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RESEARCH

The Santa Giusta lagoon (Sardinia, Italy): New archaeobotanical data from an Archaic Punic transport amphora of the sixth century BC

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Abstract
The Santa Giusta lagoon, located in Central-West Sardinia (Italy), contains one of the most significant archaeological sites of Punic Sardinia, investigated by a multidisciplinary research project since 2005. The north-eastern part of the lagoon is characterised by a wide dispersion of archaeological materials over a large area. The artefacts, Punic transport amphorae, coarse pottery and manufactured wood elements, can be ascribed to two main chronological phases, the sixth-fifth century BC and the third-second century BC. Plant macroremains, mostly pertaining to cultivated species, are present in the archaeological layers and have been recognised as part of the contents of the amphorae, together with remains mainly of ovine/caprid bones with slaughter or butchering marks. This paper presents the results of archaeobotanical analysis of a transport amphora newly discovered at the site; it contained, together with animal bones, *Vitis vinifera* remains, an association already well documented. However, this new finding reveals a novelty, as remains of two aromatic species, *Coriandrum sativum* and *Anethum graveolens*, were also identified within the assemblage. Both taxa have an eastern distribution, particularly linked to south-western Asia. Their presence suggests the introduction of these aromatic plants to Sardinia during the Punic period and supports hypotheses concerning their use in meat processing and preservation practices.

Keywords Archaeobotany · Archaic and Punic periods · *Coriandrum sativum* · Transport amphorae · Waterlogged plant remains

Introduction

The archaeobotanical study of plant macroremains is a fundamental tool for reconstructing past landscapes and understanding the role of plants in human life and the impact of human activities on the environment, including the spread of plant species and agricultural practices (Mercuri et al. 2015; Clò et al. 2025).

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Until relatively recently, the systematic recovery of plant macroremains during archaeological excavations was uncommon in Phoenician and Punic archaeology, although dedicated studies are now increasing in both number and quality. Significant data are available from the Lebanese sites of Sidon (Orendi and Deckers 2018) and Tyre (Rovira 2014), in the eastern Mediterranean. In the western Mediterranean, numerous archaeobotanical datasets from the Iberian Peninsula have been published over the years (Catalá 1999; Pérez-Jordà 2020), and growing attention has been devoted to the Phoenicians' role in introducing agricultural innovations, particularly in the spread of fruit cultivation (Pérez-Jordà et al. 2017; 2021; Pérez-Jordà & Peña-Chocarro 2024). On the Atlantic coast of Morocco, important information derives from the settlement of Lixus (Pérez-Jordà 2005). The central Mediterranean has also restituted relevant results, beginning with the analyses of plant macroremains from stratigraphic sequences of Carthage (van Zeist et al. 2001). Recent research at Mozia has also shed new light on the plant-related aspects of Punic Sicily (Moricca et al. 2020; 2021b; Moricca 2024). Moreover, Sardinia has yielded evidence of plant macroremains from Punic-period contexts since the nineteenth century, as demonstrated by the underwater site in the Santa Gilla lagoon (Vivanet 1892; 1893). From the second half of the twentieth century onward, more systematic investigations have produced additional data from Nora—both underwater (Marinval and Cassien 2001) and on land (Miola et al. 2009)—as well as from the nuraghe Ortu Comidu at Sardara (Bakels 2002), the rural site of Truncu'e Molas at Terralba (Pérez-Jordà et al. 2010; van Dommelen et al. 2012), and S'Urachi at San Vero Milis (van Dommelen et al. 2018; Pérez-Jordà et al. 2020). Moreover, the underwater site of the Santa Giusta lagoon, the focus of this contribution, has already yielded valuable data on plant macroremains and their uses, thanks to the early application of archaeobotanical procedures during the investigations (Del Vais and Sanna 2009; 2012; Sabato et al. 2019; Del Vais et al. 2023b). Furthermore, several palynological and anthracological studies from Central-West Sardinia provide information about changes in the vegetation and presence of cultivated species during Punic times. Particularly interesting are data from Tharros and its hinterland (Palmieri and Lentini 1994; Lentini 1995; Acquaro et al. 2001; Lentini 2014) and from the nearby Mistras lagoon (Di Rita and Melis 2013), harbour of this city in the period under study (Pascucci et al. 2018; Del Vais et al. 2020; 2023a). The analyses underline a significant presence of synanthropic indicators in the plant assemblages and the increase of fire indicators starting from the 2nd millennium BC, during Nuragic times, and gradually increasing during the 1 st millennium BC, indicating a prevailing arable farming economy (Di Rita and Melis 2013). The presence of cereals is attested by taxa as *Avena/Triticum* and adventitious plants such as *Papaver* sp. and *Adonis* sp.; however, the Punic era does not show tendencies to extensive monocultures. On the contrary a wide variety of cultivated, or at least cultivable species, was registered, such as *Vitis vinifera* L., *Olea europaea* L. and *Prunus* sp. (Acquaro et al. 2001; Di Rita and Melis 2013). On the other side, after the end of the fourth century BC the situation changes progressively, until an absolute predominance of cereals during the following Roman era (Acquaro et al. 2001; Palmieri & Lentini 1994; Lentini 1993; 1995; 2014).

Archaeological context

The Santa Giusta lagoon, part of a barrier-lagoon system of complex formation situated in the central part of the gulf of Oristano, in central-west Sardinia (De Falco et al. 2022; 2025), contains one of the most intriguing archaeological sites of Punic Sardinia. The lagoon is situated near the modern village of Santa Giusta, which overlies

a previous settlement identified as Othoca, cited in ancient literary sources (Del Vais 2010). The first archaeological investigations in the lagoon were carried out during the years 1970 s and 1980sof the twentieth century (Fanari 1988; Del Vais and Sanna 2009; 2019). Since 2005 systematic underwater surveys and excavation campaigns, conducted by the Archaeological Superintendency of Cagliari in collaboration with the University of Cagliari, revealed the existence of a large area of archaeological materials in the north-eastern part of the lagoon; they cover a long period ranging from the ninth century BC to the second century AD, although most remains can be attributed to the Punic period (Del Vais and Sanna 2009; 2012; Del Vais et al. 2023b). Investigations revealed two contiguous areas (Area A and B). The Area A shows a large concentration of materials in Stratigraphic Unit 2 (SU 2), arranged in two overlapping layers, beneath the large bag-shaped amphorae (sixth-fifth century BC) resting on a layer of shells (SU 3), above the torpedo-shaped amphorae (third-second century BC) (Fig. 1). All materials, including botanical remains, were incorporated into SU 2. The Area B, which is much larger, was delimited only thanks to the discovery of large bag-shaped amphorae (sixth-fifth century BC), all found following surveys with rods and manual excavation tests, lying on a layer of shells (SU 3) and incorporated into SU 2 (Fig. 2). The interpretation of the site is still uncertain. It is constituted of 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 remains of piers and various artefacts (Del Vais and Sanna 2009; 2012; Del Vais et al. 2023b). Many of the transport amphorae contained animal bones, among which were recognised remains of ovicaprids and bovids, fish scales and bones, as well as carpological remains, represented by seeds and fruits (Fig. 3). Plant remains are preserved thanks to the waterlogged and anoxic conditions of the stratigraphy (Del Vais and 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.; pinecones of *Pinus halepensis* Mill. and *Pinus pinea* L., represented

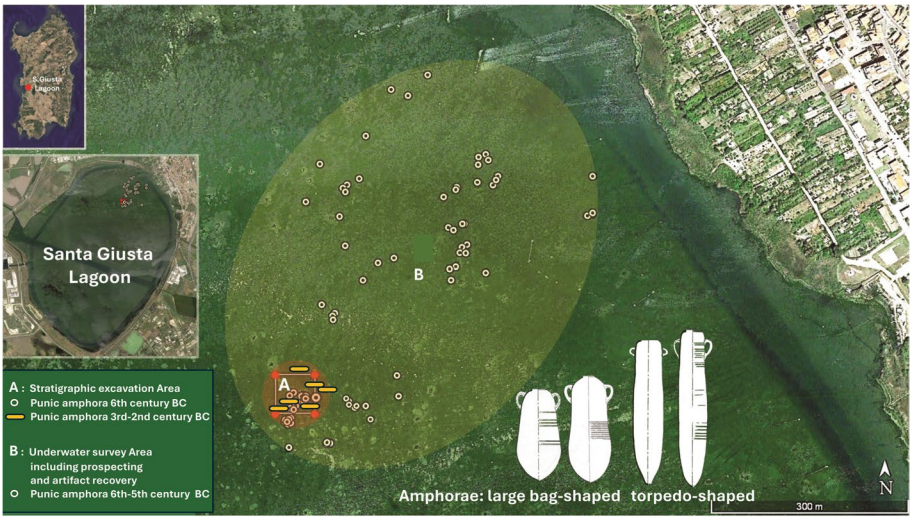


Fig. 1 Northern sector of the Santa Giusta lagoon: identified underwater archaeological areas, type and distribution of Punic amphorae (graphic design by I. Sanna)

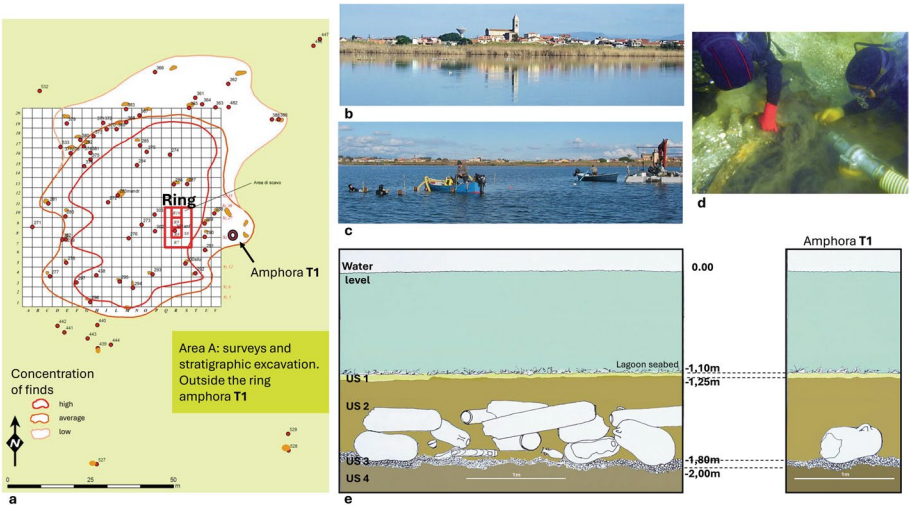


Fig. 2 **a** Area A: location of the excavation sector and amphora T1; **b** Village of Santa Giusta; **c** Underwater excavation site; **d** Underwater excavation in progress; **e** Stratigraphic section of the square 8 of the excavation area and of the area of the amphora T1 (graphic processing and underwater photos by I. Sanna, surface photos by C. Del Vais)

Fig. 3 **a-c** The methodology used for the excavation and recovery of the archaeobotanical plant remains: excavation with unloading via a filtering aerial bridge, recovery of amphorae filled with sediment and organic remains; **d** presence of seeds and organic materials still in the layer; **e** washing operations in the laboratory and selection of the finds; examples of taxa recovered from the amphorae include almond, hazelnut, fig, grape seeds and two pine cones. All botanical data was previously published in Sabato et al. 2019 (photo I. Sanna & C. Del Vais)

also by shell fragments; 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.; among 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 *P. domestica* fruitstones, probably introduced in Sardinia during the Punic period (Ucchesu et al. 2017). The carpological remains were partially contained into transport amphorae, but they were also largely present in the sediment of the SU 2. The dispersion could be the result of the loss of content from the same vessels, as these were not sealed and presented fractures (Del Vais and Sanna 2009; 2012; Sabato et al. 2019).

This work presents the archaeobotanical results coming from the analysis of the content of an Archaic Punic transport amphora previously unpublished (Anf. T-01; Fig. 4), recovered in the lagoon 10.60 m east of the Area A in the SU 2 and resting on the SU 3. The amphora was found during geophysical surveys and multiproxy analysis of sediment cores combined with underwater archaeological investigations in the areas under examination; this multidisciplinary project, carried out in collaboration with the CNR of Oristano, the University of Cagliari, and the Archaeological Superintendency of Cagliari, aimed to reconstruct the palaeoenvironmental evolution of the coastal lagoon of Santa Giusta (De Falco et al. 2025).

Fig. 4 The Punic transport amphora T-01 (drawings and photos by C. Del Vais)

The amphora, in addition to the carpological remains, contained few animal bones that at first sight seem pertinent to ovicaprids. It has a raised rim that is distinct from the shoulder, a grooved pear-shaped body and slightly elongated handles; only part of the lower portion of the body is missing. The remaining height is cm 76. The amphora can be attributed to the Ramon T-1.2.1.2. (Ramon 1995: 167–168), dating back to the first two thirds of the sixth century BC; the shape has already been documented in the Santa Giusta lagoon (Del Vais and Sanna 2009: 137; 2012: 212).

Based on this context, the present study focuses on the archaeobotanical analysis of Anf. T-01, with the following specific aims (1) to characterise the archaeobotanical assemblage preserved within the amphora, through the identification, quantification, and taxonomic assessment of waterlogged carpological remains, distinguishing between cultivated, gathered, ruderal, and aquatic taxa. (2) To interpret the nature and function of the amphora's original contents within the economic and cultural framework of Punic Sardinia, with particular attention to grape exploitation, the use of aromatic plants, and food processing or preservation practices, and to contextualise the results within the wider Punic Mediterranean.

Materials and methods

The sediment filling amphora T-01 was recovered intact during underwater excavation, in accordance with the operating standards adopted by the Archaeological Superintendency of Cagliari for underwater interventions, to prevent the loss of small materials contained inside together with the lagoon sediment. The contents were then extracted from the container, which has a capacity of 53 cm^3, and sifted using a wash-over technique in the Superintendency's Underwater Archaeology-Conservation and Restoration Laboratory located in the Port of Cagliari. Afterwards, further sorting and cleaning of the muddy residues from the botanical samples was carried out in the laboratories of the Sardinian Germplasm Bank (BG-SAR) (University of Cagliari). The entire sediment sample was processed using a sieve mesh size of 0.25 mm to retain the maximum amount of remains. The sieved material was subsequently examined under a stereomicroscope (Nsz800 EasyLab Stereo Microscope) to separate the carpological findings from other types of remains, such 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 (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 likelihood of their presence, were defined with updated plant references and checklists (Mabberley 2017; Bartolucci et al. 2024). The carpological remains were then stored in deionised water at 5 °C in the facilities of the BG-SAR.

Results

A total of 3,786 carpological remains belonging to 23 *taxa* were identified (Table 1). All the remains were preserved through waterlogging, which allowed an exceptional level of preservation and detailed analysis.

Among them, *Vitis vinifera* L., the grapevine, is particularly abundant, with 1,973 remains counted, including seeds (Fig. 5, 1a) and seed fragments, immature seeds

Table 1 Carpological remains found in the Archaic/Middle Punic (sixth-fifth century BC) transport amphora Anf. T-01 from the Santa Giusta lagoon

Taxa	Plant part	No. of remains
Fructiferous plants		
Ficus carica L.	achene	376
Vitis vinifera L.	seed	1973 *7
	undeveloped seed	54
	undeveloped fruit	29 *11
	pedicel	48
Aromatic plants		
Anethum graveolens L.	diachene	1
Coriandrum sativum L.	mericarp	289 *293
	diachene	65 *29
Shrubs		
Rubus ulmifolius Schott	drupe	*1
Synanthropic plants		
Asphodelus ramosus L.	seed	59
Brassicaceae	seed	1
Clematis Dill. ex L. sp.	fruitlet	1
Cyperaceae	fruit	1
Fallopia convolvolus (L.) Á.Löve	achene	1
Fumaria Tourn. ex L.	fruit	3
Galium L. sp.	mericarp	1
Medicago cf. minima (L.) L.	fruit	1
Papaver dubium L./P. *rhoeas* L.	seed	86
Ranunculus sardous Crantz	achene	1
Rumex crispus L.	fruit	5
Rumex L. sp.	tepal	6
Trifolium Tourn. ex L. sp.	perianth	7
Wetland and aquatic plants		
Bolboschoenus maritimus (L.) Palla	achene	2
Najas L.	drupe	2 *7
	seed	2
Ruppia maritima L.	achene	25
Stuckenia pectinata (L.) Börner	fruitlet	149
	circumscissile	31
Zannichellia palustris L.	fruit	219
Total specimens		3786
Total taxa		23

*n=fragments

(Fig. 5, 1b), fruits, and pedicels (Fig. 5, 1c). Also remarkable is the presence of fig, *Ficus carica* L. (Fig. 5, 2), represented by 376 achenes. Remains of the aromatic plant of coriander, *Coriandrum sativum* L., are also extremely abundant (Fig. 5, 3), as hundreds of entire and fragmented mericarps were found; the presence of seeds separated from the mericarps seems attributable to post-depositional processes that could have

Fig. 5 1–4) Fructiferous plants: 1) *Vitis vinifera* L. (1a: seed; 1b: undeveloped seed; 1c: pedicel); 2) *Ficus carica* L.; 3) *Coriandrum sativum* L.; 4) *Anethum graveolens* L. 5) Shrubs: *Rubus ulmifolius* Schott. 6–14) Synanthropic plants: 6) *Asphodelus* Tourn. ex L.; 7) *Clematis* Dill. ex. L.; 8) *Fallopia convolvulus* (L.) Á. Löve; 9) *Fumaria* Tourn. ex L.; 10) *Galium* L.; 11) *Medicago* cf. *minima* (L.) L.; 12) *Papaver dubium* L./*rhoeas* L.; 13) *Ranunculus sardous* Crantz.; 14) *Rumex crispus* L. 15–19) Wetland and aquatic plants: 15) *Bolboschoenus maritimus* (L.) Palla; 16) *Najas* L.; 17) *Ruppia maritima* L.; 18) *Stuckenia pectinata* (L.) Börner; 19) *Zannichellia palustris* L ▶

damaged the remains. Dill, *Anethum graveolens* L. (Fig. 5, 4), is attested by a single fruit.

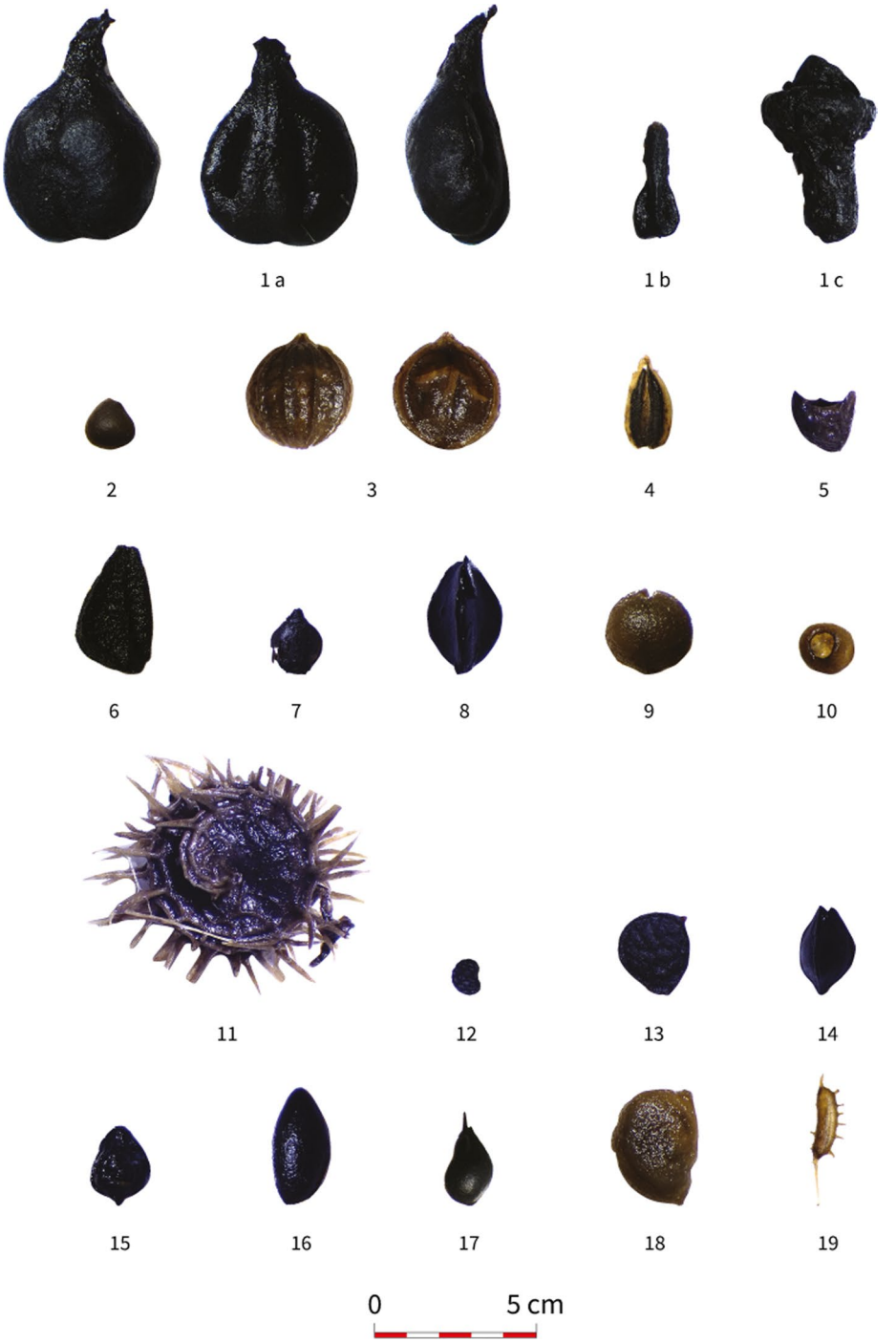
Wild vegetation is represented by shrubs as *Rubus ulmifolius* Schott (Fig. 5, 5), and synanthropic plant species as *Asphodelus* Tourn. ex L. (Fig. 5,6), *Clematis* Dill ex L. sp. (Fig. 5, 7), *Fallopia convolvolus* (L.) Á.Löve (Fig. 5, 8), *Fumaria* Tourn. ex L. (Fig. 5, 9), *Galium* L. sp. (Fig. 5, 10), *Medicago* cf. *minima* (L.) L. (Fig. 5,11), *Papaver dubium* L./*P. rhoeas* L. (Fig. 5, 12), *Ranunculus sardous* Crantz (Fig. 5, 13) and *Rumex crispus* L. (Fig. 5, 14) All these taxa are present in low numbers, 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 (Fig. 5, 15) remains, while more represented are aquatic plants typical of fresh and brackish water as *Najas* L. (Fig. 5, 16), *Ruppia maritima* L. (Fig. 5, 17), *Stuckenia pectinata* (L.) Börner (Fig. 5, 18), *Zannichellia palustris* L. (Fig. 5, 19). The remains of these last two species are particularly abundant, as around 200 specimens were counted for both of them. The remains recovered are illustrated in Fig. 5.

Discussions

The assemblage is dominated by species that were either cultivated or deliberately gathered, reflecting the original content of the amphora.

The representativeness of *Vitis vinifera* within Anf. T-01 is unequivocal, with more than 2,000 grape pips recorded. This abundance clearly indicates that grapes—whether fresh, dried or derived from some form of processing—constituted a major component of the amphora's original contents. The pertinence of the remains to cultivated grapevine appears likely and is supported by the attestation of undeveloped seeds (Fig. 5, 1b), a trait generally associated with domesticated varieties (Zohary et al. 2012); although further analyses will help to refine this interpretation. Moreover, the importance of viticulture in ancient Sardinia is well documented, as the first signs of this agricultural practice, together with the proof of secondary domestication processes held on the Island, date to the Bronze Age (Ucchesu et al. 2015; 2024; 2025). During the 1 st millennium BC, grapevine cultivation appears to have continued and possibly increased in importance, as indicated by the widespread occurrence of *V. vinifera* remains in Punic contexts where archaeobotanical analyses have been conducted (Marinval & Cassien 2001; Bakels 2002; van Dommelen and Gómez Bellard 2012; van Dommelen et al. 2010; 2012; 2018; Del Vais et al. 2020; Moricca et al. 2020; Pérez-Jordà et al. 2020; Moricca et al. 2021a, b).

A particularly noteworthy aspect of the Santa Giusta assemblage is the presence of *Coriandrum sativum*; the only other archaeobotanical evidence of coriander fruits from Sardinian sites derives from the waterlogged harbour context of the Punic city of Tharros, in the nearby Mistras lagoon (Del Vais et al. 2020; 2023a). Coriander is one of the oldest aromatic plants used in the Mediterranean: in South-West Asia its presence is attested at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Neolithic sites, and clear evidence of its domestication appears at sites in Egypt and Greece dating to the 2nd millennium BC (Megaloudi 2005; Zohary et al. 2012). Its introduction to the western Mediterranean for the moment seems to date to the 1 st millennium BC, when it is documented in Punic Carthage (van Zeist et al. 2001), in Sicily (Stika et al. 2008) and in the Iberian Peninsula (Pérez-Jordà 2020; Pérez-Jordà & Peña-Chocarro 2024). At Santa Giusta, the association of coriander with ovine/caprid bones showing clear signs of slaughter or butchering suggests a possible role in food processing and preservation. In this framework, coriander may have been used together with grape products (wine or grape by-products) and possibly resin-rich pinecones attested in other amphorae from the site, contributing not only to flavouring but also to preservative or antioxidant effects. While this interpretation remains hypothetical, it is consistent with patterns observed in other Punic contexts.

Another noteworthy element is the presence of *Anethum graveolens*, an aromatic plant native to South-West Asia and naturalised in southern Europe. Dill has a long history of use in the ancient Mediterranean: it was found in the tomb of the Egyptian Pharaoh Amenhotep II, dating to around 1400 BC, later evidence comes from the Greek city of Samos, around the seventh century BC, and it is mentioned by Theophrastus (371–287 BC) (Prance and Nesbitt 2012). Since the timing of its introduction in Sardinia remains unknown, and it is represented by only a single specimen in the Santa Giusta assemblage, we approach the interpretation of its presence with caution, although its occurrence in a well-defined, closed context may still be chronologically significant.

As for the fig achenes found inside the amphora, 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 contents of transport amphorae documented in the underwater context of the Santa Giusta lagoon—including both the material examined in this study and that previously published—find numerous parallels within the Punic world, particularly in other Sardinian underwater contexts (Del Vais and Sanna 2009; 2012; Sabato et al. 2019). The earliest evidence of animal bones inside Punic transport amphorae comes from the Santa Gilla lagoon near Cagliari, where the first excavations took place at the end of the nineteenth century, followed by several interventions during the past century (Vivanet 1892; 1893; Moscati 1991; Solinas and Orrù 2005); some vessels contained nuts of *Corylus avellana*, while others were full of pinecones, recognised as *Pinus nigra* J.F.Arnold subsp. *laricio* Palib. ex Maire and *Pinus sylvestris* L., according to Vivanet (1893). Underwater excavations carried out by a Franco-Italian mission off the coast of Nora documented the association of animal remains with *V. vinifera* seeds inside Punic amphorae (Marinval and Cassien 2001; Poplin 1980; 2014). The same association of grapevine remains, seeds and pedicels, with animal bones as a content of the amphorae has already been documented in the Santa Giusta lagoon (Del Vais and Sanna 2009; 2012; Sabato et al. 2019).

Comparable evidence is emerging from the Mistras lagoon, where ongoing research by the University of Cagliari has revealed the recurrent co-presence of fragmentary Punic amphorae, animal bones and a diverse assemblage of cultivated and wild carpological remains (Del Vais et al. 2020; 2023b). Further parallels 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).

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 the existence of an industry dedicated to the production of preserved meat, processed thanks to a by-product of the grapevine (Marinval and Cassien 2001; Poplin

1980; 2014; Del Vais & Sanna 2019; Sabato et al. 2019; Sanna 2019). In this sense the association with *C. sativum* attested in the present study may be particularly significant, as this plant has proven antibacterial properties and it serves as a natural food preservative (Sulieman et al. 2023; Ahmad et al. 2024). Even considering the different chronology, it can be worth mentioning that, according to an information of the Roman author Marcus Terentius Varro, as reported by Pliny the Elder (*Naturalis Historia* XX, 82) in the first century AD, coriander was used for the preservation of meat, together with cumin and vinegar.

However, in the interpretation of the amphora content, it should not be forgotten that in some other cases the osteological remains were attributed to meat that had already been consumed (Poplin 1980). A more integrated and systematic approach to the study of transport amphorae and their contents is therefore required to refine these interpretations.

In any case the origin of the products remains to be established. In the context of Punic Sardinia, in which agriculture and breeding had a central role (van Dommelen and Gómez Bellard 2008; 2012; van Dommelen et al. 2010; 2012; Roppa and van Dommelen 2012; Del Vais 2014; Roppa 2014), it seems reasonable to hypothesize the possibility of a production in the hinterland of the city for the edible goods, at least for a part of them. As for the transport amphorae, preliminary analyses seem to point to a local origin (Del Vais and Sanna 2012).

Finally, for the wild species documented within Anf. T-01, it seems possible to hypothesise an introduction inside the amphora during the post-depositional process. This is the case for aquatic plants *Najas* sp., *Ruppia maritima*, *Stuckenia pectinata* and *Zannichellia palustris*, typical of fresh and brackish water environments (Pignatti 2017). As for the ruderal species found in the sediment of Anf. T-01 the possibility of an intrusion in the original content of the amphorae, due to casual recollection together with the harvested products, can be taken into consideration.

Conclusions

The data from the archaic amphora Anf. T-01 found in the Santa Giusta lagoon is consistent with previous evidence from Punic sites of Sardinia, where the copresence of animal bones and grapevine is attested as remains of the content of transport amphorae. However, this finding gives new and extremely interesting information, as an unprecedented association with the aromatic fruits of coriander and dill is attested. Further studies will eventually help in defining the nature of these attestations, which suggests the existence of a system for preserving meat thanks to a by-product of the grapevine, in this case implemented with the use of aromatic and antimicrobial ingredients. The presence of coriander and dill gives new information about the diffusion of these plants and their use, as they are native to South-West Asia and appear in the western Mediterranean along the 1st millennium BC.

Furthermore, the study provides information on the wild vegetation, attesting the presence of ruderal species, possibly gathered with the cultivated ones, but also of aquatic plants, presumably included in the sediment during the post-depositional process.

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Author contributions All authors conceived the study; Maria Mureddu, Mariano Ucchesu and Marco Sarigu dealt with the materials and methods, Gianluigi Bacchetta helped in the taxonomic identification of

the species; Maria Mureddu, Ignazio Sanna and Carla del Vais prepared all figures. All authors wrote and reviewed the manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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