1)	8.3 (1)
SS_M (228)	49.1 (112)	48.2 (110)	48.2 (110)
SA_M (36)	25.0 (9)	33.3 (12)	30.6 (11)
SE_M (36)	11.1 (4)	11.1 (4)	11.1 (4)
VI_M (23)	34.8 (8)	34.8 (8)	34.8 (8)
MN_M (60)	26.7 (16)	26.7 (16)	26.7 (16)
AR (120)	42.5 (51)	42.5 (51)	42.5 (51)
BO (120)	6.7 (8)	3.3 (4)	-
CD (144)	18.1 (26)	20.8 (30)	19.4 (28)
CL (126)	15.1 (19)	22.2 (28)	19.0 (24)
GP (120)	18.3 (22)	18.3 (22)	17.5 (21)
SP (108)	25.9 (28)	25.9 (28)	25.9 (28)
IC (117)	27.4 (32)	29.9 (35)	29.9 (35)
MA (119)	27.7 (33)	25.2 (30)	25.2 (30)
MF (120)	13.3 (16)	16.7 (20)	16.7 (20)
PS (119)	23.5 (28)	25.2 (30)	25.2 (30)
SM (120)	82.5 (99)	82.5 (99)	82.5 (99)
SN (120)	17.5 (21)	20.0 (24)	20.8 (25)
SE (117)	4.3 (5)	-	-

CS (119)	10.9 (13)	15.1 (18)	16.8 (20)
TE (83)	12.0 (10)	14.5 (12)	14.5 (12)
TR (131)	19.1 (25)	20.6 (27)	21.4 (28)
PAW (195)	31.8 (62)	32.3 (63)	30.8 (60)
VI (92)	55.4 (51)	57.6 (53)	57.6 (53)
Overall	26.3 (2752)	29.4 (2563)	30.4 % (2443)

ESM 5 – Correct classification percentages of ancient trees and wild olives. The samples with a classification <5,0 % were progressively excluded, and the analysis repeated until all the samples reached a correct classification >5,0%.

Sample code	Correct classification percentage 1st step	Correct classification percentage 2nd step
G1 (418)	39.0 (163)	41.1 (172)
CA (220)	11.4 (25)	14.1 (31)
G2 (445)	46.4 (16.1)	48.7 (169)
GI (216)	26.9 (58)	31.9 (69)
G3 (217)	8.3 (18)	9.7 (21)
HB (215)	65.1 (140)	61.9 (133)
KA (220)	55.5 (122)	53.6 (118)
KO (218)	59.6 (130)	59.2 (129)
LE (217)	20.7 (45)	23.0 (50)
MAN (220)	35.5 (78)	36.4 (80)
MO (216)	36.1 (78)	36.1 (78)
G4 (767)	63.1 (484)	63.1 (484)
NB (219)	53.0 (116)	52.5 (115)
G5 (902)	54.8 (494)	55.2 (498)
NE (220)	45.5 (100)	45.0 (99)
PE (118)	58.5 (69)	58.5 (69)
PI (220)	52.7 (116)	52.3 (115)
G6 (231)	45.0 (104)	45.9 (106)
SEM (219)	40.6 (89)	39.7 (87)
SV (214)	42.5 (91)	46.7 (100)
AS (99)	17.2 (17)	18.2 (18)
BC (85)	57.6 (49)	58.8 (50)
BS (100)	37.0 (37)	35.0 (35)
CAR (100)	72.9 (72)	72.0 (72)
CAS (98)	80.6 (79)	80.6 (79)
KON (99)	9.1 (9)	10.1 (10)
COR (100)	46.0 (46)	46.0 (46)
CU (99)	22.2 (22)	22.2 (22)
ER (100)	30.0 (30)	30.0 (30)
GR (99)	4.0 (4)	-
LEU (100)	49.0 (49)	48.0 (48)
LU (99)	9.1 (9)	9.1 (9)
MAI (100)	21.0 (21)	20.0 (20)
MAU (104)	31.7 (33)	31.7 (33)
MEM (99)	51.5 (51)	53.5 (53)
NM (94)	14.9 (14)	14.9 (14)
NO (95)	51.6 (49)	51.6 (49)
NR (100)	3.0 (3)	-
NU (99)	24.2 (24)	29.3 (29)

OL (25)	52.0 (13)	52.0 (13)
PAS (44)	15.9 (7)	13.6 (6)
PIC (99)	21.2 (21)	21.2 (21)
SF (100)	59.0 (59)	59.0 (59)
TI (100)	26.0 (26)	26.0 (26)
UP (96)	54.2 (52)	55.2 (53)
Overall	42.6 % (8167)	44.2 % (7968)

ESM 6 – Correct classification percentages of cultivar groups. The samples with a classification <5,0 % were progressively excluded, and the analysis repeated until all the samples reached a correct classification >5,0%.

Chapter 4

New insights on *Vitis vinifera* L. domestication process thanks to morphometric analysis of archaeological grape pips from Archaic and Punic sites of Sardinia

Introduction

The great interest that the grapevine has exercised and continues to exercise on researchers, whether they are involved in biology, agronomy, archaeobotany or other connected sciences, is quite understandable at the light of the importance of this plant in history, since its domestication thousands of years ago until these days. Its wild form, *Vitis vinifera* subsp. *sylvestris,* present in temperate regions of Eurasia and North-Africa, is a perennial climber that reproduces from seeds (Zohary et al. 2012). The domesticated form, *V. vinifera* subsp. *vinifera*, nowadays spread in almost all the temperate regions of the world, is propagated by cuttings or grafting (Zohary et al. 2012; Mabberley 2017). The berries of *V. vinifera* have been an attractive fruit for humans since ancient times, as they can be consumed fresh or dried, and used to produce the alcoholic product of wine through fermentation (Zohary et al. 2012; Mabberley 2017). In fact, together with *Olea europaea* L., *V. vinifera* represents one of the first cultivated fruit trees, as the very first hints of its domestication date to 6000 BC in South Caucasus (Hancock 2013; McGovern et al. 2017). From that region the culture of the grapevine spread to South-West Asia, then to the Aegeus and finally to the western Mediterranean (Zohary et al. 2012). Several studies, based both on molecular data (Grassi et al. 2003; Arroyo-García et al. 2006; Myles et al. 2011) and on morphometric features (Terral et al. 2010; Ucchesu et al. 2015), point to the existence of secondary domestication centres in the western Mediterranean. It also seems that the circulation of germplasm between East and West was probably limited (Bacilieri et al. 2013); geographical origin and morphological characteristics have been used to define different morphotypes, the *orientalis* with larger berries, the *occidentalis* with smallest berries and fruitful shoots, and the *pontica* with intermediate characteristics (Hancock 2013).

The role of archaeobotanical investigations is fundamental in understanding how and when the viticulture started or was introduced to the different areas, and how the techniques and the cultivated varieties evolved, producing the cultivars used nowadays. The data for the western Mediterranean revealed that grapevine was already cultivated during the Bronze Age in the Italian Peninsula (Marvelli et al. 2013) and in Sardinia

(Ucchesu et al. 2015). In this areas there was perhaps an external input from the eastern Mediterranean, especially the Aegean; it seems in any case that indigenous populations quickly started the domestication of local resources (Marvelli et al. 2013; Ucchesu et al. 2015). In France grapevine cultivation and wine production started presumably after the foundation of the Phocean city of Marseille in 600 BC, and a few centuries later the Etruscan also had a part in the establishment of viticulture in other French Mediterranean areas (McGovern et al. 2013). In the Iberian Peninsula the Phoenicians probably played a major role in the introduction of this agricultural practice (Buxó i Capdevila 1997; Prados Martínez 2011).

Grape pips constitute the element of *V. vinifera* most usually found on archaeological excavations, and they are therefore the main object at disposition for archaeobotanical studies concerning this plant. Their analysis presents several aspects that still deserve deeper consideration. Some research groups managed to extract DNA from archaeological grape pips, obtaining precious information (Manen et al. 2003; Cappellini et al. 2010; Bouby et al. 2021). However the extraction of the DNA from archaeobotanical remains, a part from being a destructive technique, is not always possible or easy. Morphology is considered by some scholars a not completely safe diagnostic trait, because the range of shape variation between wild and cultivated pips overlaps considerably (Zohary et al. 2012); however, morphometric analysis remains one of the main tools at disposition for the study of archaeological grape pips (Milanesi et al. 2011; Bouby et al. 2013; Orrù et al. 2013; Pagnoux et al. 2015; Ucchesu et al. 2015; Ucchesu et al. 2016; Karasakis et al. 2018; Valamoti et al. 2020). Lately the efforts are concentrating in understanding the relationship between the pip shape and the berry shape, in an effort of obtaining a better interpretation of the pip morphology (Bonhomme et al. 2020), and in developing more effective models for the interpretation of the data (Martín-Gómez et al. 2020).

With regard to the western Mediterranean, Sardinia is an area of great interest to understand the development of viticulture, thanks to its central position and to multiple contacts at cultural, economic and political level during the centuries. Here *V. vinifera* subsp. *sylvestris* grows spontaneously (Lovicu 2010), but until recently the major role in the introduction of the cultivated subspecies was attributed to the Phoenicians, although grape pips had been found in contexts dated to the Bronze Age (Bakels 2002). Thanks to an increased attention for archaeobotanical studies, and to some successful excavations, it is now possible to state that the autochthonous Nuragic people had already started a process of selection of local wild grapevines in the second half of the 3rd millennium BC, during the Middle Bronze Age, developing domesticated varieties at least from the Late Bronze Age; the process progressively increased between the 9th and the 7th century BC (Ucchesu et al. 2015). This makes Sardinia an early centre of secondary domestication of *V. vinifera* in the western Mediterranean. The importance of viticulture probably increased in the following centuries, as proved by remarkable finds, especially in Archaic and Punic sites (Marinval and Cassien 2001; Del Vais and Sanna 2012; van Dommelen et al. 2012; Sabato et al. 2019).

The aim of this work is to study, with the help of morphometric analysis, the grape pips found on Archaic and Punic sites of Sardinia; the study will give information helpful to understand how viticulture evolved during the 1st millennium BC, and to find eventual relations with the actual situation of *V. vinifera* in the Mediterranean.

Archaeological contexts

The archaeological grape pips considered in the work come from different waterlogged contexts, namely the Mistras Lagoon, the Santa Giusta Lagoon and the coastal area of the ancient city of Nora (Fig. 1).

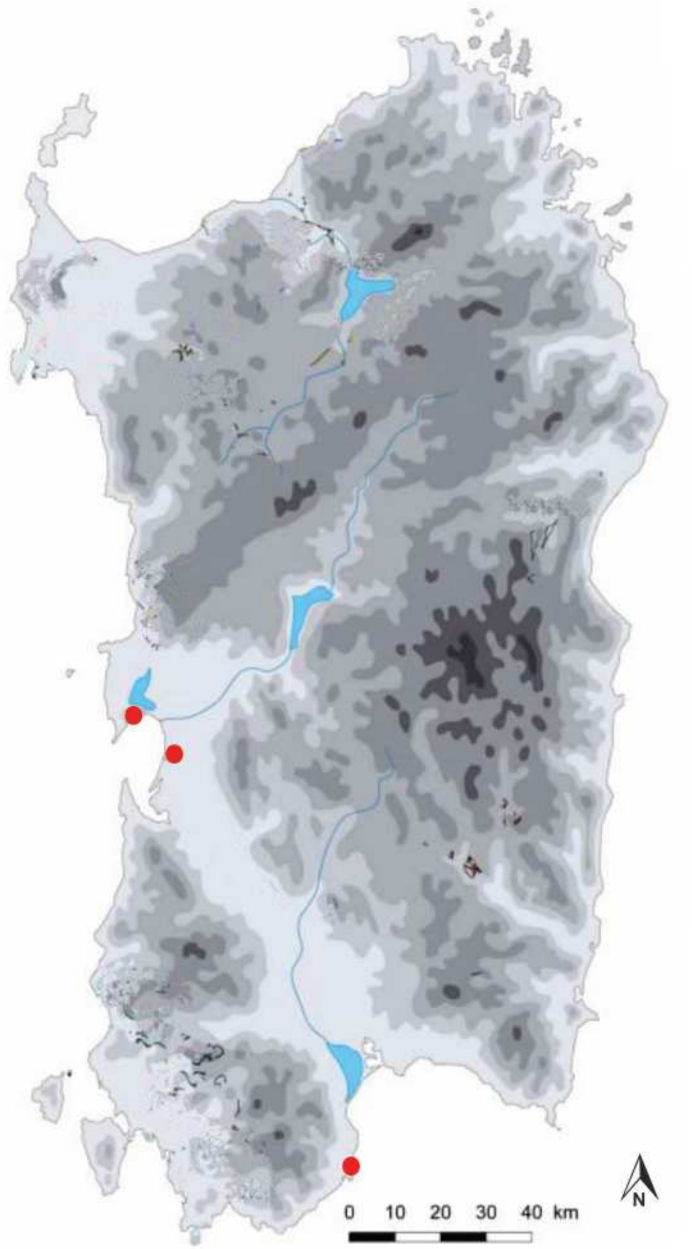

Fig. 1 – Position of the archaeological contexts. From North to South: Mistras Lagoon, Santa Giusta Lagoon, Nora.

The Mistras Lagoon is situated in the northern part of the gulf of Oristano, in central-west Sardinia; multidisciplinary researches interested the area since 2003, held by the University of Cagliari, the Soprintendenza Archeologica of Cagliari, the University of Sassari and the CNR (Del Vais et al. 2008; 2010; Pascucci 2018; Del Vais et al. 2020). The archaeological interest of the lagoon is related to its closeness to the ancient city of Tharros; the investigations allowed to identify the area as the harbour of this city between the 7th and the 3rd century BC (Pascucci et al. 2018; Del Vais et al. 2020). Several excavation campaigns took place in different interesting spots of the lagoon, providing, among the other results, the archaeobotanical materials here presented. In 2009 a monumental structure present in the middle of the lagoon was investigated thanks to an underwater survey; the carpological remains were found in association with ceramic fragments dating to the 3^{rd}-2^{nd} century BC (Del Vais et al 2020). Then during 2014 and 2015, the University of Cagliari excavated two different areas of a sandy barrier located inside the lagoon, formerly a palaeobeach (Pascucci et al. 2018). The materials found in the two sites are represented by pottery, animal bones, wood and carpological remains; according to preliminary results, they concern a period going from the 7^{th} to the 3^{rd} century BC in the 2014 excavation, and from the 5^{th} to the 3^{rd} century BC in the 2015 case (Del Vais et al. 2020), but further studies are underway to provide more specific dating.

The Santa Giusta Lagoon is situated in the central part of the gulf of Oristano, and is related to the ancient Othoca, one of the most important settlements during the Archaic and Punic period in Sardinia (Del Vais 2010). The presence of an archaeological site dating to the Archaic and Punic period inside the lagoon has been known for several decades (Fanari 1988). The Soprintendenza Archeologica of Cagliari and the University of Cagliari undertook extensive surveys and underwater excavations since 2005, documenting a large dispersion of archaeological material in the middle of the lagoon, dating to two main phases attributable to the 6^{th}-5^{th} century BC and the 3^{rd}-2^{nd} century BC (Del Vais and Sanna 2009; 2012). The context is characterised by the presence of manufactured wood and ceramics, predominantly transport amphorae, most of which preserved in their entirety, although not sealed (Del Vais and Sanna 2009; 2012). Those amphorae, presumably produced locally according to archaeometric studies (Amadori et al. 2016), contain zoological remains, attributed in large part to ovicaprids, and carpological remains (Del Vais and Sanna 2009; 2012; Ucchesu et al. 2017; Sabato et al. 2019).

Finally Nora, as Tharros and Othoca, is another of the main cities in ancient Sardinia. It is situated on the promontory of Capo di Pula, in the southern part of the Island. Between 1978 and 1984 a French and Italian mission, under the authorisation of the Soprintendenza Archeologica of Cagliari, accomplished underwater investigations in front of the promontory (Marinval and Cassien 2001; Bonetto 2014). The materials recovered probably indicate the presence of several shipwrecks of different age; among those materials were present transport amphorae of Phoenician and Punic tradition, dated to the 6th century BC and the 3rd-2nd century BC, containing animal bones and grape pips (Marinval and Cassien 2001; Poplin 2014).

Materials and methods

Archaeological samples

A total of 5948 archaeological grape pips were considered in the analysis (Table 1).

From the Mistras 2014 and 2015 excavations (MIS14 and MIS15) were selected respectively 1960 and 321 pips, proceeding from different stratigraphic units. The carpological remains were recovered thanks to the systematic sampling of the sediment held during the campaigns; they are in an optimal preservation state, thanks to the underwater and anoxic conditions of the site. The sediment was processed by wash-over and the seeds selected in the laboratories of the Sardinian Germplasm Bank (BG-SAR), were they are stored in deionised water at 5°C.

From the survey of Mistras 2009 (MIS09) come 250 pips, recovered on place during the excavation and preserved in analogous conditions as the MIS14 and MIS15 samples.

The pips from Santa Giusta were recovered in the filling of two transport amphorae (Anf 627, from now on called SGT-A, and Anf T-01, called SGT-B) pertaining to the most ancient phase of the archaeological site. As for the samples from Mistras, the preservation of the remains is optimal thanks to the characteristics of the sedimentation, and a total of respectively 1130 and 1826 pips were used in the analysis.

From Nora (NR) 461 grape pips were at disposition. They come from a transport amphora of Punic tradition, dated to the 3rd-2nd century BC. As the excavations in Nora took place several years ago, the pips were eventually stored in dried conditions, but this does not seem to have altered the shape significantly.

Context	Sample	Date (centuries BC)	Seed number
Mistras 2014	MIS14 US23	7th-3rd	7
	MIS14 US24		13
	MIS14 US25		143
	MIS14 US27		37
	MIS14 US28		9
	MIS14 US32		1011
	MIS14 US34		413
	MIS14 US35		327
Mistras 2015	MIS15 US25	5th-3rd	150
	MIS15 US26		171
Mistras 2009	MIS09	3rd-2nd	250
Santa Giusta	SGT-A	6th-5th	1130

	SGT-B		1826
Nora	NR	3rd-2nd	461
Total			5948

Table 1 - Archaeological grape pips lot details.

Modern samples

The modern samples used as comparison material were selected in Sardinia. Pips from 5 different populations of wild grape were collected along riverbanks and colluvial sites, in areas as much as possible isolated from anthropized environments, for a total of 1959 pips (Table 2).

The great part of the cultivars were selected in the field collection of Agris Sardegna (Agricultural Research Agency of Sardinia) of Ussana, adding to them an accession harvested in the countryside of Cabras. In all, 32 cultivars, for a total of 3199 pips, were used (Table 2).

Samples	**Subspecies**	**Sample provenance**	**Distribution**	**Berry skin color**	**Utilisation**	**Total seed number**
Aritzo	W	-	-	-	-	443
Flumini	W	-	-	-	-	424
Gutturu	W	-	-	-	-	339
Laconi	W	-	-	-	-	431
Santadi	W	-	-	-	-	322
Alicante	C	Agris Ussana	SAR, FR, SP	Black	Wine	100
Apesorgia nera	C	Agris Ussana	SAR	Black	Table	100
Arvesiniadu	C	Agris Ussana	SAR	White	Table	99
Axina de tres bias	C	Agris Ussana	SAR, GR	Black	Wine	100
Bovali mannu	C	Agris Ussana	SAR, SP	Black	Wine	100
Caddiu	C	Agris Ussana	SAR	Black	Wine/Table	100
Cannonau	C	Agris Ussana	SAR, FR, SP	Black	Wine	100
Caricagiola	C	Agris Ussana	SAR, COR, SP	Black	Wine	100
Carignano	C	Agris Ussana	SAR, FR, TUN, INT	Black	Wine	100
Corniola	C	Agris Ussana	SAR, INT	White	Table	100
Galoppu	C	Agris Ussana	SAR, SP	White	Wine/Table	100
Girò	C	Agris Ussana	SAR	Black	Wine	100
Granatza	C	Agris Ussana	SAR	White	Wine	100
Gregu nieddu	C	Agris Ussana	SAR	Black	Wine	100
Grillu	C	Agris Ussana	SAR, SIC	White	Wine	100
Lacconarzu	C	Agris Ussana	SAR	White	Table	100
Licronaxu	C	Agris Ussana	SAR	White	Wine/Table	100
Licronaxu nero	C	Agris Ussana	SAR	Rosé	Wine/Table	100
Luglienca	C	Agris Ussana	SAR, IT	White	Wine/Table	100

Malvasia di Sardegna	C	Agris Ussana	SAR, CR, IT, POR, SP	White	Wine	100
Monica	C	Agris Ussana	SAR	Black	Wine	100
Moscatello	C	Agris Ussana	SAR, INT	White	Wine	100
Muristellu	C	Agris Ussana	SAR, COR, SP	Black	Wine	100
Nasco	C	Agris Ussana	SAR	White	Wine	100
Nieddera	C	Agris Ussana	SAR	Black	Wine	100
Nuragus nero	C	Agris Ussana	SAR	Rosé	Wine	100
Pascale di Cagliari	C	Agris Ussana	SAR	Black	Wine	100
Remungiau di Serri	C	Agris Ussana	SAR	White	Wine	100
Semidano	C	Agris Ussana	SAR	White	Wine	100
Tittiacca	C	Agris Ussana	SAR, SP	White	Table	100
Vermentino	C	Agris Ussana	SAR, COR, IT	White	Wine	100
Vernaccia di Oristano (local name Crannaccia)	C	Cabras - Sa Ruda	SAR, IT?	White	Wine	100

Table 2 - Modern grape pips lot details. The cultivars are defined according to their predominant denomination in Sardinia. The correspondence of some of the cultivars to varieties internationally distributed is attested by genetic analysis (Robinson et al. 2012; Lovicu 2017; *Vitis* International Variety Catalogue www.vivc.de). W = wild, C = cultivar, SAR = Sardinia, COR = Corsica, CR = Croatia, FR = France, GR = Greece, INT = International, IT = Italy, POR = Portugal, SP = Spain.

Image analysis

The archaeological and modern grape pips were scanned using a flatbed scanner (Epson Perfection V550), with a resolution of 400 dpi, in order to acquire their digital images (Bacchetta et al. 2008). The morphometric parameters of each grape pip were extrapolated from the images using the open source software ImageJ v. 1.52 (http://rsb.info.nih.gov/ij); 26 morphometric variables were extracted thanks to the plugin Particles8 (http://www.mecourse.com/landinig/software/software.html). Further 80 elliptic Fourier descriptors (EFDs), describing the contour shape, were extrapolated as described by Sau et al. (2019). The variables were used to build a database containing the descriptive features of the archaeological grape pips groups and of the modern wild and cultivar accessions.

Statistical analysis

The database obtained was statistically examined using the SPSS software (Statistical Package for the Social Sciences) release 16.0 (SPSS Inc. for Windows, Chicago, Illinois), applying the Linear Discriminant Analysis (LDA). The LDA, minimising the between class distance and maximising the within-class distance, is useful to achieve the maximum class discrimination. The approach is commonly used to classify and identify groups characterised by quantitative and qualitative variables (Bacchetta et al. 2008; Orrù et al. 2013; Ucchesu et al.2015; Sarigu et al. 2017; Sau et al. 2019), and is therefore apt to find the best match between unknown groups.

Results

During the first step the analysis involved exclusively the archaeological grape pips, to better define the groups and their eventual affinities. A first comparison between the samples of the different stratigraphic units of MIS14 and MIS15 was executed, to investigate the opportunity of considering them as separate groups or as a unique group. That was done under the consideration that the contexts of the two excavations were analogous, and that their chronology overlaps in great part. The analysis revealed how the grape pips lots from the different layers, and from one site to another, find high percentages of similarity between them, impeding the individuation of specific subgroups (ESM 1). For this reason they are considered in the following analysis as a unique lot, MIS14-15.On the contrary the samples from the two amphoras of Santa Giusta, SGT-A and SGT-B, found a high percentage of correct classification, and constitute therefore two distinct groups (ESM 2).

The different archaeological samples, as defined by archaeological and morphometric considerations, were then compared one to another (Table 3).

	MIS14-15	MIS09	SGT A	SGT B	NR	Total
MIS14-15	**34,7** (792)	15,1 (345)	15,9 (362)	22,1 (504)	12,2 (278)	100,0 (2281)
MIS09	16,0 (40)	**46,0** (115)	9,2 (23)	22,0 (55)	6,8 (17)	100,0 (250)
SGT-ST A	11,6 (131)	3,7 (42)	**67,4** (762)	7,6 (86)	9,6 (109)	100,0 (1130)
SGT-ST B	17,9 (326)	9,0 (165)	5,0 (91)	**63,9** (1166)	4,3 (78)	100,0 (1826)
NR	7,6 (35)	2,6 (12)	8,7 (40)	1,3 (6)	**79,8** (368)	100,0 (461)
Overall						53,9 (5948)

Table 3 - Correct classification percentages of archaeological grape pips from the different contexts. Number of pips into brackets.

The overall correct classification was 53,9%. The highest classification percentage was reached by NR with 79,8%, followed by SGT A with 67,4% and SGT B with 63,9%. MIS14-15 and MIS09 found lower correct classification percentages, respectively 34,7% and 46,0%; their misidentifications are distributed on all the other samples, with the highest percentages on SGT B and the lowest on NR.

An additional analysis, which considered the centroids of the morphometric parameters deriving from the previous results, recognised a remarkable level of distance of SGT-A and NR from the other samples (Fig. 2). On the contrary the group MIS14-15, and the samples MIS09 and SGT-B found a closer relation.

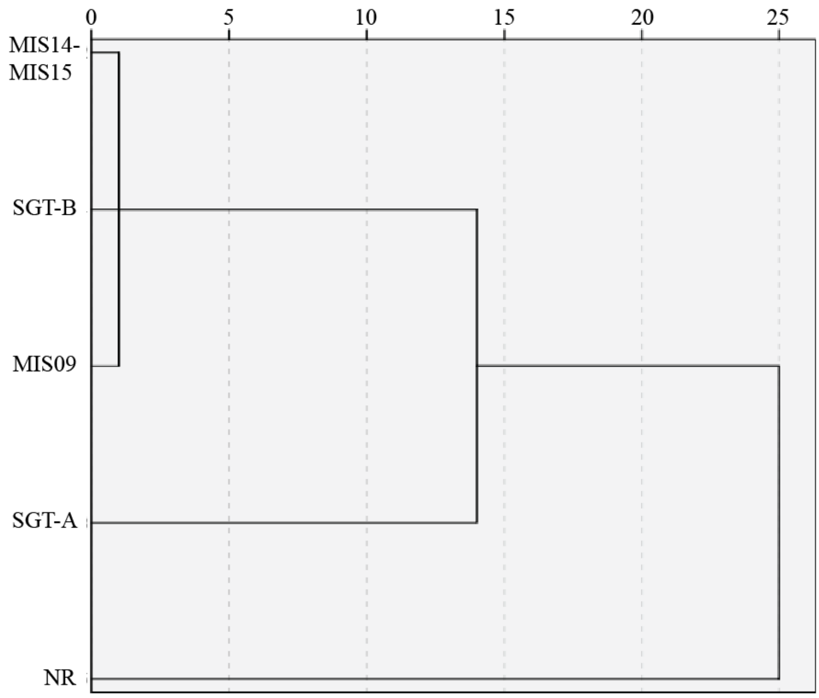

Fig 2 - Distribution of centroids deriving from morphometric analysis of archaeological grape pips.

The archaeological grape pips were subsequently analysed in comparison to the database of the modern wild and cultivars accessions. Each archaeological sample was compared as an unknown group to the entirety of the modern database divided into subspecies, to evaluate the presence of wild or domestic morphotypes (Table 4).

	W	C	Total
W	**77,7** (1522)	22,3 (437)	100,0 (1959)
C	23,8 (761)	**76,2** (2438)	100,0 (3199)
Overall			76,8 (5158)
MIS14-15	34,4 (784)	65,6 (1497)	100,0 (2281)
MIS09	34,0 (85)	66,0 (165)	100,0 (250)
SGT A	34,9 (394)	65,1 (736)	100,0 (1130)
SGT B	19,3 (353)	80,7 (1473)	100,0 (1826)
NR	34,1 (157)	65,9 (304)	100,0 (461)

Table 4 - Correct classification of modern and archaeological grape pips according to their pertinence to *V. vinifera* ssp. *sylvestris* or *V. vinifera* ssp. *vinifera*. The archaeological grape pips were compared to the modern lots as unknown groups. Number of pips into brackets. W = wild, C = cultivar.

Wild and cultivar modern samples reached a good overall classification of 76,8%; nevertheless, it has to be noted that low percentages of the two groups found misidentifications on the other subspecies. As for the archaeological grape pips, all the groups were attributed with percentages highest than 65% to the cultivars; in particular SGT B reached the 80,7% of identification on the group of the modern cultivars.

Considering this last result, that recognised the majority of the archaeological grape pips as pertaining to domestic morphotypes, a deeper analysis concerned the comparison of the archaeological pips with the cultivar accessions. In this phase only 500 grape pips from each of the archaeological samples were randomly chosen and used in the analysis, except in the case of MIS09 and NR, were all the pips were considered, as those samples do not reach the number of 500. The selected archaeological assemblages were then compared to all the cultivars present in the database (ESM 3). The archaeological grape pips lots continued to find good correct classification percentages in the case of SGT A, SGT B and NR, even if with some misidentifications, while MIS14-15 and MIS09 were much more frequently misunderstood either with the other archaeological groups, either with many of the modern cultivars in the database. On the contrary the modern cultivars, which were in general well classified, only rarely found misidentifications in the archaeological groups.

In order to better investigate to which type of cultivars the archaeological grape pips find the best resemblances, a final analysis was executed, in which the archaeological samples were compared one by one to the cultivars as unknown groups (Table 5).

Cultivars	Correct classification of modern samples	Archaeological seed lots classification				
		MIS14-15 (500)	**MIS09** (250)	**SGT A** (500)	**SGT B** (500)	**NR** (461)
Alicante (100)	38,0 (38)	0,6 (3)	-	-	0,4 (2)	-
Apesorgia nera (100)	45,5 (45	0,6 (3)	0,8 (2)	-	0,2 (1)	0,2 (1)
Arvesiniadu (99)	59,6 (59)	0,4 (2)	-	-	-	0,2 (1)
Axina de tres bias (100)	58,0 (58)	0,2 (1)	-	-	-	-
Bovali mannu (100)	45,0 (45)	6,4 (32)	4,4 (11)	0,8 (4)	5,8 (29)	2,0 (9)
Caddiu (100)	56,0 (56)	2,8 (14)	1,6 (4)	-	1,4 (7)	-
Cannonau (100)	62,0 (62)	4,4 (22)	2,4 (6)	**15,8** (79)	1,0 (5)	**22,3** (103)
Caricagiola (100)	60,0 (60)	0,6 (3)	-	0,8 (4)	1,6 (8)	0,9 (4)
Carignano (100)	60,0 (60)	4,4 (22)	3,2 (8)	2,6 (13)	9,2 (46)	2,0 (9)
Corniola (100)	71,0 (71)	1,0 (5)	2,4 (6)	0,6 (3)	3,6 (18)	-
Galoppu (100)	50,0 (50)	3,8 (19)	**14,4** (36)	-	1,2 (6)	-
Girò (100)	41,0 (41)	2,4 (12)	1,2 (3)	0,4 (2)	5,4 (27)	1,1 (5)
Granatza (100)	70,0 (70)	1,2 (6)	0,8 (2)	-	-	-
Gregu nieddu (100)	64,0 (64)	4,0 (20)	1,2 (3)	3,2 (16)	0,4 (2)	**11,9** (55)
Grillu (100)	42,0 (42)	6,6 (33)	1,6 (4)	**14,8** (74)	1,2 (6)	**15,8** (73)
Lacconarzu (100)	52,0 (52)	0,4 (2)	-	-	-	-
Licronaxu (100)	25,0 (25)	3,4 (17)	0,8 (2)	2,8 (14)	1,8 (9)	2,6 (12)
Licronaxu nero (100)	29,0 (29)	4,2 (21)	8,0 (20)	9,4 (47)	5,2 (26)	6,9 (32)
Luglienca (100)	52,0 (52)	**13,4** (67)	**19,6** (49)	5,8 (29)	**39,8** (199)	0,4 (2)
Malvasia di Sardegna (100)	36,0 (36)	1,2 (6)	0,4 (1)	0,6 (3)	1,8 (9)	4,6 (21)
Monica (100)	72,0 (72)	0,6 (3)	-	-	0,4 (2)	-
Moscatello (100)	87,0 (87)	14,2 (71)	6,4 (16)	**28,2** (141)	-	7,4 (34)
Muristellu (100)	44,0 (44)	2,2 (11)	0,8 (2)	0,6 (3)	2,6 (13)	0,7 (3)
Nasco (100)	31,0 (31)	3,8 (19)	10,4 (26)	0,2 (1)	7,8 (39)	0,4 (2)
Nieddera (100)	31,0 (31)	4,4 (22)	2,4 (6)	4,4 (22)	2,2 (11)	3,5 (16)
Nuragus nero (100)	31,0 (31)	0,8 (4)	0,8 (2)	2,0 (10)	1,4 (7)	2,4 (11)
Pascale di Cagliari (100)	27,0 (27)	0,2 (1)	-	-	0,2 (1)	-
Remungiau di Serri (100)	61,0 (61)	0,8 (4)	1,2 (3)	0,2 (1)	1,0 (5)	1,3 (6)
Semidano (100)	48,0 (48)	4,8 (24)	9,2 (23)	0,6 (3)	1,4 (7)	2,4 (11)
Tittiacca (100)	98,0 (98)	0,6 (3)	1,2 (3)	-	0,6 (3)	-
Vermentino (100)	41,0 (41)	4,6 (23)	4,0 (10)	6,2 (31)	1,4 (7)	11,1 (51)
Vernaccia di Oristano (100)	57,0 (57)	1,0 (5)	0,8 (2)	-	1,0 (5)	-
Overall	51,4 (3199)					

Table 5 - Correct classification percentages of modern cultivars, and classification percentages of archaeological grape pips lots compared to modern cultivars and considered as unknown. Number of pips into brackets.

All the archaeological samples were widely distributed among the various modern cultivars. However MIS14-15, MIS09 and SGT B found the highest classifications on cultivars nowadays used both as wine grapes and as table grapes, such as Galoppu and

Luglienca. On the contrary SGT A and NR found the highest correspondences on wine grapes, such as Cannonau, Grillu and Moscatello.

Discussions

Several observations are possible at the light of the morphometric and statistical analyses which were executed. Concerning the archaeological pips, the results showed closer affinities between the samples coming from MIS14-15 and MIS09. This might be a consequence of the closeness and analogy of the contexts. The nature of the area investigated in the Mistras Lagoon is that of a palaeobeach with its foreshore, which was used as harbour during the Archaic and Punic period (Pascucci et al. 2018; Del Vais et al. 2020). It is possible that the archaeological materials detected by the investigations represent a consequence of the loss of cargo from anchored ships during transhipment operations; sea and sedimentation dynamics could have therefore spread analogous materials in the wide area over the centuries, until the final occlusion of the lagoon (Pascucci et al. 2018). A certain caution is necessary in the interpretation; the presence of a harbour, and of ships, does not necessarily mean that we are dealing with imported products, neither with local products destined to an exportation at large scale. The harbour could have also been used as a quick transport route for the products of the hinterland destinated to the same Tharros, or to the neighbouring areas. Intensive archaeological surveys on the territory made in fact clear that this was intensively exploited for agricultural purposes, especially from the 5th century BC, under the control of Tharros and the economic and political impulse of Carthage in Tunisia, which exercised a powerful influence on the Punic regions of the central Mediterranean (Del Vais 2014). Concerning in particular the viticulture, the northern part of the gulf of Oristano provided proof of the presence of this activity since the Bronze and Iron Age (Orrù et al. 2013; Ucchesu et al. 2015). The activity probably increased in the following centuries, as seems proved by palynological analysis that revealed an increase in *V. vinifera* concentrations during the 5th century BC in the area of Tharros (Acquaro et al. 2001; Di Rita and Melis 2016).

It is then interesting to note how the samples from Santa Giusta, SGT-A and SGT-B, coming from two different transport amphorae, are clearly distinguished the one from the other. This could mean that the two amphorae, even if chronologically close, contained different types of grapes. The full study of the containers, and of the other products found inside them in association with the grape pips, will hopefully help for a better interpretation of this result. It can also be noted that SGT A does not seem to show affinities with any particular one of the other archaeological samples, while SGT B shows a certain similarity with MIS14-15 and MIS09; this could mean the presence of grapes coming from varieties present also in the MIS assemblages; as a partial explanation the vicinity between the sites, and a possible sharing of products or agricultural techniques, should not be disregarded, but only more inclusive studies on the development of the viticulture will enable more founded assessments. Significantly, NR represents the most characterised sample in comparison with the others, in accordance to its provenience from a completely different area of Sardinia; besides, the chronology of the transport amphora from Nora, 3rd-2nd century BC, overlaps only in part the dates attested in the Mistras Lagoon, while it is quite distant from those of the amphoras of the Santa Giusta Lagoon here considered.

From the archaeological point of view, it is also necessary to underline the continuous recurrence of the association of grape pips, zoological remains and transport amphorae on the Archaic and Punic sites of Sardinia: this is the case of Mistras (Del Vais et al. 2020), of Santa Giusta (Del Vais and Sanna 2009; 2012), of Nora (Marinval and Cassien 2001). As already suggested (Marinval and Cassien 2001), the findings seem to indicate the use of grapes, and perhaps of a fermented by-product, in the conditioning of meat for its conservation, even if other hypothesis, as an interpretation as food waste (Poplin 1980), should not be completely disregarded. Moreover the Anf T-01 from Santa Giusta, that provided the sample SGT B here studied, revealed an interesting association with remains of the aromatic plant *Coriandrum sativum* L.

Passing to the comparison with the modern materials, what seems clear is the pertinence of the majority of the archaeological grape pips to domesticated morphotypes. However, a certain percentage of wild morphotypes was also found in all the cases; the presence of low percentages of fruits gathered directly from the wild cannot be completely excluded, also considering that this is a practice well documented in historical times (Lovicu 2010). Other hypothesis can be considered, first of all the fact that the high degree of shape variability does not always enable a sure classification at subspecies level, as already stated (Zohary et al. 2012). This is a point to take in even greater consideration when dealing with ancient material, where the existence of weakly domesticated forms should be considered.

The comparison of the archaeological grape pips with the modern cultivars underline other aspects. First of all, the fact that MIS14-15 and MIS09 find extremely numerous resemblances with a wide number of modern cultivars, in addition to the misidentifications with the other archaeological groups, makes patent the presence, inside of the grape pips lots coming from Mistras, of numerous varieties of grapes, confirming an impression resulting also from the optic exam of the samples (Fig. 3). On the other side the remaining groups, SGT A, SGT B an NR, even if they also show similarities with the other archaeological and modern samples, seem quite more homogenous. This can be easily explained by the consideration that each lot of grape pips from Santa Giusta and Nora come from one individual container, while the layers of the Mistras Lagoon present a mixture of materials, consequence of several events and of natural sedimentation processes.

Fig. 3 – Different morphotypes detected at the optic exam inside the grape pips lot of MIS14-15.

Finally, the similarities found with the last analysis, that compared the archaeological grape pips to the cultivars as unknown, seem to open new interesting perspectives to future research. In fact, while the archaeological groups MIS14-15, MIS09 and SGT B showed greater percentages of affinity with modern cultivars used nowadays both as wine and table grapes, in reason of a bigger dimension and consistence of the berries, as Galoppu and Luglienca, SGT A and NR found highest correspondences with varieties used exclusively for the production of wine, as Cannonau, Grillu and Moscatello (Robinson et al. 2012; Lovicu 2017). It seems therefore possible to infer the presence of a diversified viticulture in Archaic and Punic Sardinia, interested by the presence of several developed domestic varieties, with the selection of grapes with larger berries, more attractive for the consumption of the fruit, fresh or dried. This aspect, concerning the correlation between the size and shape of the berries, and the subsequent development of the pips, certainly deserves a deeper investigation and will be object of special consideration in the prosecution of the study.

In conclusion, the situation of the viticulture in Sardinia seem to have successfully continued its evolution since its first documentation during the Bronze Age (Ucchesu et al. 2014). This could have happened thanks to other local secondary domestication events, and perhaps to the circulation of vine-stocks between regions. The transport and exchange of grapevine varieties is in fact proved by the finding of vine root-stocks on the El Sec shipwreck, off the coast of Mallorca, dated to the 4th century BC (Arribas et al. 1987).

In more general terms we can point out how, with the increase of archaeobotanical researches, the picture of Sardinia during the Archaic and Punic period is becoming more and more variegated. If until a few decades ago prevailed its interpretation as a region dedicated predominantly to the cultivation of cereals for the supply of Carthage (Barreca 1988; Moscati, et al. 1997; Manfredi 1993, Krings 2000), it is now clear that a diversified agriculture and circulation of vegetal food supplies interested the island, as proved by the increasing findings of other cultivated species, notably fruit trees as for example the plum (*Prunus domestica* L.) and the olive (*Olea europaea* L. var. *europaea*) (Ucchesu et al. 2017; Sabato et al. 2019).

Conclusions

The morphometric analysis of the grape pips found on Archaic and Punic archaeological sites of Sardinia point out the importance of the viticulture during that period, revealing the presence of high percentages of domesticated grape. The development of different grape varieties is another clear result of the study, including the possibility of the selection of types with larger berries, more attractive in terms of edibility, an aspect that will be more deeply investigated in the following studies.

Furthermore, this work gives an important contribution to the reconstruction of the agriculture and economy of Sardinia during that period; the situation seems nowadays much more diversified than what thought in the past decades, and characterised by a variegated presence of cultivated products.

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Additional materials

		MIS14								MIS15		Total
		US23	US24	US25	US27	US28	US32	US34	US35	US25	US26	
MIS14	US23	**57,1 (4)**	-	-	14,3 (1)	14,3 (1)	-	-	14,3 (1)	-	-	100,0 (7)
	US24	15,4 (2)	**23,1 (3)**	-	15,4 (2)	15,4 (2)	-	15,4 (2)	15,4 (2)	-	-	100,0 (13)
	US25	4,9 (7)	6,3 (9)	**7,0 (10)**	12,6 (18)	16,8 (24)	8,4 (12)	17,5 (25)	11,2 (16)	2,8 (4)	12,6 (18)	100,0 (143)
	US27	13,5 (5)	13,5 (5)	10,8 (4)	**16,2 (6)**	13,5 (5)	5,4 (2)	10,8 (4)	8,1 (3)	-	8,1 (3)	100,0 (37)
	US28	11,1 (1)	33,3 (3)	-	-	**22,2 (2)**	11,1 (1)	-	11,1 (1)	-	11,1 (1)	100,0 (9)
	US32	9,3 (94)	9,3 (94)	6,8 (69)	7,8 (79)	27,6 (279)	**6,8 (69)**	13,3 (134)	8,0 (81)	1,0 (10)	10,1 (102)	100,0 (1011)
	US34	13,1 (54)	9,7 (40)	4,6 (19)	4,8 (20)	7,3 (30)	4,1 (17)	**28,6 (118)**	18,2 (75)	1,0 (4)	8,7 (36)	100,0 (413)
	US35	29,7 (97)	7,6 (25)	1,5 (5)	7,6 (25)	6,4 (21)	2,4 (8)	22,0 (72)	**17,7 (58)**	0,6 (2)	4,3 (14)	100,0 (327)
MIS15	US25	15,3 (23)	4,7 (7)	8,7 (13)	8,7 (13)	18,7 (28)	4,0 (6)	17,3 (26)	10,0 (15)	**2,7 (4)**	10,0 (15)	100,0 (150)
	US26	8,8 (15)	8,2 (14)	4,7 (8)	9,4 (16)	19,3 (33)	6,4 (11)	16,4 (28)	8,8 (15)	1,2 (2)	**17,0 (29)**	100,0 (171)
	Overall											13,3 (2281)

ESM 1 - Correct classification percentages of archaeological grape pips from MIS14 and MIS15. Number of pips into brackets.

	SGT A	SGT B	Total
SGT A	83,5 (943)	16,5 (187)	100,0 (1130)
SGT B	7,4 (136)	92,6 (1690)	100,0 (1826)
Overall			89,1 (2956)

ESM 2 - Correct classification percentages of archaeological grape pips from SGT A and SGT B. Number of pips into brackets.

	MIS14-15	MIS09	SGT A	SGT B	NR	Alicante	Apesorgia nera	Arvesiniadu	Axina de tres bias	Bovali mannu	Caddiu	Cannonau	Caricagiola	Carignano	Corniola	Galoppu	Girò	Granatza	Gregu nieddu	Grillu	Lacconarzu	Licronaxu	Licronaxu nero	Luglienca	Malvasia di Sardegna	Monica	Moscatello	Muristellu
MIS14-15	**6,2** (31)	5,0 (25)	12,4 (62)	15,8 (79)	6,4 (32)	-	1,4 (7)	0,6 (3)	0,4 (2)	3,8 (19)	2,4 (12)	0,6 (3)	0,4 (2)	2,6 (13)	1,0 (5)	4,0 (20)	1,2 (6)	1,0 (1)	2,6 (13)	2,0 (10)	0,2 (1)	1,2 (6)	2,2 (11)	2,6 (13)	0,4 (2)	0,6 (3)	9,8 (49)	1,0 (5)
MIS09	3,2 (8)	**15,2** (38)	8,8 (22)	14,4 (36)	3,2 (8)	0,4 (1)	1,6 (4)	0,4 (1)	-	2,0 (5)	0,4 (1)	0,4 (1)	-	1,6 (4)	0,8 (2)	14,0 (35)	0,8 (2)	0,8 (2)	1,6 (4)	0,4 (1)	-	1,2 (3)	2,0 (5)	3,6 (9)	-	-	3,6 (9)	0,8 (2)
SGT A	3,4 (17)	0,8 (4)	**57,8** (289)	2,8 (14)	9,0 (45)	-	-	-	-	0,4 (2)	-	0,6 (3)	1,2 (6)	1,8 (9)	0,2 (1)	0,2 (1)	0,2 (1)	-	1,6 (8)	1,2 (6)	-	1,0 (5)	2,2 (11)	1,4 (7)	-	-	10,2 (51)	0,4 (2)
SGT B	3,2 (16)	4,0 (20)	6,0 (30)	**47,4** (237)	2,2 (11)	-	0,2 (1)	-	-	1,8 (9)	-	0,2 (1)	1,8 (9)	6,0 (30)	1,4 (7)	1,2 (6)	2,6 (13)	-	0,4 (2)	0,6 (3)	-	1,4 (7)	1,8 (9)	6,2 (31)	0,4 (2)	0,4 (2)	-	1,6 (8)
NR	3,3 (15)	0,2 (1)	4,3 (20)	1,5 (7)	**45,8** (211)	-	0,2 (1)	0,4 (2)	-	1,3 (6)	-	7,2 (33)	1,5 (7)	1,1 (5)	-	-	0,9 (4)	0,2 (1)	6,1 (28)	4,3 (20)	-	0,9 (4)	2,6 (12)	-	1,5 (7)	-	5,0 (23)	0,7 (3)
Alicante	-	-	-	-	-	**36,0** (36)	1,0 (1)	-	1,0 (1)	6,0 (6)	7,0 (7)	-	5,0 (5)	2,0 (2)	-	-	8,0 (8)	-	-	-	6,0 (6)	-	-	2,0 (2)	4,0 (4)	1,0 (1)	-	-
Apesorgia nera	1,0 (1)	-	-	-	-	2,0 (2)	**43,0** (43)	3,0 (3)	-	9,0 (9)	2,0 (2)	-	-	2,0 (2)	-	10,0 (10)	4,0 (4)	-	-	-	2,0 (2)	-	4,0 (4)	2,0 (2)	-	-	-	1,0 (1)
Arvesiniadu	-	-	-	-	-	-	4,0 (4)	**57,6** (57)	-	2,0 (2)	-	-	8,1 (8)	-	-	1,0 (1)	-	-	9,1 (9)	-	1,0 (1)	-	-	-	-	-	2,0 (2)	-
Axina de tres bias	-	-	-	-	-	-	-	-	**61,0** (61)	2,0 (2)	1,0 (1)	-	1,0 (1)	1,0 (1)	4,0 (4)	5,0 (5)	5,0 (5)	-	-	-	1,0 (1)	-	1,0 (1)	1,0 (1)	-	2,0 (2)	-	-
Bovali mannu	4,0 (4)	-	-	-	-	4,0 (4)	-	4,0 (4)	2,0 (2)	**44,0** (44)	1,0 (1)	-	9,0 (9)	-	-	2,0 (2)	2,0 (2)	-	3,0 (3)	-	-	-	1,0 (1)	-	1,0 (1)	2,0 (2)	1,0 (1)	-
Caddiu	-	-	-	-	-	6,0 (6)	-	2,0 (2)	2,0 (2)	5,0 (5)	**54,0** (54)	-	1,0 (1)	-	-	-	3,0 (3)	-	-	-	4,0 (4)	-	-	-	-	5,0 (5)	-	-
Cannonau	-	-	2,0 (2)	-	6,0 (6)	1,0 (1)	-	-	-	1,0 (1)	-	**55,0** (55)	-	-	-	-	1,0 (1)	5,0 (5)	5,0 (5)	7,0 (7)	-	-	-	-	2,0 (2)	-	4,0 (4)	1,0 (1)
Caricagiola	-	-	-	-	1,0 (1)	-	2,0 (2)	8,0 (8)	-	1,0 (1)	-	1,0 (1)	**58,0** (58)	6,0 (6)	-	-	-	-	-	-	-	2,0 (2)	-	-	-	-	7,0 (7)	2,0 (2)
Carignano	-	-	2,0 (2)	1,0 (1)	1,0 (1)	1,0 (1)	1,0 (1)	1,0 (1)	-	-	1,0 (1)	-	8,0 (8)	**62,0** (62)	-	-	-	-	-	2,0 (2)	2,0 (2)	2,0 (2)	2,0 (2)	2,0 (2)	1,0 (1)	-	1,0 (1)	3,0 (3)
Corniola	-	-	-	-	-	-	-	-	5,0 (5)	1,0 (1)	1,0 (1)	1,0 (1)	-	-	**70,0** (70)	-	-	4,0 (4)	-	-	-	-	-	3,0 (3)	-	1,0 (1)	-	2,0 (2)
Galoppu	1,0 (1)	-	-	-	-	-	4,0 (4)	-	1,0 (1)	4,0 (4)	8,0 (8)	-	1,0 (1)	-	-	**48,0 (48)**	-	-	-	-	-	1,0 (1)	1,0 (1)	-	-	1,0 (1)	-	-
Girò	1,0 (1)	-	-	-	-	1,0 (1)	3,0 (3)	-	5,0 (5)	12,0 (12	1,0 (1)	-	-	-	1,0 (1)	2,0 (2)	**36,0** (36)	2,0 (2)	1.0 (1)	-	-	1,0 (1)	6,0 (6)	2,0 (2)	5,0 (5)	2,0 (2)	-	2,0 (2)
Granatza	1,0 (1)	-	-	-	1,0 (1)	-	-	-	1,0 (1)	-	2,0 (2)	1,0 (1)	1,0 (1)	-	-	-	3,0 (3)	**69,0** (69)	-	-	4,0 (4)	-	-	-	4,0 (4)	-	-	4,0 (4)
Gregu nieddu	-	-	-	-	3,0 (3)	-	1,0 (1)	2,0 (2)	-	3,0 (3)	-	-	2,0 (2)	1,0 (1)	-	-	2,0 (2)	2,0 (2)	**57,0** (57)	2,0 (2)	-	-	1,0 (1)	-	2,0 (2)	-	8,0 (8)	-
Grillu	1,0 (1)	-	3,0 (3)	-	6,0 (6)	-	1,0 (1)	-	-	2,0 (2)	-	3,0 (3)	3,0 (3)	10,0 (10)	-	-	-	2,0 (2)	-	**48,0** (48)	-	-	1,0 (1)	-	1,0 (1)	-	7,0 (7)	1,0 (1)
Lacconarzu	-	-	-	-	-	2,0 (2)	2,0 (2)	1,0 (1)	2,0 (2)	3,0 (3)	2,0 (2)	1,0 (1)	-	-	-	-	1,0 (1)	13,0 (13)	1,0 (1)	1,0 (1)	**53,0 (53)**	-	-	-	2,0 (2)	1,0 (1)	-	1,0 (1)
Licronaxu	1,0 (1)	-	2,0 (2)	-	1,0 (1)	1,0 (1)	3,0 (3)	-	-	-	1,0 (1)	3,0 (3)	7,0 (7)	10,0 (10)	-	-	1,0 (1)	1,0 (1)	1,0 (1)	4,0 (4)	-	**26,0** (26)	10,0 (10)	3,0 (3)	1,0 (1)	-	-	6,0 (6)
Licronaxu nero	2,0 (2)	6,0 (6)	-	2,0 (2)	1,0 (1)	-	3,0 (3)	-	-	1,0 (1)	-	-	3,0 (3)	5,0 (5)	1,0 (1)	3,0 (3)	4,0 (4)	-	1,0 (1)	2,0 (2)	-	10,0 (10)	**30,0** (30)	8,0 (8)	1,0 (1)	-	-	4,0 (4)
Luglienca	1,0 (1)	6,0 (6)	-	4,0 (4)	-	-	2,0 (2)	-	7,0 (7)	5,0 (5)	-	-	2,0 (2)	4,0 (4)	5,0 (5)	2,0 (2)	4,0 (4)	-	-	-	-	2,0 (2)	5,0 (5)	**38,0** (38)	-	-	-	-
Malvasia di Sardegna	-	-	-	-	5,0 (5)	5,0 (5)	1,0 (1)	-	-	2,0 (2)	1,0 (1)	4,0 (4)	-	-	3,0 (3)	-	-	10,0 (10)	3,0 (3)	-	8,0 (8)	-	1,0 (1)	-	**35,0** (35)	-	-	9,0 (9)
Monica	-	-	-	-	-	1,0 (1)	1,0 (1)	-	2,0 (2)	-	-	-	-	1,0 (1)	1,0 (1)	13,0 (13)	3,0 (3)	-	-	-	5,0 (5)	-	-	-	-	**61,0** (61)	-	-
Moscatello	-	-	1,0 (1)	-	1,0 (1)	-	-	1,0 (1)	-	-	-	-	2,0 (2)	-	-	-	-	-	1,0 (1)	1,0 (1)	-	-	-	-	-	-	**88,0** (88)	-
Muristellu	1,0 (1)	-	-	1,0 (1)	1,0 (1)	5,0 (5)	1,0 (1)	-	-	4,0 (4)	-	1,0 (1)	-	1,0 (1)	-	1,0 (1)	2,0 (2)	9,0 (9)	7,0 (7)	2,0 (2)	-	2,0 (2)	-	1,0 (1)	2,0 (2)	-	-	**38,0** (38)
Nasco	1,0 (1)	2,0 (2)	-	2,0 (2)	-	1,0 (1)	2,0 (2)	-	6,0 (6)	8,0 (8)	-	1,0 (1)	-	-	-	9,0 (9)	8,0 (8)	1,0 (1)	1,0 (1)	-	-	1,0 (1)	-	5,0 (5)	2,0 (2)	7,0 (7)	-	1,0 (1)
Nieddera	3,0 (3)	-	-	-	-	-	-	-	-	3,0 (3)	-	-	5,0 (5)	3,0 (3)	-	-	3,0 (3)	-	3,0 (3)	6,0 (6)	-	7,0 (7)	3,0 (3)	1,0 (1)	-	-	4,0 (4)	6,0 (6)
Nuragus nero	1,0 (1)	-	1,0 (1)	-	4,0 (4)	1,0 (1)	-	1,0 (1)	6,0 (6)	1,0 (1)	1,0 (1)	4,0 (4)	9,0 (9)	5,0 (5)	1,0 (1)	-	2,0 (2)	6,0 (6)	4,0 (4)	2,0 (2)	-	3,0 (3)	2,0 (2)	-	1,0 (1)	-	-	7,0 (7)
Pascale di						3,0 (3)	3,0 (3)	8,0 (8)	25,0	5,0	2,0 (2)		10,0 (10)	2,0 (2)	1,0 (1)	3,0 (3)									1,0 (1)	1,0 (1)		

Conclusions

The present work provides numerous and diversified information on the exploitation of the vegetal resources, and on the impact of the human activities on the environment, during the Archaic and Punic period in Sardinia.

The selection of materials proceeding from waterlogged contexts was very useful at this regard, in particular for what concerns the harbour site investigated in the Mistras Lagoon. The impregnation in water, and the anoxic conditions, favoured the preservation of a quantity and variety of vegetal macroremains never recovered before in a Sardinian context, although a significant role in the obtention of such relevant results had the application of specific archaeobotanical procedures since the beginning of the archaeological excavations held on the site. The traditional crops, as cereals and pulses, are joined by a great range of cultivated and gathered fruits, in some cases already well attested in preceding Bronze Age sites, as the grapevine and the fig, and in some cases new acquisitions of the period under consideration, as the cultivated olive, the plum, the pomegranate, to cite only a few of the attested species. The fact that the territory was intensively exploited is confirmed by the analysis of the macroremains ascribable to the spontaneous vegetation, attributed in great part to synanthropic plants, typical of pastures and cultivations.

The new data provided from the vessel recovered in the Santa Giusta Lagoon is in line, from the one side, with previously known data on the association of bones of slaughtered animals with grapevine remains, as a content of transport amphorae of Phoenician and Punic tradition; on the other side the study produced a new important information, thanks to the attestation of abundant coriander remains, proving an introduction and utilisation of this spice.

Moreover the morphometric analysis on the olive endocarps found in Mistras and Santa Giusta proved that the domestication of this plant was already well developed in the Island at the times, documenting varieties somehow similar to actual traditional olive cultivars of Sardinia. In analogous way the morphometric analysis on the grape pips from Mistras, Santa Giusta and Nora, revealed the copresence of low numbers of wild morphotypes, with a clear predominance of cultivated morphotypes; inside the different assemblages it was possible to identify various morphotypes, revealing how the viticulture was developed at the point that it was already characterised by the presence of a great number of types of cultivated grapevine.

In conclusion, the study provided data useful in the archaeological reconstruction of the Archaic and Punic Sardinia, more specifically for what concerns the agricultural and environmental aspects. Particularly important are the considerations which regard the introduction of new cultivated species, presumably a consequence of the action of Phoenician people, and in great part of the insertion of the Island in the economic, political and cultural influence of the North-African city of Carthage. The image that can be pictured is that of a developed and well diversified agriculture.

These considerations cannot be regarded in any way as a point of arrival; on the contrary they must be looked at as a point of depart for new investigations, to be conducted in more detailed, interdisciplinary and comprehensive way.