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Wood exploitation and food supply at the border of the Roman Empire: the case of the *vicus* of Thamusida – Sidi Ali ben Ahmed (Morocco)

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This paper presents the results of inter-disciplinary work drawing on archaeobotanical and archaeometric studies to trace the agroforestry landscape and the supply economy at the *vicus* of Thamusida in north-west Morocco at the border of the Roman Empire. The available data indicate the self-sufficiency of the settlement in both forestry and agricultural products throughout the period investigated from the end of the 1st century BC to the beginning of the 4th century AD. Charcoal data testify to the presence of a *Quercus suber* forest in the close surroundings of the site and its exploitation for a variety of forestry products such as timber, fuelwood, cork, and probably also leaves and acorns to feed livestock. The overwhelming presence of *Q. suber* in the archaeological layer investigated clearly indicates that this forest was under human influence prior to Roman occupation and was already partially degraded. Charred seed and fruit remains suggest that the diet of both troops and civilians was mainly based on locally grown products and that all the inhabitants of the site had access to good cereals such as barley, naked wheats and pulses with large seeds such as horse bean and pea; quality fruits, such as olive and grape, were also produced locally for fresh consumption. Organic residue analyses of the contents of ceramic vessels and plastered vats allowed archaeobotanical data to be complemented, thereby shedding light on some of the imports at Thamusida. Despite the remote location of this settlement, imported goods such as oil and wine were transported here in amphorae from different parts of the Empire.

Keywords: Multi-functional forest, Cork oak, *Quercus suber*, Barley, Northern Africa, Charcoal analysis, Archaeobotany

Introduction

No ancient trade matched in structure, scale and intensity of the trade economy of the Roman World. An important ancillary outcome of this globalised trade system was an unprecedented extension of settlements along the network, especially in northern Africa, Western and Central Europe, and Asia Minor Hitchner 2008).

The archaeological site of Thamusida – present-day Sidi Ali ben Ahmed – is situated in north-western Morocco (34°19′N–6°29′W) about 50 km away from the city of Rabat and about 30 km from the Atlantic coast (Fig. 1). The site was discovered early on, at the end of 19th century, and three archaeological excavations at the site were carried out by a French mission between 1930 and 1960 (Akerraz and Papi 2008). Since 1999 more extensive and systematic exploration has been carried out by the University of Siena in collaboration with the Institut National de Sciences de l'Archéologie et du Patrimoine de Rabat (INSAP).

The 15-hectare site is located on a low hill near the left side of the Sebou river. It consists of a military quarter with an adjacent civil settlement, namely, the *vicus*, with all the main private and public infrastructures such as houses, thermal baths, temples, taverns, shops and workshops. It was built in the 1st century AD, following the establishment of *Mauretania Tingitana* as a Roman province. At the end of the 3rd century AD, after the withdrawal of the Roman army, Thamusida continued to be inhabited until the Arab conquest (7th–8th century AD).

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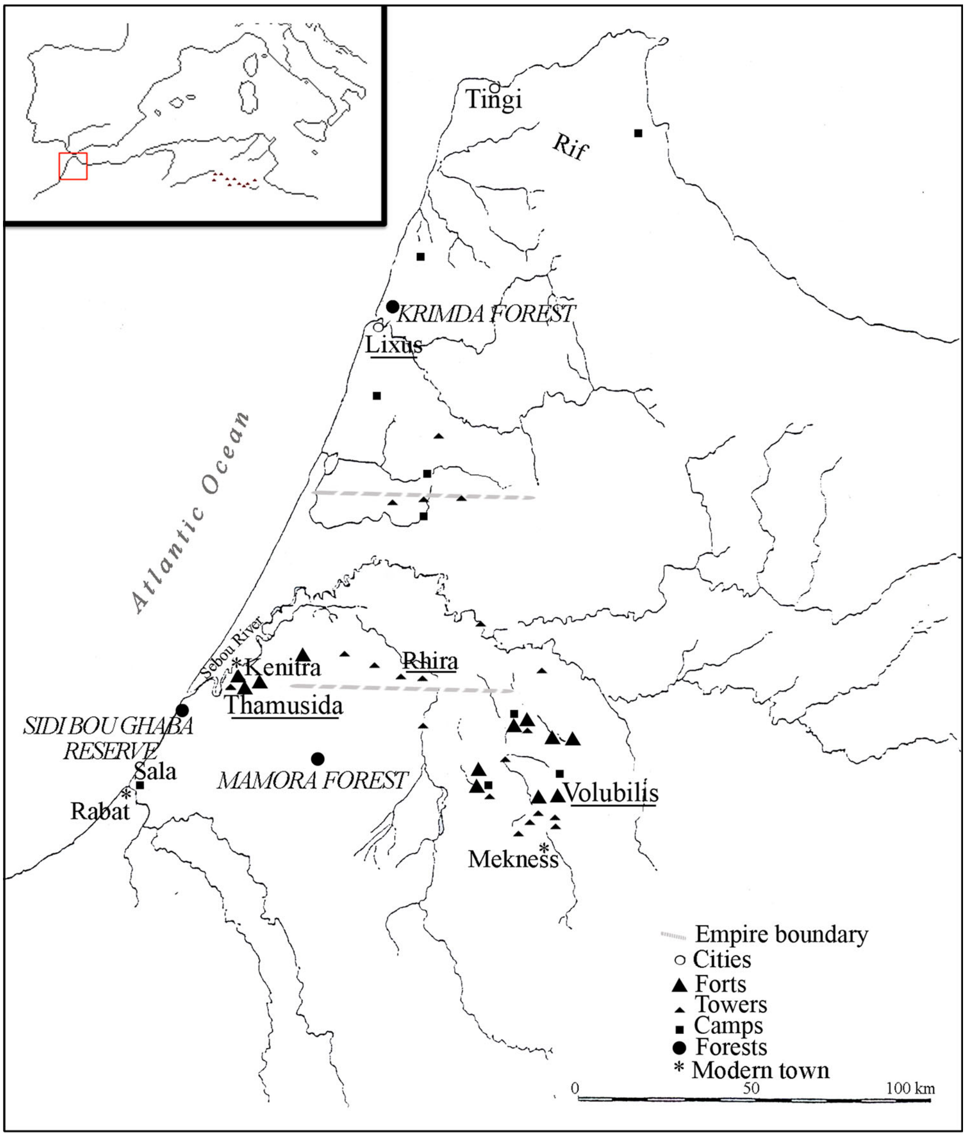

Figure 1 **Study site and main sites cited in the text. Modified from Akerraz *et al*. 1995.**

Here, we present the results of inter-disciplinary work using archaeometric and archaeobotanical studies in order to map out the supply economy at the *vicus* of Thamusida. Charred archaeobotanical remains (seed and fruit remains and charcoal) were analysed in order to provide information on the plant environment, and on the exploitation of woodland as well as the production and consumption of food in the area.

Chemical analyses of the contents of ceramic vessels (dolia and amphorae) recovered in a warehouse in the military quarter were carried out to identify the organic residues preserved in them and provide information on the import and consumption of wine, oil or fish sauces. Moreover, the plastered coatings of two vats excavated at the site were carried out to identify any substances contained in them and therefore ascertain whether they were used in the production of wine, oil or fish sauces (Pecci *et al*. 2013a), and whether they suggested the existence of production structures at the site.

The present-day environment of Thamusida

The coastal region of Kenitra-Rabat is subject to a thermomediterranean sub-humid bioclimate: the mean annual precipitation is 600 mm and the rainiest periods are in winter (mainly in November and December). Easterly sea breezes in the summer carry wet air masses from the Atlantic Ocean. The mean annual temperature is 17.2°C, with a seasonal average temperature of 13°C in winter and 27°C in summer (Kabbour *et al*. 2006). Soils are mainly marshy and saline (Cavallar 1950).

The current vegetation in the vicinity to the site is represented by the prevailing *Chamaerops humilis* and scattered shrubs of *Ziziphus lotus* and *Olea europaea*. Along the Sebou river, riparian vegetation consists of scattered plants of *Vitex agnus-castus* and *Crataegus monogyna*. Along the coast, 20 km away from the site, the "Biological Reserve of Sidi Bou Ghaba" (Fig. 1) includes shrubby formations with *Juniperus phoenicea*, *Phillyrea angustifolia*, *Pistacia lentiscus*, *Rhamnus oleoides* and *Retama monosperma*.

Riparian vegetation with prevailing *Populus alba* characterises the surrounding area of the Merja (lagoon) of Sidi Bou Ghaba. The Mamora forest (Fig. 1) is located a few kilometres away from the site; it is at present one of the most degraded forests in Morocco with few woody taxa (Rejdali 2004). *Quercus suber* is the only tree taxon and is accompanied by few shrubby species, such as the endemic *Pyrus mamorensis* and sporadically *O. europaea*, *Phillyrea latifolia* and *Teline linifolia*.

Materials and methods

Charcoal

Sediment samples were collected from deposits archaeologically dated between the end of the 1st century BC and the beginning of the 4th century AD. The sampling strategy followed Chabal *et al.* (1999), each sample ranging between 5 and 10 kg according to the thickness and surface area of the archaeological layer. All the collected sediments were floated on a sieve column with a mesh size of 4.0 and 2.0 mm and then dry sieved. Further, two trenches (namely, trench 39,000 and trench 40,000), close to a hill described as a productive area, were excavated and sampled. The charcoal fraction >4 mm was sorted by the naked eye while fragments > 2 < 4 mm were sorted with the help of a dissecting stereomicroscope with a low magnification (10X–40X). All charcoal fragments were analysed with an incident light microscope (100X–1000X) and identified by referring to wood anatomy atlases (Neumann *et al.* 2001; Schweingruber 1990; Vernet *et al.* 2001), as well as to our reference collection.

In a previous paper, 2610 charcoal fragments from 50 SUs were analysed and presented (Allevato *et al.* 2013). Charcoal analysis at the site was then carried out by Bellavia (2011).

After in-depth examination of the function of the context and further refinement of archaeological dating of all analysed layers, we used for our reconstruction only those layers which were well constrained chronologically so as to avoid bias in the representativeness of the assemblages due to ambiguous provenance of the charcoal. A total of 4354 charcoal fragments from a total of 70 archaeological layers, which are referred to here as stratigraphic units (SUs), are now presented in this definitive paper.

Carpological remains

At least 20 l of sediment samples were taken from 50 archaeological layers, which are referred to here as stratigraphic units (SUs), related to 10 archaeological structures (Table 2). By the term "archaeological structure", we indicate the presumed function of the features in the settlements, such as barracks and fortified walls. Sediment samples were labelled according to the SU and the structure identification follows the same numbering sequence as the excavation plan. SUs cover a chronological range between the end of the 1st century BC and the beginning of the 4th century AD.

The samples were processed by flotation and macroremains were recovered from mesh sizes 4, 2, 1, 0·50 and 0.25 mm. All recovered plant remains were well preserved under a charred condition. They were observed and separated into "individuals" and "fragments", and then counted. We use the term "individual" when the fragments had diagnostic features that allowed us to count them as entire, following the principle of the "minimum number of individuals" (Antolìn and Buxò 2011; Jones 1990). Identified fragments without these characteristics were counted and classified as fragments.

Taxonomic identification was carried out by using a reference seed collection for comparison, atlases and the specialist literature (e.g. Hubbard 1992; Maier 1996; Neef *et al.* 2012; Renfrew 1973; Schoch *et al.* 1988). Since grain remains of naked wheat cannot be identified at a species level (Alonso Martinez 2005; Jacomet 2008; Maier 1996; Ruas 2005), the term *Triticum aestivum/durum* is used in accordance with Jacomet (2008).

All percentages and frequencies were calculated for each taxon by considering the minimum number of individuals (MNI) according to Antolìn and Buxó (2011); rachis forks were included as individuals in percentage calculations for cereals, as well as floret in weeds. For *O. europaea*, since only fragments were present, they were considered as individuals following Alonso Martinez (2005). The percentage of each taxonomic group out of MNI recovered is reported in Fig. 2. The general proportions of the food plants in Thamusida (cereals, pulses and fruits), excluding *Hordeum/Triticum*, *Pisum/Vicia*, and undifferentiated pulses, are reported in Fig. 3.

In order to observe spatial distribution of the carpological remains in the settlements, to detect the differences between the archaeological structures and to explain the use of crops, we selected only 4 out of 10 archaeological structures recording >30 MNI. The percentages of MNI of the taxa from the total sum of cereals, pulses and fruits of these four selected structures are reported in Fig 4.

Residue analysis

A total of 15 samples were analysed for the organic residue analysis (Table 3, Fig. 6). Two samples were recovered from the plastered coatings of two small vats with the objective of ascertaining whether they could be related to the presence of small production structures at the site. In fact, the study of vats can provide information on food production at archaeological sites (Pecci *et al.* 2013a, Pecci and D'Andria

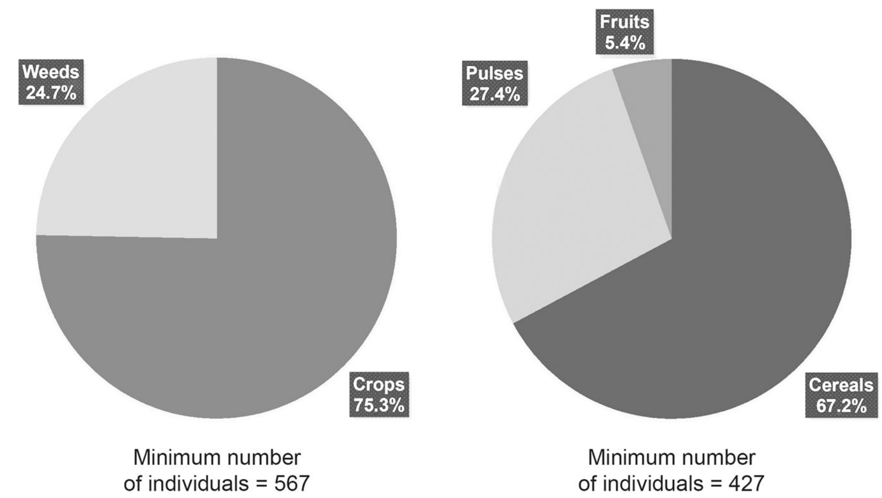

Figure 2 Crop plants from Thamusida: percentages of each taxonomic group out of the minimum number of individuals recovered.

2014). One sample was recovered from the plastered coating of a vat possibly related to a domus dated to the Flavian period (sample 1, Table 3) and another was recovered from a vat located nearby (sample 2, Table 3) and related to a probable re-use of the area between the end of the 2nd and the beginning of the 3rd century AD.

Samples 3 and 4 were taken from two Dressel 20 amphorae coming from one production structure (Salvini *et al*. 2007). The other materials analysed come from the military quarter: they were recovered in a storage room where amphorae and *dolia* were abandoned between the end of the 3rd and the beginning of the 4th century AD (area XII). The materials

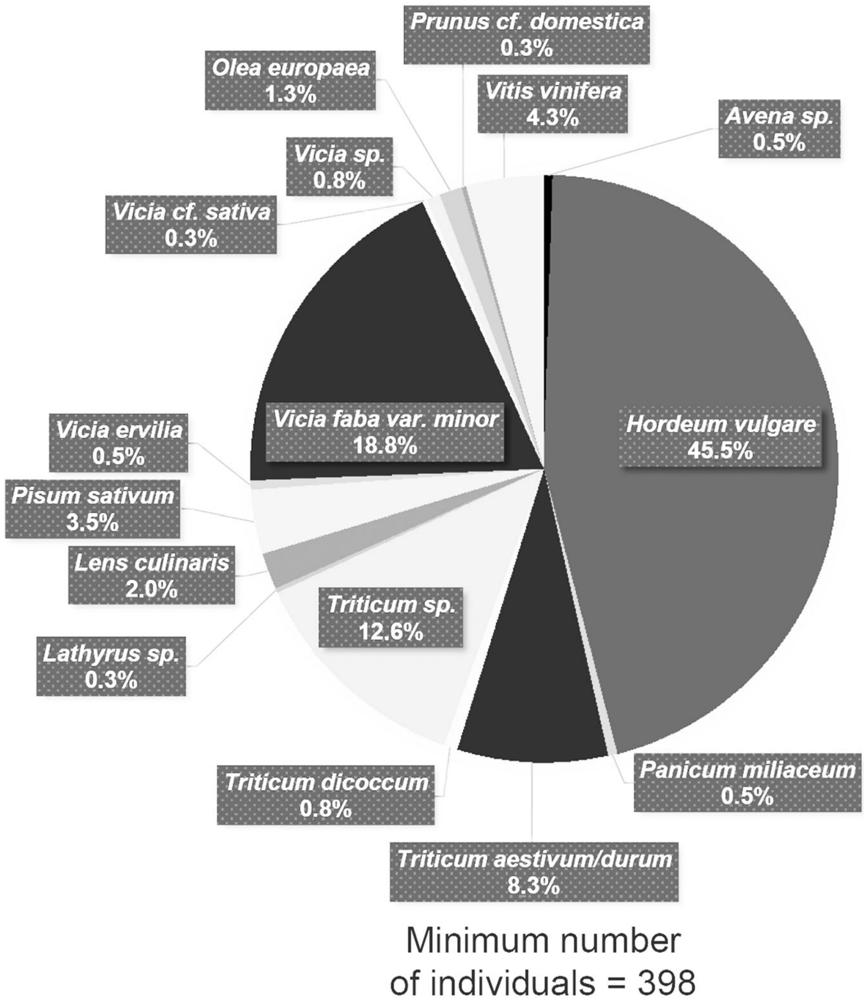

Figure 3 Food plants in Thamusida: percentages of each taxonomic group out of the minimum number of individuals considered.

Figure 4 Food plants in Thamusida by archaeological structures with more than 30 minimum number of individuals. Percentages of MNI of the taxa from the total sum of cereals, pulses and fruits, excluding *Hordeum*/*Triticum*, *Pisum*/*Vicia*, and undifferentiated pulses.

consist of one Dressel 20, one Dressel 30, five *amphorae* Africana (three provisionally identified as Africana IID, one Africana IIB and one Africana II non-id.) and four *dolia* (Table 3).

The samples were mechanically cleaned with a scalpel and then ground. Each powdered sample was submitted to three extractions: (a) lipid extraction following the procedure described by Mottram *et al.* (1999); (b) after total lipid extraction the solid residue was extracted following Pecci *et al.* (2013b); (c) to identify wine markers the extraction method proposed by Pecci *et al.* (2013c) was followed.

All the extracts were derivatised by adding 25 µl of *N*,*O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA, Sigma-Aldrich) and heating at 70°C for 1 h. Analyses were carried out in collaboration with the Chemistry Department of the University of Siena at the Centre for Analysis and Structural Determinations (CIADS) using instruments and parameters reported in Giorgi *et al.* (2010).

Results

Charcoal

Out of a total of 4354 analysed charcoal fragments from 70 SUs, 23 taxa were identified. The percentage of each taxon is represented in Table 1. Percentages were calculated from the total number of charcoal fragments in the coeval SU grouped by functional hypothesis. The number of SUs and the count of charcoal fragments are indicated for each period and typology. The results for 16 SUs comprising furnaces, kilns and ovens are not represented in the figure because only charcoal belonging to the *Quercus* genus (mainly *Q. suber*) was present therein (861 fragments).

The most abundant charcoal fragments belong to the *Quercus* genus: along the entire investigated period and in all functional contexts *Q. suber* is always dominant; *Q. suber*-*ilex* and *Quercus* are also present among the identified taxa. Charcoal fragments were attributed to *Q. suber* only when we were able to observe the transition from early to late wood in large and complete growth rings (Schweingruber 1990). Additional testing was also performed by measuring vessel diameter following Vernet *et al.* (2001). Alternatively, charcoal fragments were attributed to *Q. suber*-*ilex* and *Quercus*. However, the absence in the identifications of *Quercus* charcoal identifiable at a species level other from *Q. suber* strongly suggests that all the charcoal fragments belong exclusively to the latter.

Additional analysis of two trenches (namely, trench 39,000 and trench 40,000, Fig. 4), close to a hill identified as a presumed production area and consisting of

Table 1 Percentages of charcoal fragments grouped by dating and functional type of the excavated contexts.

					Taxa (%)																							
Chronology	Context	Excavation areas	USs (count)	Analysed charcoal (count)	*Quercus suber*	*Quercus suber-ilex*	*Quercus*	*Frankenia*	*Gymnospermae*	*Tetraclinis articulata*	*Pinus pinaster*	*Pinus*	*Daphne-Thymelaea*	*Erica*	*Ceratonia siliqua*	% cf. *Prunus* sp.	*Cistus*	*Prunus*	*Crataegus*	*Olea europaea*	*Vitis vinifera*	*Pistacia lentiscus*	*Populus*	*Fabaceae*	*Juglans*	*Arbutus unedo*	Rosaceae maloideae	Undetermined
End 3rd AD–Beg. 4th AD	Collapses	12,000	5	354	29·38	19·49	17·23	2·26	0·85	5·37	_	_	0·28	0·56	_	0·85	_	_	0·28	1·13	_	0·28	_	_	_	0·28	_	21·75
	Living floors	5000, 7000	4	97	77·17	16·30	5·43	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	1·09
Second half 3rd century AD	Living floors	14,000	5	157	42·04	51·59	1·91	_	_	1·27	_	_	_	_	_	_	_	_	_	0·64	0·64	_	_	_	_	_	_	1·91
	Accumulation	14,000	1	16	_	87·50	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	12·50
First half 3rd century AD	Accumulations	14,000	2	63	33·33	42·86	_	_	_	_	_	_	_	_	_	_	_	_	_	7·94	_	_	_	_	_	_	_	15·87
	Living floors	4000, 14,000	7	262	23·13	48·84	3·73	_	_	0·75	4·48	0·75	_	_	_	_	_	_	_	2·65	0·10	_	_	_	_	_	_	15·57
Mid-2nd century AD–3rd century AD	Living floors	15,000	2	86	5·81	81·40	_	_	_	_	_	_	_	_	_	_	_	_	_	4·65	_	_	_	_	_	_	_	8·14
Mid-2nd century. AD–Beg. 3rd century AD	Accumulations	1000, 14,000	2	144	40·28	40·28	3·47	_	_	0·69	_	_	_	_	_	_	_	_	_	2·08	0·69	_	_	_	_	_	0·69	11·81
	Waste discharges	1000, 37,000	3	1033	96·03	0·29	0·68	_	0·10	0·39	_	_	0·10	_	0·48	_	_	_	_	0·19	_	_	_	_	_	_	_	1·84
	Living floors	4000, 5000, 12,000	3	171	38·60	11·11	7·60	0·58	1·17	0·58	0·58	_	_	_	_	_	1·17	3·51	0·58	_	1·17	_	0·58	0·58	_	0·58	2·34	29·24
Flavian Age (AD 69–96)	Living floors	5000	4	324	70·06	8·64	6·48	0·31	0·31	_	0·31	_	_	_	_	_	_	_	_	0·93	0·31	_	_	_	0·62	_	_	12·04
	Accumulation	1000	1		73·42	10·13	7·59	2·53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	6·33
	Collapses	20,000	2	34	26·47	41·18	23·53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	8·82
End 1st cent BC–Beg. 1st century BC	Accumulations	1000, 4000	2	155	58·06	11·61	10·97	1·29	_	_	5·81	_	_	_	_	_	_	_	_	5·16	_	_	_	_	_	_	_	7·10
	Living floors	4000, 5000	7	488	74·59	8·40	7·38	0·82	_	0·20	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	8·61
End 1st AC–Beg. 1st century AD	Living floors	5000	1	109	14·68	16·51	11·01	_	11·93	15·60	_	_	_	_	_	_	_	_	_	3·67	_	_	_	_	3·67	_	_	22·94
	Total		51	3493																								
	Furnaces and ovens with Quercus 100%	19,000, 35,000	17	861																								
	Trenches	T39,000, T40,000	2	_																								
	Total		70	4354																								

Notes: Percentages were calculated from the total number of charcoal fragments in the coeval SUs grouped by functional hypothesis (i.e. by archaeological structure). Provenance areas of the excavated layers are also listed.

Table 2 Carpological (seed and fruit) remains from Thamusida.

Archaeological structure		**1000**	4000	5000	7000	**12,000**	14,000	**19,000**	20,000	36,000	**37,000**
		Huge fortified walls	Granary	Street	Street	**Military barracks**	Inhabited layer	**Rubbish dump**	Accumulation	Military bread oven	**Rubbish dump**
Samples (SU)		1025, 1035, 1040	4053, 4060, 4061	5018, 5019, 5020, 5021, 5024, 5026, 5028, 5051, 5052	7044, 7078, 7091, 7098, 7100, 7112, 7113	12,112, 12,113, 12,121, 12,119, 12,126, 12,155, 12,174	14,112, 14,118, 14,127, 14,144, 14,147, 14,202, 14,203	19,002, 19,003, 19,006, 19,008, 19,018, 19,041, 19,050, 19,056	20,116	36,007, 36,012	37,012, 37,015, 37,026
Cereals											
Avena sp.	Caryopsis			1				1			
Hordeum vulgare	Caryopsis	3	3		6	37	3	47	1	5	6
Hordeum vulgare fragm	Caryopsis				3	60	1	62	3	5	3
Hordeum vulgare fragm	Rachis			1							
Panicum miliaceum	Caryopsis					1		1			
Triticum aestivum/*durum*	Caryopsis	8		5	6	7			1	1	
Triticum aestivum/*durum* fragm	Caryopsis			1		5			1		
Triticum cf. *aestivum*/*durum*	Caryopsis			1							
Triticum dicoccum	Caryopsis	1		1							1
Triticum sp.	Caryopsis	12	2	4	1	3	1	1	1	1	3
Triticum sp. fragm	Caryopsis			18	3	15	2				3
Hordeum/*Triticum*	Caryopsis							2	2		11
Hordeum/*Triticum* fragm	Caryopsis				2						
Pulses											
Lathyrus sp.	Seed	1									
Lens culinaris	Seed			1	1	1					3
Lens culinaris fragm	Seed	3				1					
Pisum/*Vicia*	Seed	3					1				1
Pisum/*Vicia* fragm	Seed	9			2						
Pisum sativum	Seed	10	1			1					2
Vicia ervilia	Seed	1									1
Vicia faba var. *minor*	Seed	15						3			4
Vicia faba var. *minor* fragm	Seed	94						7			4
Vicia cf. *sativa*	Seed				1						
Vicia sp.	Seed				3						

Pulses undiff.	Seed			1	1						
Fruits											
Olea europaea fragm	Endocarp	2							3		
Prunus cf. *domestica*	Endocarp	1									
Vitis vinifera	Pip	2	1	1				3			5
Vitis vinifera fragm	Pip	10									
Weeds											
Carex sp.	Achene					3					
Chenopodiaceae	Achene		1								
Cyperaceae	Achene	2		1					1	1	
Hordeum cf. *secalinum*	Caryopsis					3					
Hordeum cf. *secalinum*	Floret					1					
Lolium sp.	Caryopsis				2	20		1			
Malvaceae	Seed	30				7	4			2	2
Medicago sp.	Seed					3		2			
Phalaris sp.	Caryopsis	3	1		3	7	1	2			
Rumex sp.	Achene				1	17				1	
Sherardia arvensis	Endocarp					1					
Vicia cf. *cracca*	Seed		1		1		1	6			
Vicia cf. *cracca* fragm	Seed					1					
Vicia sp.	Seed							2	2		
Poaceae undiff.	Caryopsis				2						
Unidentified		3	5	4	1	7		10			
Unidentified fragm				1		1					
Total		213	15	41	39	202	14	150	15	16	49

Absolute values grouped by archaeological structures of settlement. Heading of the structures with more than 30 minimum number of individuals are in bold.

Table 3 Samples analysed and summary of the results of the organic residue analyses of amphorae, dolia and vats from Thamusida

Sample Id.	Typology	Content			
		Oil	Wine	Animal fats	Pinaceae
1	Plaster coating of a vat				
2	Plaster coating of a vat	■		■	■
3	Dressel 20	■			■
4	Dressel 20	■			■
5	Dressel 20	■			■
6	Dressel 30		■	■	■
7	Africana IID		■	■	■
8	Africana IID	░	░ Fermentation markers	■	■
9	Probable Africana IID			■	■
10	Africana IIB		■	■	■
11	Africana non id	■	■	■	■
12	Dolium		■		■
13	Dolium				■
14	Dolium		■		■
15	Dolium				■

Notes: Dark grey squares indicate presence; light grey indicates probable presence of the substance.

several levels of ash mixed with soil and pottery fragments, revealed the presence of five layers entirely constituted by partially charred *Q. suber* cork separating the levels. Overall, the constant presence of *Q. suber* cork in almost all contexts is noteworthy.

Carpological remains

The results are given as absolute counts and grouped by the 10 archaeological structures. From the 752 charred remains recovered, 26 taxa were identified of which 14 were cultivated or cultivable taxa and 12 weed taxa (Table 2). Considering the MNI, crop plants were the most common remains with 75·3% (Fig. 2).

Crops

Cereals represent 67·2% of the crop plant individuals (Fig. 2). *Hordeum vulgare* in its hulled form dominates the carpological assemblage (45·5%), followed by *T. aestivum/durum* (8·3%) and *Triticum* sp. (12·6%) (Fig. 3). *Avena* sp., *Panicum miliaceum* and *T. dicoccum* are also present.

Pulses account for 27·4% of the crops (Fig. 2), with the cultivated *Vicia faba* var. *minor* (18·8%), *Pisum sativum* (3·5%), and *Lens culinaris* (2·0%) (Fig. 3). *Vicia* sp., *Lathyrus* sp., *V. ervilia*, and *V.* cf. *sativa* are scarcely present. Only three taxa (5·4%) are attributable to fruit plants (Fig. 2); among them, *Vitis vinifera* and *O. europaea* are the most important (respectively 4·3% and 1·3%). *Prunus* cf. *domestica* is also reported.

Weeds and wild plants

Twelve wild plant taxa were identified (Table 2), representing 24·7% of plant individuals (Fig. 2). Poaceae, such as *Phalaris* sp., *Lolium* sp. and *Hordeum* cf. *secalinum*, and Fabaceae of the genus *Vicia* were the most commonly attested taxa; wild plants consisted mainly of ruderals, and weeds of cultivated fields and wetlands, such as *Rumex* sp.

Residue analysis

Analysis of the plaster coating from the first vat of the Flavian period (sample 1, Table 3) shows no residues. These results are consistent with the fact that the vat can be interpreted as a fountain related to the triclinium of a Roman *domus* present at the site. Therefore, the presence of a structure for the production of food for the Flavian period in this area can be excluded. By contrast, analysis of the sample of the plastered coating of the other vat from a later re-use of the area (sample 2, Table 3 and Fig. 5) shows the presence of β-sitosterol and abundant $C_{18:1}$ that is higher than $C_{18:0}$ in all the extracts. Besides, in extract (b) azelaic acid is the highest among the dicarboxylic acids and C_9 is the highest among the short-chain fatty acids. These data are compatible with the presence of a vegetable oil, possibly olive oil, in the vat. The presence of dehydroabietic acid suggests the existence of an organic coating of the vat made of *Pinaceae* products, as already suggested for vats in production structures in other archaeological sites (Allevato *et al*. 2012; Pecci *et al*. 2013a). The presence of cholesterol, marker of animal products, suggests that some fats could have been added to the plaster for the coating.

Analysis of the two Dressel 20 amphorae (samples 3 and 4, Table 3, Fig. 6) coming from the production structure show the presence of β-sitosterol and abundant $C_{18:1}$ acid, while in the hydrolyses there is azelaic acid together with other acids related to the presence of oil (Pecci *et al*. 2013b; Salvini *et al*. 2007). Also in the Dressel 20 amphorae from the storehouse of the military quarter (sample 5, Table 3), there is abundant azelaic acid, which is the relatively highest

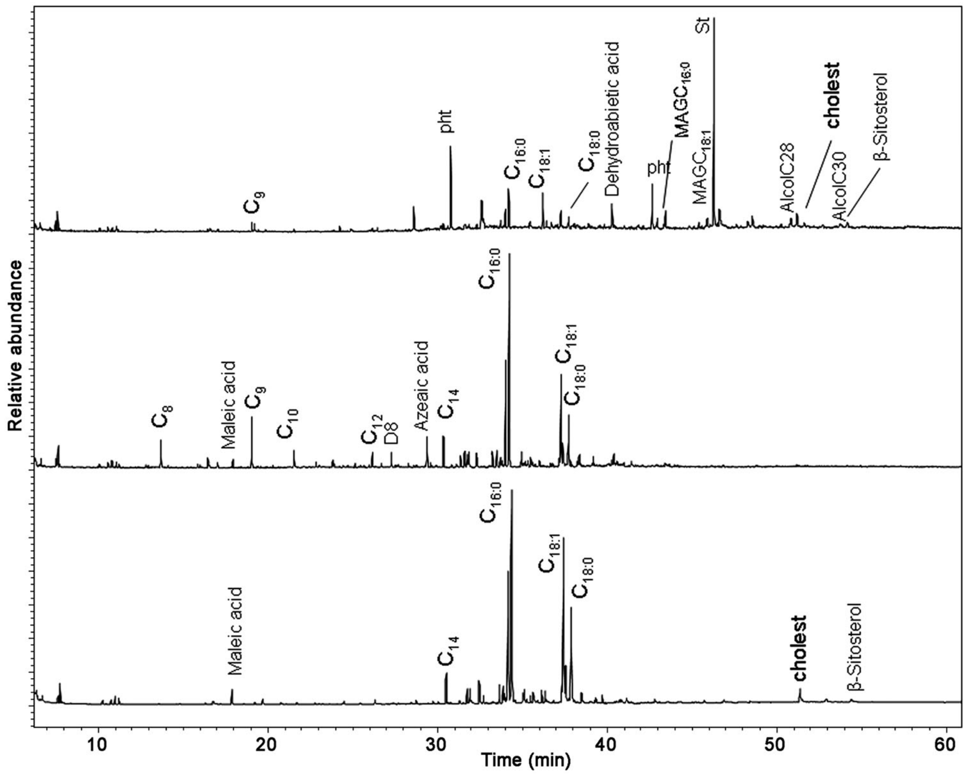

Figure 5 Chromatograms of the analysis of the total lipid extract (upper), the extract for the identification of wine markers (middle) and the hydrolysis on the solid residue after total lipid extraction of sample 2.

among the dicarboxylic acids. Further, among the short-chain fatty acids C_9 is the relatively most abundant, and there are other acids usually present in oil (Pecci *et al.* 2013a, Figs. 13 and 14). These data confirm the archaeological hypothesis of an oil content for this type of amphora (Pecci *et al.* in press).

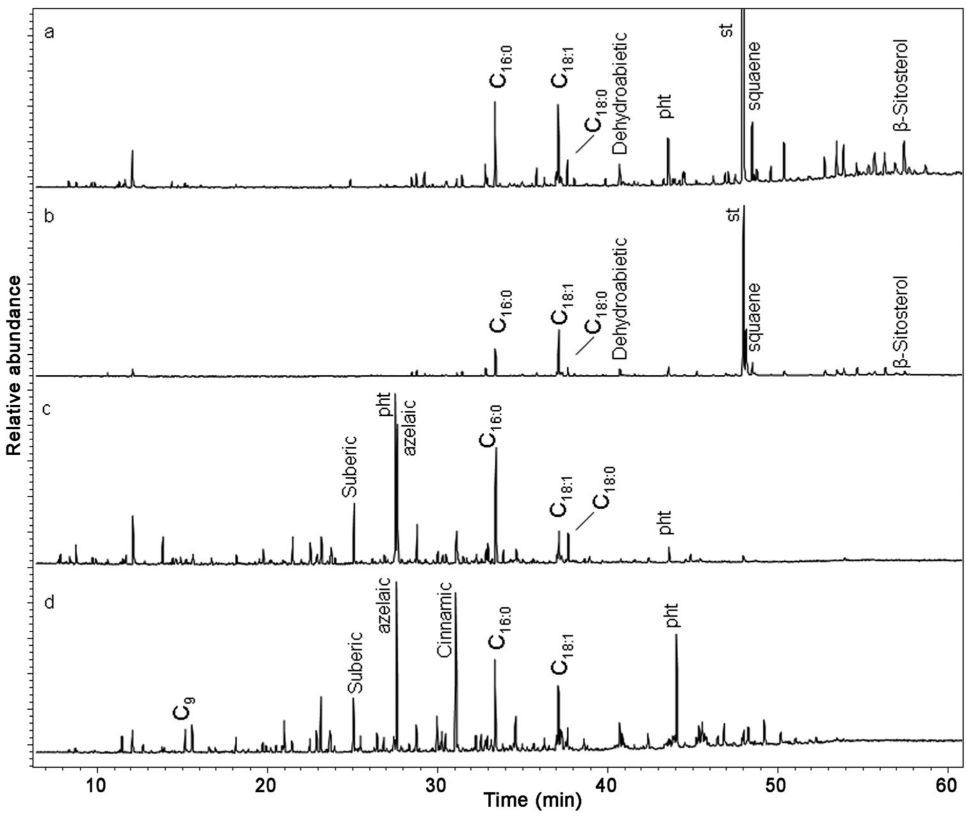

Figure 6 Chromatograms of the analysis of samples 3 and 4, Dressel 20 amphorae. (3a and 3b: extraction a of samples 3 and 4; 3c and 3d: extraction c of samples 3 and 4).

The presence of dehydroabietic acid and methyl-dehydrobietate in the samples suggests that the amphorae were coated with *Pinaceae* pitch, extracted directly from the wood (Colombini *et al*. 2005). This is consistent with the recently demonstrated idea that also amphorae for oil were coated with an organic coating (Garnier *et al*. 2011; Pecci and Cau 2010; Pecci *et al*. 2010; Romanus *et al*. 2009; Salvini *et al*. 2007).

As for the Dressel 30 amphorae, also from the military quarter (sample 6, Table 3 and Fig. 7), the presence of traces of tartaric acid, together with malic and succinic acids confirms that wine (or its derivatives) was contained in the amphorae. The traces of dehydroabietic acid may be related to the presence of a coating of *Pinaceae* products.

As for the *Africana* amphorae, wine was contained in one probable Africana IID, in one probable Africana IIB and in a non-identified Africana (samples 7, 10 and 11, Table 3). Indeed, in the Africana IID (sample 7, Table 3), total lipid extract traces of malic, fumaric, succinic and hydroxycinnamic acids are detected and in the extraction for the identification of wine markers tartaric acid is present. Although other fruits also contain tartaric acid (Barnard *et al*. 2011), these acids can be considered to be markers of wine and its derivatives (Pecci *et al*. 2013c). *Pinaceae* products could be associated with an organic coating of the amphora, while the traces of cholesterol (marker of animal products) could indicate an animal content of the amphora or the mixing of animal fats for the softening of the coating. In the probable Africana IIB (sample 10, Table 3), there are traces of tartaric acid together with malic, vanillic and succinic acids, suggesting that wine was held within the amphora. Dehydrabietic acid indicates that *Pinaceae* products were used to coat the amphora. Here as well, the presence of cholesterol suggests the presence of animal fats either mixed to the *Pinaceae* products or contained in the amphora, suggesting a possible re-use. In the Africana amphora not identifiable precisely (sample 11, Table 3), the results of the analysis show the presence of tartaric, malic, maleic and succinic acid, that are related to the wine content of the amphora. Dehydroabietic acid is present only in traces, and may be connected with the use of *Pinaceae* products for the coating. The presence of β-sitosterol, azelaic acid and C_9 higher than the other short-chain fatty acids suggests the presence of an oil, possibly from olives. Here as well the traces of cholesterol indicate the presence of animal origin fats perhaps mixed with *Pinaceae* products or re-use of the amphora.

In another Africana IID (sample 8, Table 3), there are traces of an organic coating of the amphora with *Pinaceae* products (dehydrabietic acid). The abundance of cholesterol and MAGs as well as stearic acid suggests the presence of animal fats, while the presence of β-sitosterol, higher azelaic acid contents compared to other dicarboxylic acids and higher C_9 compared with the other short-chain fatty acids also suggests the presence of vegetable fats, possibly oil. Malic, glutaric and hydroxyglutaric acids are also present in the sample.

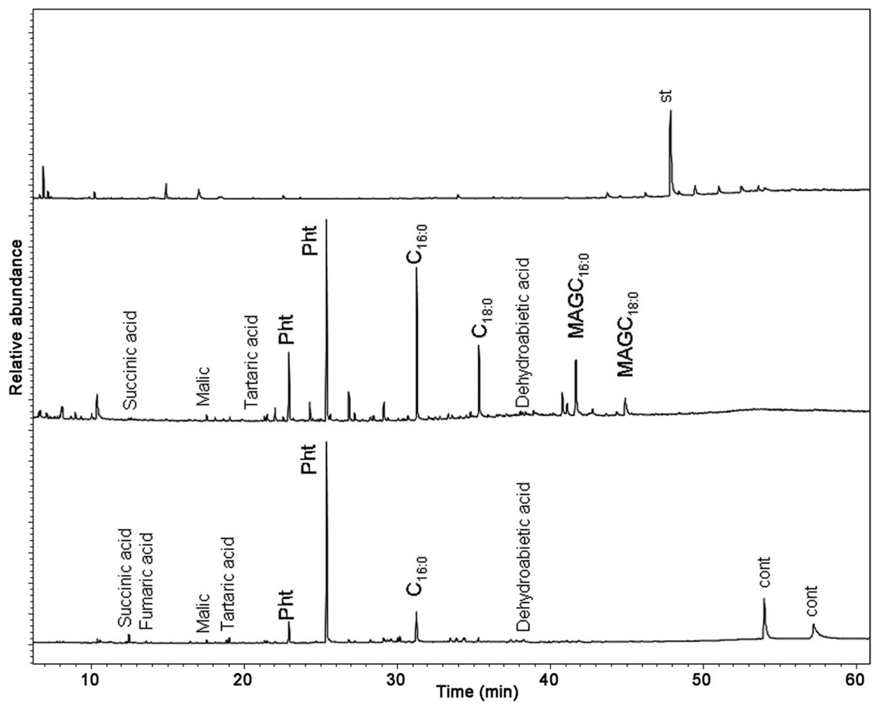

Figure 7 Chromatograms of extraction a and c of sample 6 and of extraction c of sample 12.

In the last Africana amphora (sample 9, Table 3), a possible Africana IID, there are traces of organic coating with Pinaceae products (dehydrabietic and isopimaric acids), while there are no traces of wine. Here, there is abundant cholesterol, suggesting the presence of animal fats, either mixed with Pinaceae products in the coating or related to an animal content of the amphora.

As for the *dolia*, the presence of tartaric, malic, fumaric and succinic acids in sample 12 and the presence of tartaric and succinic acids in sample 14 suggest the presence of wine (Table 3 and Fig. 7). In sample 12, the abundant dehydroabietic acid (Fig. 7) is related to a coating of the dolium with *Pinaceae* products, which are present in traces also in sample 14 (Table 3). There are also β-sitosterol and long-chain hydrocarbons in sample 12, suggesting the presence of waxes. In the other two *dolia* (samples 13 and 15, Table 3), there is only the presence of an organic coating, which is very abundant in sample 15, suggesting that the *dolia* were used for solid contents such as grains that do not leave any traces.

Discussion

The multi-functional role of the ancient Mamora forest

Q. suber is the most abundant taxon throughout the period in question. Its presence does not seem to be related to specific usages since it was found in each analysed layer regardless of the functional type of the sampled context. Taken together, this evidence testifies to the intense and continuous use of this wood both for fires and also for structures. Two interesting comparisons of extensive use of *Q. suber* come from Sicily (Italy): at Segesta (W. Sicily) this tree species was widely used for building purposes in the Middle Ages (Castiglioni and Rottoli 1997); in the necropolis of the Greek colony of Himera (648–409 BC, N. Sicily) cork oak was the main fuel used for funeral pyres (Di Pasquale, unpublished data). In this respect, it is noteworthy that in these areas, alongside the traditional use of cork, *Q. suber* plays a significant role as a timber product, clearly related to its abundance in the landscape.

The almost constant presence of cork fragments in the investigated contexts attests to its habitual harvesting. The layers with charred cork between the levels of ash, soil and fragments of pottery in the two trenches also constitute clear evidence of the extensive use of cork, which was related to its great availability in the close surroundings of the site. Unfortunately, it is far from straightforward to interpret the function of this context since no archaeological comparisons are available to our knowledge.

Archaeozoological data from the site of Thamusida attest that during the whole period cattle, sheep/goat and pig were the three main domestic animals (De Grossi Mazzorin and De Venuto 2010). Thus, it is also supposable that further uses of this cork forest were related also to grazing and to the gathering of acorns and foliage for feeding livestock. To sum up, it seems that cork oak forests represented multi-functional forests used for cork harvesting, wood exploitation and livestock farming just like nowadays (Pastor-López *et al.* 1997; Quézel and Médail 2003).

In Morocco, cork oak forests constitute huge forest resources occupying 347,000 ha, accounting for approximately 15·4% of the cork oak forests in the Mediterranean area (Pastor-López *et al.* 1997). This forest is judged to be very old (Emberger 1928a; Sauvage 1961) and probably extended on the Atlantic plane at least from the Holocene optimum (Ballouche and Damblon 1988).

Isolated individuals of *Q. suber* in proximity of Thamusida were still present in the 1960s, on the opposite shore of the Sebou river (Sauvage 1961). These trees can be considered remnants of a forest, suggesting that the cork oak wood probably extended up to the close surroundings of the site. This assumption fits well with the greater cork oak forest cover revealed by pollen analysis on a larger scale in Morocco at least until the middle Holocene (Ballouche and Damblon 1988). Also Emberger (1928b, 1934) hypothesised a previous greater acreage of *Q. suber* forest in northern Morocco. The nearby Mamora forest (Fig. 1) seems to have been the most probable area supplying both wood and cork. At present, this forest covers 60,000 ha and despite the massive exploitation suffered in recent centuries (Oubrahim *et al*., 2015) and the huge reforestation programme with exotic species, it remains the largest cork oak forest in the world (Fraval and Villemant 1997).

Recent floristic impoverishment and canopy cover reduction of Mamora cork oak open woodland due to overexploitation have been revealed by ecological studies, in which this forest is considered one of the most degraded in Morocco (Bugalho *et al.* 2011; Natividadae 1950; Rejdali 2004; Sauvage 1961). For the Iberian Peninsula, Carrion *et al.* (2000) consider monospecific cork oak forests as a result of human impact and suggest that, in its absence, *Q. suber* would share the tree layer both with other sclerophyllous and deciduous *Quercus* and *Pinus* species. Thus, the scarcity of other tree taxa in the charcoal assemblages from Thamusida, although an effect of human selection has to be taken in account, leads us to believe that, at least in the close surroundings of the site of the *vicus*, human-driven degradation processes had already started at the time of the Roman occupation when the tree layer was already mainly composed by cork oak. Therefore our data testify to overexploitation of cork oak during the Roman occupation of the site. In this respect it is interesting that at Lixus, 160 km north of Thamusida, the degradation of sclerophyllous oak forests and their replacement by scrub bushes and pine-covered areas was already evident during the Punic period (Grau Almeru, 2011).

Certain taxa, namely *Cistus*, *P. lentiscus*, *Erica*, *Daphne*-*Thymelaea* and *Arbutus unedo* recorded in the charcoal assemblages could have been used as kindling cuttings used for fuel, like in the present day, and most probably represented the understorey of the cork oak forest. That said, they could also represent the shrubland formation growing at present on the costal dunes together with *P. lentiscus* and *Frankenia*. If we interpret the presence of these taxa as a proxy of a multilayer cork oak open forest, their scarcity documents the eradication process of the shrub layer followed by the expansion of a grassland layer composed by annual winter terophytes. A biodiversity reduction of the *Q. suber* forest understorey in Morocco under high slashing, cutting and grazing pressure is widely documented (Marañón *et al.* 1999; Montoya Oliver 1986).

The presence of *Erica arborea* and *E. scoparia* is well documented until the second half of the last century in the Mamora forest (Métro and Sauvage 1955). A few years later the disappearance of *E. arborea* and a severe reduction in *E. scoparia* cover were attested (Sauvage 1961). A more recent floristic survey (Aafi *et al.* 2005) pointed out that they are now both extinct in the Mamora cork oak forest.

A different situation can be mapped out for the coastal cork oak forest of Krimda (Fig 1), where pollen analysis shows that human impact did not affect the extent and composition of the forest until the 11th century AD and *E. arborea* still persists (Damblon 1991), indicating a different history of forest resource exploitation. In the Thamusida site, since *Tetraclinis articulata* is present in a variety of contexts, a specific use cannot be ascertained. At present, it occurs widely in northern Africa, on the slopes of the Atlas Mountains, on the Central Plateau, from the Rif to the Anti-Atlas (Fennane *et al.* 1984). *T. articulata* is considered a valuable tree because its wood is highly prized for its homogeneity and natural beauty and is used for marquetry and cabinet work, especially burls produced by repeated fires (Sánchez Gómez *et al.* 2011). Wood of *T. articulata* identified from furniture in the Vesuvius area (Herculaneum, Italy) in the 1st century AD (Mols 2002) testifies to its wide circulation around the Mediterranean area during Roman times due to it being highly prized in craftwork employment.

A small amount of *Pinus pinaster* charcoal was found both in occupation layers and in "accumulation" layers; the presence of maritime pine in the site surroundings is very improbable since this tree grows at present on the Rif and in the Middle Atlas between 1200 and 2000 m a.s.l. Thus, we suppose that the recovered charcoal could belong to imported woodwork from one of these north African mountains or from Iberia.

Populus charcoal was found in only one context – a living floor in a granary (<1%) – and could belong to *P. alba*, today found around the coastal lake of Sidi Bou Ghaba. It may have been common in the riparian vegetation along the Sebou river. The few charcoal fragments referable to *Juglans regia* could well belong to wooden objects present in the site. According to Quézel and Médail (2003), walnut has now spread in the wild in a few areas of Morocco (Rif and High Atlas), having escaped from ancient cultivation. Only Ballouche (1991) suggests an indigenous origin of *J. regia* since walnut is present in the pollen record of Eastern Morocco since Early Holocene. However, this tree has a long history of cultivation and in Roman times it was already very widely grown (Zohary and Hopf 2000). At present, it is widely cultivated in Morocco in remote upland areas between 800 and 1800 m a.s.l. (Lansari *et al.* 2001). *Ceratonia siliqua* was found uniquely in a waste layer dated to the mid-2nd century AD–early 3rd century AD. Thus, its presence is improbable in the surrounding of the site. Its origin remains unclear, with recent domestication only since Roman times of the plant as a consequence of the introduction of grafting (Zohary and Hopf 2000). However, the carob tree is still an important economic resource for Morocco's rural populations, also being used in reforestation programmes and in exploiting marginal lands (Sidina *et al.* 2009).

Food supply at the border of the Empire

Spatial distribution of food plants at the site was assessed for those structures where more than 30 individuals were only found (Fig. 4). Here, the calculated ratio among the taxa can be considered representative. Based upon the results from four structures and 320 MNIs, barley (*H. vulgare*) predominates in three out of the four structures considered: inside the military quarter (area 12,000) as well as in the two rubbish dumps of the *vicus* (areas 37,000 and 19,000). In these three contexts, naked wheat (as naked wheat we consider *T. aestivum/durum* and *Triticum* sp.) is present as the second most commonly represented cereal, while it is predominant in the layer close to the huge fortified walls (area 1000). Interestingly, although the total number of carpological remains is very low and they have to be considered with caution, naked wheat prevails on two street floors of the vicus (areas 5000 and 7000) and barley predominates in a bread oven zone (area 36,000) (Table 2).

The regular presence of naked wheat in the sampled contexts suggests a widespread use of this cereal, but it is worth pointing out that the greatest presence of wheat was found in the area of the fortified walls of the military quarter (Fig. 4), suggesting the privileged access of Roman troops to better cereals such as naked wheat.

Carpological analysis carried out in *Mauretania Tingitana* showed an agriculture based on barley and naked wheat already existed from the Phoenician period (8th century BC). However, with the transition to the Roman Age (mid-1st century AD), the presence of wheat was gradually more important due to dietary and commercial considerations (Grau Almero *et al.* 2001; Grau Almero 2005). The literature on the Roman military diet describes wheat as the foundation of the military diet, adding that barley was used either for horses (Marcone 2002; Zohary and Hopf 2000), or normally given to soldiers as a punishment ration (Davies 1971). Since barley was not highly favoured as human food from a Roman perspective, we would not expect to find it as food, but at Thamusida hulled barley was found in the military barracks and the bread oven, strongly suggesting that it was intended for human consumption and probably for making bread. Furthermore, the ubiquity of the finds could suggest that barley was a common food in the diet of both civilians and soldiers. In the human diet barley plays a well-known subordinate role to wheat, particularly in bread making: characterised by poor gluten, barley is unable to confer sufficient elasticity in the rising phase. However, Syrian soldiers in the first military contingent headquartered until the 2nd century AD would not have disapproved of barley since the cereal is one of the most ancient staple foods in the region (Zohary and Hopf 2000) and the preference of Syrian and African soldiers for barley is well documented (Vossen and Groot 2009). Interestingly, even today in some north African cultures the use of barley for food is still important (Baik and Ullrich 2008).

Human consumption of barley is attested in the quarrying district of Mons Porphyrites in Egypt (Van der Veen and Tabinor 2007). Further, recent research into the consumption of cereals in Romano-British military sites from the analysis of cereal bran fragments in faecal material showed that barley was commonly consumed by troops, especially in soups and stews (Britton and Huntley 2011). Another aspect suggesting barley consumption in Roman Thamusida is linked to environmental considerations. According to Cavallar (1950), the area of Thamusida and the low valley of Sebou are characterised by a fluvial-lagoon plain with a semi-arid climate and phenomena of salinity (Billaux and Bryssine 1967). Compared with barley, wheat is less resistant to abiotic stress: barley withstands drier conditions, poorer soils and higher salinity levels. Therefore, barley could be the most suitable arable crop cultivated in proximity of the site. Furthermore, barley completes its life cycle in a shorter time than wheat and matures before the summer drought that affects the area around Thamusida. On the whole, barley was the most cultivable cereal in hostile environmental conditions, such as those in south-western *Mauretania Tingitana*. This evidence agrees well with the widespread use of barley in human consumption at Thamusida, probably also related to the abundance of this locally grown cereal. A further example of human consumption of barley is attested in four military forts in the Eastern Desert of Egypt, a region where the environmental conditions were unfavourable for local production of other cereals (Van der Veen and Tabinor 2007). Wheat cultivation would have been limited to more appropriate areas, such as the hilly soils close to the settlement. In order to complement the local production, foreign supplies are even conceivable, as suggested by the presence of a granary near the Sebou, for collecting *annona* from the south-western areas of *Mauretania Tingitana*.

As regards other crops, our data show that, among pulses, horse bean (*V. faba* var. *minor*) and pea (*P. sativum*) were common in several structures at the site, suggesting an important role in farming (Fig. 4). These pulses grow well in both warm, dry Mediterranean environments, and in clay and light drained soil. Hence, they could be sown close to the settlement of Thamusida. The highest presence of horse bean and pea was found close to the walls of the military quarter (area 1000) and to a rubbish dump (area 37,000) in the *vicus* (Fig. 4). This suggests the use of the best pulses with larger seeds in the whole settlement. The fact that two *dolia* from the military quarter did not show residues of wine, oil, or fish products, suggesting the presence of solid contents, could be related to the storage of cereals and pulses for the troops lodged at the military quarter.

Lentils were also found (*L. culinaris*). Because of the crop's characteristics, it is conceivable that it may well have been sown on the poorest soils. Other cereals, such as oats (*Avena*), emmer (*T. dicoccum*), millet (*P. miliaceum*) and pulses, such as bitter vetch (*V. ervilia*) and red/grass pea (*Lathyrus*) were found in such low percentages that our data are insufficient to support the hypothesis of their cultivation at the site and/or exclude their presence as contamination of the cereal crops.

In general, crops were carefully processed before being stored in the settlement, since very small amounts of spikelet forks and rachis were found. Instead, Malvaceae, Poaceae and Fabaceae weeds were widely found and they belonged mainly to ruderals and weeds of wetland and cultivated fields. Seed sizes of the recovered Poaceae weeds, such as *Lolium* sp. and *Phalaris* sp., are generally very similar to those of cultivated cereals, which complicates their elimination from the grain during both sieving and hand cleaning (Hillman 1981, 1984; Jones 1984).

Among fruit trees growing at Thamusida, both charcoals of *O. europaea* and *Vitis vinifera* were found, suggesting their presence in the surroundings of the site. It is widely known that the spread of grape and olive growing in northern Africa took place after the Phoenician expansion (Brun 2003). In Morocco, archaeobotanical data from contexts between the 8th and the 1st century BC show the presence of charcoals and seeds of olive and wine grape, suggesting their cultivation (Grau Almero 2005; Jordà 2005; Grau Almero *et al.* 2001). In the Thamusida area, the oleaster is present in the wild, associated with *P. lentiscus* in low scrub. Nevertheless, the scarce presence of olive charcoal and five fragments of olive stones indicate that *O. europaea* was also scantily cultivated in the site surroundings and was probably intended for self-consumption of fresh fruits in the military quarter as well as in the vicus (Tab. 1). A limited production of oil is likely to have occurred since chemical analyses identified oil residues in the small vat (sample 2, Table 3) which was built as part of the restructuring of the Flavian *domus* dated to the end of the 2nd/beginning of the 3rd century AD. To sum up, botanical and chemical evidence indicates very limited olive growing and oil production at Thamusida, while archaeological data show the presence of equipment for huge olive oil production between the 2nd and 3rd century AD in the nearby Roman site of *Volubilis* (Fig. 1) (Akerraz and Lenoir 1982). At Thamusida imports probably fulfilled the demand for oil as confirmed by the identification of oil traces in three Dressel 20 amphorae, possibly in one Africana IID and in one non-id. Africana amphora.

With regard to *Vitis*, it is considered sub-spontaneous in the Moroccan flora (Fennane *et al.* 2007) while, according to Zohary and Hopf (2000), wild grape is spontaneous in north-west Africa. The almost constant presence of grape charcoal from the Flavian Age and the recovery of 12 pips in our archaeobotanical record could suggest the beginning of a scant cultivation of grape in the surroundings of the site, probably for consumption of fresh fruits by both civilians and soldiers, as the spatial analysis suggests (Fig. 4). The presence of grapes is not necessarily linked to wine production. This beverage was probably imported, as the results of the residue analysis of some amphorae show: wine was contained in the Dressel 30 amphora and in three of the Africana amphorae analysed and in two of the four dolia analysed from the military quarter storeroom (Table 2). Although these amphorae could have been reused, these data suggest that imports had an important role in fulfilling the demand for wine.

Conclusions

The data on the whole amply documents the self-sufficiency of the settlement both in forestry and agricultural products. Charcoal data illustrate the intensive, multi-functional use of the cork oak Mamora forest throughout the Roman occupation of the site, between the 1st and the 3rd century AD, testifying to a variety of forest products such as timber, fuelwood, cork, and probably leaves and acorns to feed livestock. The dominance of *Q. suber* in the tree layer clearly indicates that this forest was being exploited prior to the Roman occupation.

Archaeobotanical data demonstrate that the diet in the vicus was mainly based on locally grown products. Local resources satisfy the food needs both the troops and civilians, and both of them have access to good cereals such as barley, naked wheat and to pulses with large seeds such as horse bean and pea. Quality fruits, such as olives and grapes, were also locally produced for fresh consumption. Barley was locally cultivated and was the main cereal consumed in the diet, due either to its abundance or to food preferences of soldiers coming from areas where it was a staple crop. Analysis of organic residues suggests a small local production of oil. For the most part, oil and wine would have been imported from different parts of the Empire; wine mostly from Africa and oil from *Baetica*.

In general, the integration of archaeobotanical and organic residue analyses was able to shed light on the local production and consumption of food as well as on some imports at this settlement situated at the border of the Roman Empire.

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