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The Holocene history of grapevine (*Vitis vinifera*) and viticulture in France retraced from a large-scale archaeobotanical dataset

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ABSTRACT

Grapevine and wine have deeply shaped the landscapes, economy and cultures of Europe and the Mediterranean. In France, it is considered that viticulture started in the south via contacts with Mediterranean populations

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(Greeks, Etruscans, Phoenicians), during the second half of the 1st millennium BCE, and spread further with the Romans. Wild grapevines were nevertheless present in various areas of the country all through the Holocene. No archaeological or historical source allows us to follow the history of grapevine and viticulture over the entire Holocene period and over the whole territory.

In this paper we investigate the potential of archaeological plant macroremains (seed/fruits and wood) to trace the history of the vine on a large scale. We have assembled the largest possible database of published and unpublished archaeobotanical data, comprising 4449 site-phases for seed and fruits and 1356 site-phases for wood remains. In spite of taphonomic discrepancies and imbalances in the datasets, the different types of macroremains and modes of preservation produce consistent patterns. They provide the first comprehensive picture of the spread of grapevine, fluctuations in the economic role of viticulture and grape uses over time, although some periods and regions are less documented.

Grapevine remains are regularly recorded from the Mesolithic to the Iron Age in most regions showing that human societies were already familiar with the wild plant and its fruits, especially in the Mediterranean. In this region, *Vitis* remains become considerably more frequent and numerous during the Iron Age, from around 500 BCE onwards, testifying to the rapid and strong implantation of viticulture. Grapevine macroremains confirm that the spread of viticulture outside the Mediterranean area occurred mainly during the Roman period. However, this expansion was limited and mainly focused on the South. The main expansion into the temperate zone took place during the Middle Ages. However, the more detailed fluctuations of viticulture, particularly in relation to climate oscillations are still difficult to follow. Pip remains are mainly associated with urban sites. This is a consequence of the actual consumption of grapes and may be evidence of a viticulture centered around urban areas.

1. Introduction

Grapevine (*Vitis vinifera* L. subsp. *vinifera*) has been playing a prominent economic and cultural role in western Eurasia and in the Mediterranean for a thousand years. Over the course of history, wine was consumed and traded throughout Europe, but its production took place mainly in the South (Braudel, 1982). At the crossroads of southern and northern Europe, France represents a key area for studying the spread of grapevine and viticulture outside the Mediterranean region. According to both archaeological and genetic evidence this plant was domesticated in southwest Asia around 9000–3000 BCE. Apparently, its cultivation spread westwards, reaching the Mediterranean shores of France with the first colonization by Mediterranean populations, in particular with the foundation of Marseille by the Greeks, around 600 BCE (Brun, 2004; McGovern, 2019; Zohary et al., 2012). However, the European wild grapevine (*Vitis vinifera* subsp. *sylvestris* (C.C. Gmel.) Hegi), ancestor of all the traditional cultivated varieties, is distributed as sparse small populations from the western Himalayas to the southern Atlantic coast of Europe (Arnold et al., 2017; Arroyo-García et al., 2016). The question of the contribution of these local wild vines to the history of viticulture in Europe is still debated: were there episodes of independent or secondary domestication (multiple origins model) or only introgression events between the two subspecies (Arroyo-García et al., 2006; Dong et al., 2023; Grassi and De Lorenzis, 2021; Magris et al., 2021)?

In France, viticulture still has a strong impact on rural landscapes and agricultural production. In 2020, France ranked third in the world in terms of wine-growing area (795 934 ha under cultivation) and second in terms of wine production (46.6 million hectoliters) (https://www.oiv.int/en/statistiques/). Current climatic conditions allow grape cultivation in most of the French territory, with the exception of high-altitude areas of the Alps, the Pyrenees and the Massif-Central, as well as the northern and northwestern fringes. However, climatic variability has a major impact on grape production, the quality and typicity of wines and the diversity of varieties that can be cultivated (Droulia and Charalampopoulos, 2021; Fraga, 2019; Jones and Webb, 2010). The Mediterranean climate is the most favorable for viticulture, allowing most of varieties to ripen, with the exception of a few late or apyrene varieties, as well as a steady production over the years. The colder climate zones of northern and northeastern France are at the inferior thermal limit for viticulture and only allow early varieties to reach maturity, especially white varieties, and in some places not every year (Lachiver, 2006; Tonietto and Carbonneau, 2004).

Today, vineyards are mostly located in large wine-producing regions that benefit from favorable geographical conditions and a long-standing reputation, which has led to the awarding of appellation of origin labels (AOP), ensuring commercial prosperity for the wine. However, until the second half of the 19th century, grapevine was more widely cultivated and spread within most of the country (2.37 million hectares in 1870), at least for the production of table grapes and house wines (Dion, 2011; Lachiver, 2006; Legouy, 2014). At that time, two events concurred to drastically reshape vineyards: 1) the arrival and spread of vine pests and diseases (*Phylloxera*, downy mildew) causing a massive destruction of vineyards, and 2) the arrival of the railroad that facilitated the transport of wine to less favorable areas, where viticulture was consequently no longer profitable.

Before this major crisis, the total vineyard area was in constant growth during the 19th century but we still lack data to monitor precisely the situation during previous centuries. Furthermore, despite the wealth of documentary sources, it is difficult to trace back continuously the dynamics and spatio-temporal fluctuations of the development of grapevine and vineyards over several millenia. The information comes primarily from archaeological data for the more remote times, while from the Middle Ages onwards it comes mainly from written sources. No single documentary source allows us to identify large patterns over a long period and large geographical areas.

Limited archaeological evidence of viticulture is recorded in the Mediterranean area for the centuries following the foundation of Marseille, around 600 BCE (Boissinot, 2001; Bouby et al., 2014; Limier et al., 2018; McGovern et al., 2013), but the situation drastically changed in southeast France after the Roman colonization. From the very beginning of our era, massive archaeological evidence shows the development of large-scale and export-oriented viticulture. Excavations have uncovered numerous wineries, including wine presses and cellars equipped with half-buried clay wine jars (dolia), amphora- manufacturing factories and even traces of the vineyards themselves (Brun and Laubenheimer, 2001; Jung et al., 2013). How and how fast did this viticulture of Mediterranean origin, spread to continental France? To start with it was considered that it would have required some time to adapt to colder climates, in particular with the need to develop new, more resistant and early-ripening varieties (Dion, 2011). In contrast to this traditional conception, recent excavations provided new evidence suggesting that the extension of vineyards towards the Norh and West may have occurred rapidly, from the beginning of the 1st century CE onwards (Poux et al., 2011; Toupet and Lemaître, 2003). However, changes in winemaking techniques and transport containors which occurred during the Roman

period, make it difficult to track the spread of viticulture and its fluctuations over time. Many of the long-lasting stone and clay archaeological remains, typical of the Mediterranean Roman viticulture (presses, vats, clay jars and amphorae), were replaced by more perishable equipment and tools made out of wood (presses, barrels), difficult to detect in the archaeological record (Bevan, 2014; Brun, 2020). These new techniques were developed north of the Mediterranean zone, where the barrel may have originated (Marlière, 2002). However, in the Mediterranean area, ceramic wine containers were also gradually replaced by wooden ones, which were lighter, handier and more cost-effective. Hence, archaeology identifies a viticultural crisis in the area at the end of the Roman period (3rd-4th centuries CE) which could in fact partly result from a reduction of archaeological evidence, i.e. the lesser visibility of certain artefacts (Brun, 2010; Favory et al., 1998; Van der Leeuw et al., 2003). From then onwards, it is difficult to monitor the changes in viticulture based on archaeological evidence while written sources are still scarce. It is not possible to know to what extent the climatic cooling and the socio-political disorders of the early Middle Ages triggered a crisis in viticulture (Büntgen et al., 2016). The actual importance of viticulture at this time is still a matter of discussion, but it remains prosperous at least in some regions of the Mediterranean (Drieu et al., 2021; Fuks et al., 2020).

Numerous written and iconographic sources support a significant expansion of viticulture in Western Europe during the central Middle Ages (11-13th century CE), including in less favorable areas like northern France and England (Mane, 1991; Unwin, 1990). It has been assumed that the French vineyard reached its maximal surface at the beginning of the 14th century, especially in the northern part of the country (Lachiver, 2006). This extension would have been favored by the climatic improvement between 900 and 1300 CE (Medieval Climate Anomaly) (Graham et al., 2011). However, the abundance of written sources, possibly because viticulture had become more profitable for the property owners, may contribute to the overestimation of the spread of medieval viticulture, in comparison to previous periods with scarcer and less accurate written sources.

It is therefore relevant to examine other types of proxies, such as archaeobotanical and palaeobotanical records, to compare with traditional archaeological and historical data. Palynology consistently records the presence of grapevine throughout the Holocene (Brewer et al., 2017). However, because of the low and variable diffusion of *Vitis* pollen, palynological evidence is patchy and poorly reflects the presence of the vines; it can therefore only reveal its cultivation under very specific circumstances (Turner and Brown, 2004; Vannière et al., 2003). More detailed morphological observation of fossil *Vitis* pollen could help to discriminate wild and domesticated grapevines, providing a key factor for reconstructing the history of viticulture from pollen data (Mercuri et al., 2021). On the other hand, archaeological records of plant macroremains have proven to be an invaluable source for reconstructing the history of grapevine over long periods of time and large geographical areas (Fuller and Stevens, 2019; Miller, 2008). The aim of this study is to retrace the Holocene history of grapevine and viticulture in France by exploring the potential of *Vitis* macroremains preserved in archaeological sites and, occasionally, in natural depositional contexts. Over the last 40 years, the number of archaeological sites benefitting from archaeobotanical analyses has raised drastically in France (Leroyer et al., 2018). Therefore, we have systematically recorded and analyzed this extensive corpus of several hundreds of sites and discuss its potential to shed light on the use and the spatio-temporal dynamics of grapevine and viticulture.

2. Material and methods

2.1. Grape macroremains and their relevance to document human activities

The archaeological and palaeoecological implications of plant macroremains found at the sites are determined by the type of preservation and plant parts represented. Regarding our research area, macroremains are preserved either charred or uncharred, in which case they are either waterlogged, mineralized or, very seldomly, desiccated. The preservation of uncharred plant remains depends on specific physico-chemical depositional and post-depositional conditions. In contrast, charred remains can potentially be present in all types of archaeological deposits, as charring usually results from human activities at the site allowing long-term preservation in all types of sediments. The presence of macroremains within archaeological sites is in itself a hint that they were brought by site inhabitants. Their preservation by carbonization is further evidence of their use (Dietsch, 1996). In addition, the type of preservation has a major impact on the composition and diversity of fruits and wild plants recorded at a particular site. Since fruits can be eaten raw, they are more likely to be recorded uncharred, while, on the other hand, even occasional finds of charred fruits may indicate consistent use by past societies (Antolín and Jacomet, 2015; Colledge and Conolly, 2014).

Regarding plant parts, grapevine macroremains from archaeological sites are composed of both seeds and/or fruits and wood. Together they provide information on the very different uses of vines by former populations. Seed and fruit remains bring evidence of fruit consumption; Fruits may have been eaten fresh, dried, or transformed, chiefly into wine or vinegar. In most cases, the recovery of scattered seeds does not give specific clues on the use of grapes and should be taken as evidence of their use as food in broad terms. On the other hand, in favorable conditions, the production of wine can be inferred based on the composition of the archaeobotanical assemblage. In fact, the association of grape pips with shredded skins, pedicels and undeveloped berries may be regarded as direct evidence of grape pressing (Margaritis and Jones, 2006; Murray, 1999; Ros and Ruas, 2016). Such evidence further suggests local grape production as the transport of grapes over long distances before pressing would imply additional costs, labor and risks. In this paper we will specifically look for the presence of pedicels and consider them as proxies for wine-making residues. Wood remains (charred or uncharred) should also be regarded as documenting the presence of vines growing near the site, since only timber is likely to travel over long distances. When found charred, *Vitis* is evidence of the use of wood as fuel. Vines may not represent a major source of firewood but pruning of cultivated vines produces shoots that can provide valuable complementary fuel. Therefore, the record of *Vitis* wood on a site can suggest nearby vine cultivation (Miller, 2008).

2.2. The compilation of archaeobotanical data

We created a database including as much archaeobotanical data as possible on seed, fruit and wood macroremains for the Holocene period in continental France. In order to include and critically review published and unpublished data, most of the archaeobotanists currently working on the investigated area and period were involved in the feeding of the database. To better judge the recurrence of *Vitis*, all sites with macrobotanical analyses were included in the database, whether *Vitis* was recorded or not. The database is mainly composed of archaeological sites but a few natural deposits (paleochannels) were also included. Data were recorded according to the chrono-cultural phases identified at the sites (site-phases), all the samples available for a given phase being combined to compose a single entry in the database. Chrono-cultural phases were dated either by calibrated radiocarbon dates or by archaeological material, occasionally by dendrochronology. In our analyses we used the median dates of the phases. Alternatively, site-phases were assigned to broad chrono-cultural periods, namely Epipaleolithic/Mesolithic (10000–5700 BCE), Neolithic (5700–2200 BCE), Bronze Age (2200–750 BCE), Iron Age (750–50 BCE) Roman period (50 BCE-500 CE), Middle Ages (500–1500 CE) and Modern period (1500–1900 CE). In certain situations, Iron Age, Roman period and Middle Ages were further split into shorter phases. For each site-phase, we recorded the

total number of macroremains identified and the number of *Vitis* macroremains. Seed/fruit and wood data were registered as separate entries, as well as each mode of preservation (charred, waterlogged, mineralized, desiccated). For wood, only the number of wood or charcoal fragments was recorded. For seed/fruits, the number of seeds, pedicels, whole immature and mature berries, fruit skin fragments and bunch rachis elements were recorded separately. Sites were classified into broad categories based on their socio-environmental context (cave sites, rural sites, i.e. isolated sites or hamlets, villages and urban sites) and their function or status (natural sites, harbors, specialized activities, habitats, elite sites, ritual/funerary sites). From a geographical and environmental point of view, sites were classified into four broad ecological regions, according to the division defined by the National Forest Inventory (Cavaignac, 2009) (Fig. 1): 1) Mediterranean (MEDIT), with its specific hot and dry climate, 2) West (WEST), with an oceanic climate, 3) Center-North (CENO), mainly composed of large plains and plateaux under a semi-oceanic climate and 4) East-Massif Central (EAMC), with most of the mountainous areas and a mountain or semi-continental climate.

2.3. Data processing and analysis

For wood remains, all quantitative analyses are based on the number of fragments. For seed / fruit remains, whenever entire seeds (NES) and fragments (NF) had been counted separately, the Minimum Number of Individuals (MNI) was calculated using the formula: MNI = NES + ½ NF. Analyses and graphical outcomes were mainly based on presence/absence data, visualized as scatterplots of percentages of sites with *Vitis* (referred in this paper as frequency) and as maps. In cases where counts were taken into account, the numbers of *Vitis* remains were converted to percentages based on the total MNI by site-phases, in order to cope with differences in sampling intensity between sites. In this paper, this indicator is refered to as 'proportion'. In that case, only site-phases with counts greater or equal to 100 were considered. The percentage values of macrobotanical remains were visualized as boxplots, according to ecological regions and chrono-cultural periods, and as maps. Graphs were created in the R 4.1.3. environment (R Core Team, 2023) using the packages from the tidyverse for general data manipulation and visualization (Wickham et al., 2019). Maps were generated using QGIS 3.16.

The influence of geographical location inside ecological regions, socio-environmental context and site function on the presence of *Vitis* was assessed, for each broad chrono-cultural period, using Fisher's exact tests with Monte Carlo *P*-value simulations, 5000 replicates, instead of chi-square analysis, due to the high number of expected values <5 and the often strongly unbalanced categories. For each category it was assessed whether the actual value was significantly different than the theoretical value by using Fisher's exact tests and providing a *p*-value by cell in the contingency tables. For charred and uncharred *Vitis* pips the incidence of site context and function was assessed for each combination of period and region. This procedure could not be applied to the other

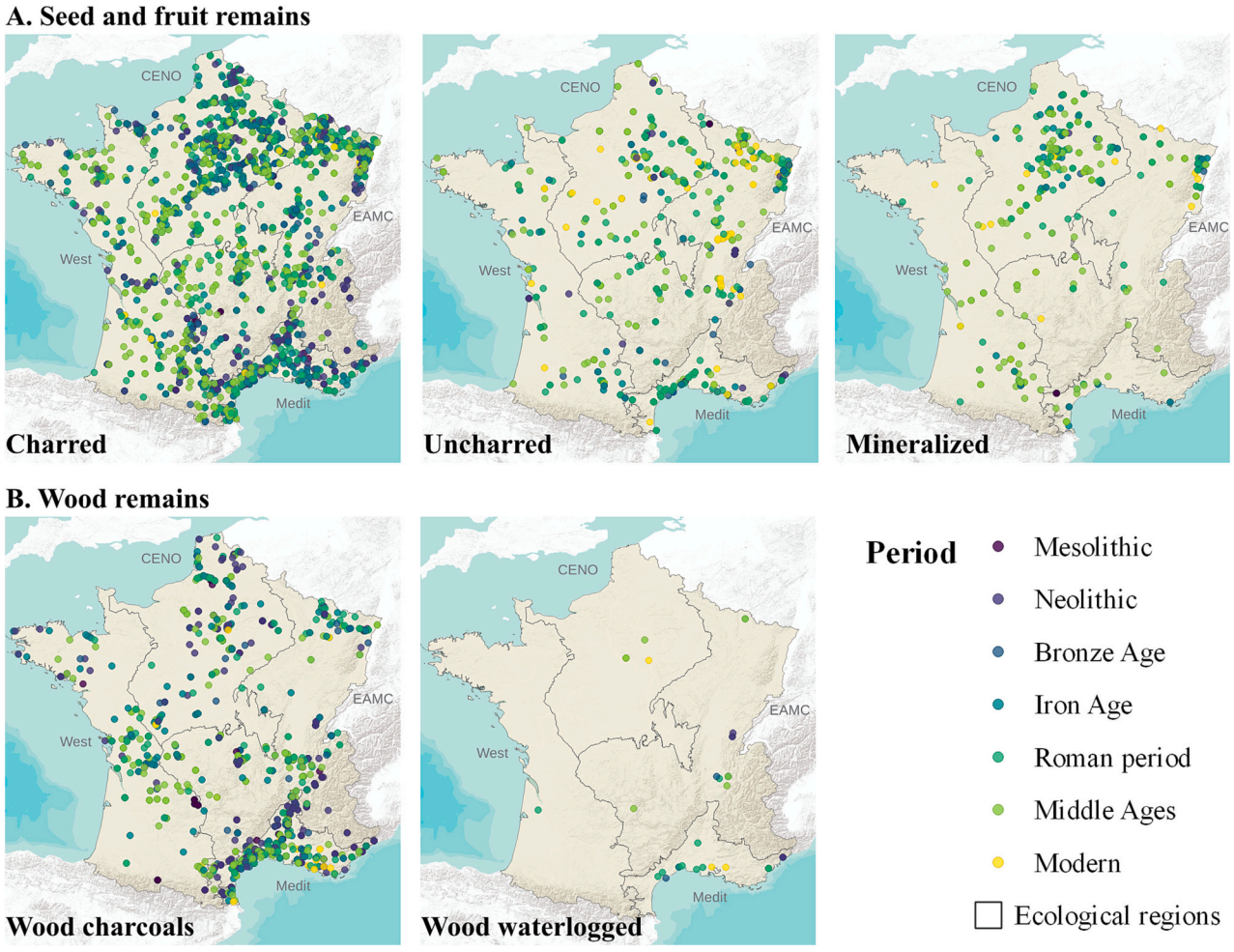

Fig. 1. Distribution of the sites included in the database according to the type of macroremains (A, Seeds and fruits; B, Wood remains) and preservation (Uncharred = waterlogged+desiccated). The color of the symbols corresponds to broad chrono-cultural periods. The French continental territory is divided into 4 broad ecological regions: Center-North (CENO), East-Massif Central (EAMC), Mediterranean (MEDIT) and West (WEST). All sites assembled in the database are represented, whether *Vitis* was recorded or not.

types of macroremains and preservation because the number of records in the database was too limited. All statistical tests were calculated using the XLSTAT software (Addinsoft, 2022).

3. Results

3.1. Assessment of the database

The total number of records in the database amounts to 4449 for seed and fruits and to 1356 for wood remains (Fig. 1, Table 1). Most entries refer to charred material (76% of seed and fruits and 97.3% of wood). While waterlogged wood remains are recorded in only 2.6% of site-phases, this proportion is higher for seed and fruits (14.1%). Mineralized (9.6% of site-phases) and very seldom (0.3%) desiccated seeds and fruits are also encountered. Because of its scarcity, desiccated material was grouped with the waterlogged seed and fruit remains in a single category labeled "uncharred material" in the subsequent data processing. Overall, the sites are spread throughout the study area, mainly in its eastern part. Most of the seed and fruit records are found in the MEDIT, CENO and EAMC regions, while wood records are more strongly concentrated in the Southeast. Mineralized seeds and fruits were more common in the North (CENO) and rarely in the MEDIT region. Overall, the greatest number of site-phases relate to the Iron Age, Roman and Medieval periods. The Iron Age is particularly well represented in the MEDIT region. The Neolithic period is best represented for wood remains while the Modern period is under-represented everywhere and this for both kinds of macroremains. Most of the records concern rural settlements and habitats. Here we consider all open-air Mesolithic and Neolithic settlements as rural sites, also in all logic this term should not be used before the existence of urbanisation. Rural sites are particularly

Table 1
Number of sites included in the database according to type of botanical macroremains, Preservation, Ecological regions [Center-North (CENO), East-Massif Central (EAMC), Mediterranean (MEDIT) and West (WEST)], Periods [Meso = Epipaleolithic/Mesolithic, Neo = Neolithic, Bze = Bronze Age, IA = Iron Age, Rom = Roman period, MA = Middle Ages, Mod = Modern period], Site Context and Site Function or status [Nat = natural site, Spec = specialized activities, Rit/Fun = ritual/funerary site].

Preservation	Periods	Total	Ecological regions				Site Context				Site Function					
			MEDIT	WEST	CENO	EAMC	Cave	Rural	Village	Urban	Nat	Harbour	Spec	Habitat	Elite	Rit/Fun
SEED & FRUITS																
Charred	Meso	**39**	12	12	8	7	25	14	–	–	–	–	–	39	–	–
	Neo	**367**	96	50	73	148	74	240	27	–	–	–	13	340	–	8
	Bze	**402**	59	50	132	161	49	289	45	–	–	–	6	363	4	20
	IA	**937**	132	112	423	270	13	682	91	121	7	4	27	841	9	33
	Rom	**823**	122	64	372	265	2	566	46	170	13	14	39	587	10	141
	MA	**741**	77	159	243	262	1	456	85	158	4	–	54	597	38	20
	Mod	**71**	4	16	23	28	–	21	6	34	2	–	–	57	5	4
	Total	**3380**	**502**	**463**	**1274**	**1141**	**164**	**2268**	**300**	**483**	**26**	**18**	**139**	**2824**	**66**	**226**
Waterlogged	Meso	**6**	2	1	1	2	–	6	–	–	5	–	–	1	–	–
	Neo	**36**	6	2	8	20	1	18	16	–	8	–	1	26	–	–
	Bze	**35**	10	3	7	15	–	28	3	–	7	–	–	24	–	–
	IA	**85**	17	18	16	34	1	51	6	25	7	5	1	67	1	3
	Rom	**248**	66	26	70	86	1	134	12	90	19	18	19	168	4	13
	MA	**150**	5	27	51	67	–	61	14	68	11	3	12	104	6	9
	Mod	**68**	6	10	15	37	–	22	2	41	20	1	2	41	3	1
	Total	**628**	**112**	**87**	**168**	**261**	**3**	**320**	**53**	**224**	**77**	**27**	**35**	**431**	**14**	**26**
Desiccated	Meso	**–**	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Neo	**–**	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bze	**1**	1	–	–	–	1	–	–	–	–	–	1	–	–	–
	IA	**–**	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Rom	**1**	–	1	–	–	–	–	–	1	–	–	1	–	–	–
	MA	**6**	–	2	–	4	–	5	–	–	–	–	–	5	1	–
	Mod	**6**	–	3	2	1	–	–	–	4	–	–	–	3	–	3
	Total	**14**	**1**	**6**	**2**	**5**	**1**	**5**		**5**			**2**	**8**	**1**	**3**
Mineralized	Meso	**3**	3	–	–	–	3	–	–	–	–	–	–	3	–	–
	Neo	**5**	–	–	2	3	–	5	–	–	–	–	–	5	–	–
	Bze	**5**	–	–	3	2	–	2	2	–	–	–	–	4	–	–
	IA	**79**	8	18	39	14	–	51	5	22	–	–	1	76	–	1
	Rom	**124**	2	13	84	25	1	60	9	50	–	–	4	106	–	6
	MA	**173**	11	42	89	31	–	76	14	76	1	1	6	132	15	9
	Mod	**38**	–	9	14	15	–	4	1	28	–	–	–	31	3	3
	Total	**427**	**24**	**82**	**231**	**90**	**4**	**198**	**31**	**176**	**1**	**1**	**11**	**357**	**18**	**19**
WOOD REMAINS																
Charred	Meso	**46**	17	13	7	9	32	14	–	–	3	–	2	40	–	–
	Neo	**264**	122	13	43	86	70	139	46	–	12	–	9	217	–	10
	Bze	**155**	53	11	25	66	27	101	21	–	9	–	3	126	–	8
	IA	**264**	86	36	64	78	7	169	29	55	9	–	17	204	–	25
	Rom	**310**	118	42	56	94	3	192	20	76	26	9	57	142	–	54
	MA	**247**	87	42	40	78	1	165	33	36	10	1	40	151	15	16
	Mod	**34**	22	–	3	9	–	26	1	6	12	–	12	6	1	2
	Total	**1320**	**505**	**157**	**238**	**420**	**140**	**806**	**150**	**173**	**81**	**10**	**140**	**886**	**16**	**115**
Waterlogged	Meso															
	Neo	**6**	3	–	–	3	–	3	3	–	3	–	–	3	–	–
	Bze	**2**	1	–	–	1	–	2	–	–	1	–	–	1	–	–
	IA	**2**	1	–	–	1	–	1	–	1	1	–	–	1	–	–
	Rom	**15**	11	1	–	3	–	9	1	5	5	1	2	7	–	–
	MA	**7**	–	–	3	4	–	3	1	3	1	–	–	4	1	1
	Mod	**4**	2	–	2	–	–	2	–	2	–	–	–	3	–	1
	Total	**36**	**18**	**1**	**5**	**12**		**20**	**5**	**11**	**11**	**1**	**2**	**19**	**1**	**2**

well represented when charred remains are considered. Cave sites are mostly located in the Southeast and mostly related to the Mesolithic, Neolithic and Bronze Age periods. They yielded almost exclusively charred material. Mineralized seeds and fruits were mostly found in urban sites, where favorable contexts to their preservation, especially cesspits, are more common. A significant proportion of the waterlogged material comes from natural sites, especially wood remains (32.4% of site-phases). The ritual and funerary sites are mostly Roman.

3.2. Spatio-temporal distribution of Vitis remains

Charred *Vitis* pips are recorded in 23% of all site-phases. Due to taphonomic reasons associated to fruit preservation, uncharred and mineralized pips are more frequently recorded (63.4% and 52.9% of site-phases, respectively) than charred ones. Pedicels are much less common than pips; we find them in only 4.9% of site-phases when charred, 19% when uncharred and 3.7% when mineralized. Compared to pips, pedicels are less frequent in the mineralized record. This may be partly due to differential preservation, but it must also be considered that mineralization mainly concerns cesspits, where undigested plant remains, such as pips, ending up in the excrements may be more common than other uncomsumed waste products. Other types of fruit remains (berry skins, aborted berries, rachis items) are very rarely found. Wood remains are less frequent than pips (17.9% of site-phases for charred and 41.2% for uncharred material) and generally found in small numbers. In short, the most consistent datasets, those on which our investigations will be primarily based, are those of charred and uncharred grape pips, charred pedicels and charcoals.

All types of *Vitis* remains present similar broad spatio-temporal patterns (Fig. 2, Supplementary Fig. 1). For the first part of the Holocene, mostly from the Mesolithic to the Early Neolithic (ca 10,000–4000 BCE), the number of sites investigated by archaeobotany is limited but *Vitis* is nevertheless regularly identified, either by carpological or wood analyses. *Vitis* seeds and charcoals were recorded in the Mediterranean area since the very beginning of the Holocene. The species is also identified around 7000–6400 BCE in the Paris Basin and in northern France (Fig. 3). The number of *Vitis* records increases during the Neolithic and Bronze Age, probably in relation to the increase in the number of sites studied. By then, grapevine is present in all ecological regions. This includes Neolithic finds of pips in a few spots of northwestern France where climatic conditions are not favorable for viticulture, and where wild grapevine is absent today. Nevertheless, for the whole period covering the Mesolithic to the end of the Bronze age, charred (Fig. 4, 5a) and uncharred (Fig. 4, 5c) pips are significantly more frequent in the Mediterranean region compared to all other regions, while no significant difference is detected in the charcoal dataset (Sup. Table 1).

During this first phase of the Holocene it is impossible to identify a long-term trend in the frequency of *Vitis* (i.e. the proportion of sites where it is reported), nor in the evolution of the proportions of *Vitis* remains per site-phases. The situation changes during the Iron Age in the Mediterranean region. Around 500 BCE, we note a sharp increase in the frequency of charred pips, pedicels and charcoals, which appears to coincide with an increase in the proportion of charred and uncharred pips within the assemblages with *Vitis* remains. No similar trend is discernible in the other three regions, while all types of *Vitis* remains are significantly more frequent in Mediterranean sites ($p < 0.0001$ for all types of remains) than in any other region (Fig. 4, Sup.Table 1).

At the scale of this wide area outside the Mediterranean region, evidence for the presence of *Vitis* increases only during the Roman period but not in all regions and not for all types of botanical remains. The frequency of *Vitis* increases in the WEST and EAMC regions for charred pips, while pedicels only increase in the WEST. The presence of *Vitis* is significantly inferior in the CENO region for both types of charred remains (Fig. 4, 3a, b & d). Similarly, the number of uncharred pips shows a slight progression in the regions EAMC and WEST. Generally speaking, the increase of *Vitis* during Roman times outside the Mediterranean is more pronounced in the southern half of France (Fig. 3), while the evidence for *Vitis* remains is much higher in the Mediterranean than in any other region. There, an increase compared to that observed during the Iron Age can even be noticed in the proportions of charred and uncharred pips, of charred pedicels and in the frequency and proportions of charcoals (Fig. 2). The frequency of *Vitis* is always significantly higher in the MEDIT region for all these types of botanical remains, as well as for uncharred pedicels (Fig. 4).

Outside the Mediterranean, our indicators point to an increase in the frequency of *Vitis* at the transition from the Roman period to the Middle Ages (500 CE), which is even more pronounced during the Middle Ages. By 500 CE, the frequency of charred pips starts rising in the CENO region and is also higher in EAMC. After a possible decline around 700 CE, the increase continues throughout the Middle Ages, except in the CENO region, where the frequency of charred pips seems to decrease between 900 and 1500 CE.

The frequency of charred pedicels also increases in all regions outside the Mediterranean throughout the Middle Ages, especially after 1100 CE and in Western France. *Vitis* charcoals are also globally more frequent in Medieval sites compared to Roman ones. The proportion of charred and uncharred pips per site-phase only increases in the Medieval period in all regions outside the Mediterranean.

During the Middle Ages, the frequency of *Vitis* is significantly lower in EAMC for charred pips, charred and uncharred pedicels and charcoals compared to other regions. It is still higher in the Mediterranean for most types of remains. In the MEDIT region not all proxies show a consistent pattern for the Medieval period compared to Roman times: the frequency of charred pips continues to increase while it decreases for charred pedicels and charcoals. In parallel, the proportions of *Vitis* remains are usually lower in the Medieval period. In the WEST region, *Vitis* is frequently recorded only in South-Western France (Fig. 3). It remains scarce in the North-West (Brittany and Normandy), where grape production is not successful every year due to climatic conditions (Dion, 2011), and where only pips, have been found in a few sites. So far, no wood (charred or waterlogged) has been recorded.

The number of sites is too limited to clearly document the situation during the Modern and Contemporary periods (ca 1500 CE to present). The differences between regions seem somewhat smoothed out compared to previous periods. Nevertheless, EAMC is still the region where the frequency of most *Vitis* remains is significantly lower, while MEDIT is the one where they are generally higher, but the number of sites is very low in the latter region. However, in all regions, the proportions of charred and uncharred pips are greater during the Modern period than those recorded in the Medieval period (Fig. 2).

3.3. Distribution of Vitis remains according to site contexts and functions

Vitis remains are registered in sites with diverse socio-environmental and functional contexts. This is already the case during the Epipaleolithic/Mesolithic – Bronze Age period, although the dispersion of records over this very long time-span and the considerable changes in human occupation modalities do not allow us to statistically investigate the influence of site context and function for these periods.

From the Iron Age onwards, regardless of the preservation type, *Vitis* pips are consistently better represented in urban than in rural sites, even though urban and rural contexts change considerably from one period to the next in terms of organisation and function (Fig. 5, Supplementary Table 2 & 3). Iron Age “towns” are far different from those of the Roman period or the Middle Ages. But, the development of cluster settlements is noticed, from the beginnings of the Iron Age 2, particularly in the Mediterranean area; they include communal structures, notably city walls, and a collective organisation of the habitat, in blocks separated by streets. Charred pedicels are also significantly more frequent in urban sites during the Iron Age (Fig. 5, 4b), while uncharred ones are more common during the Medieval and Modern periods (Fig. 5, 1c & 2c).

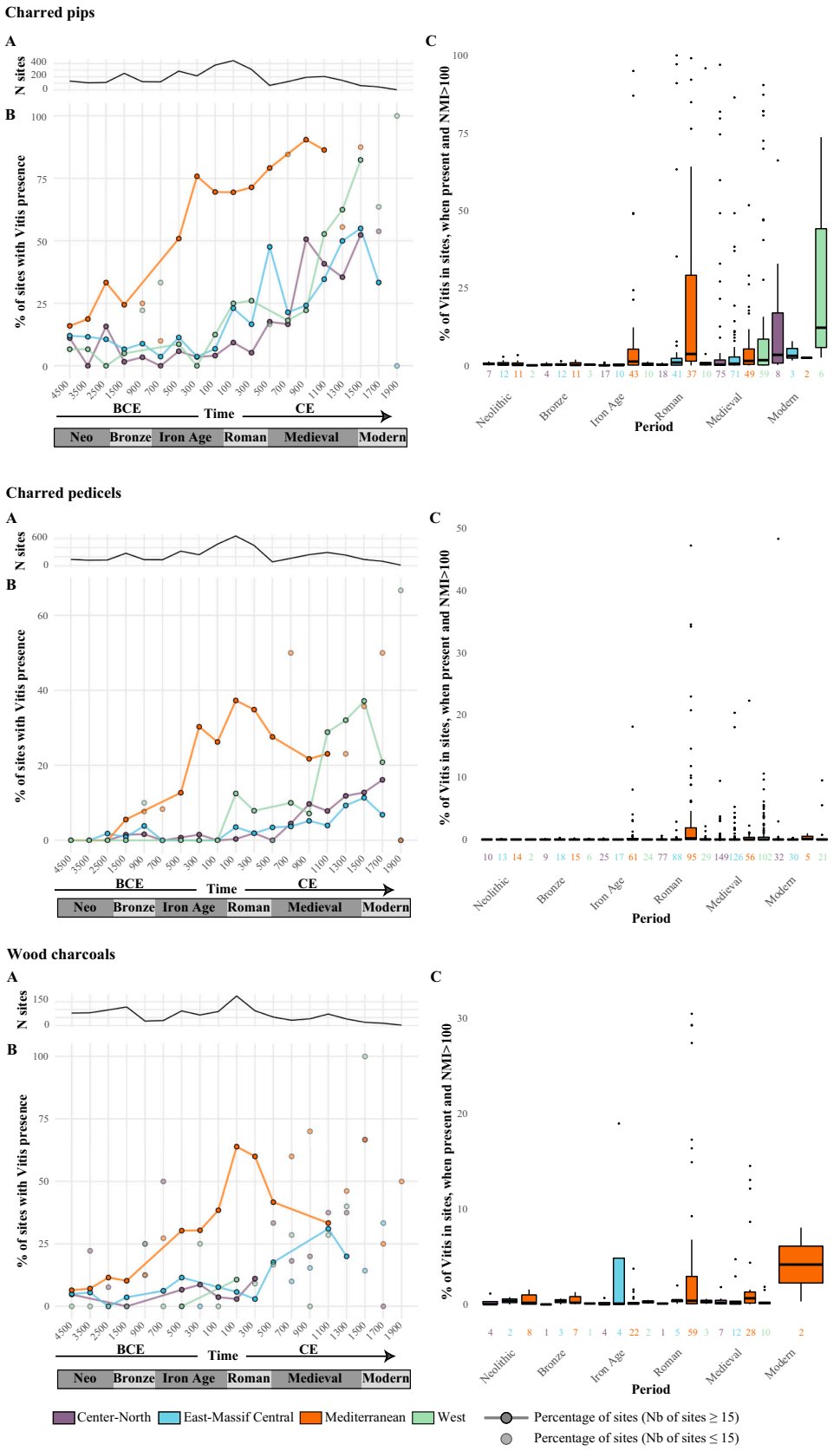

Fig. 2. Changes over time in the frequency and proportions of *Vitis* pips, charred pedicels and charcoal. A, Number of sites per time span. B, Percentage of sites with a *Vitis* record per time span (frequency). C, Percentage of *Vitis* remains in sites per period (proportion). Only sites with NMI > 100 are taken into account.

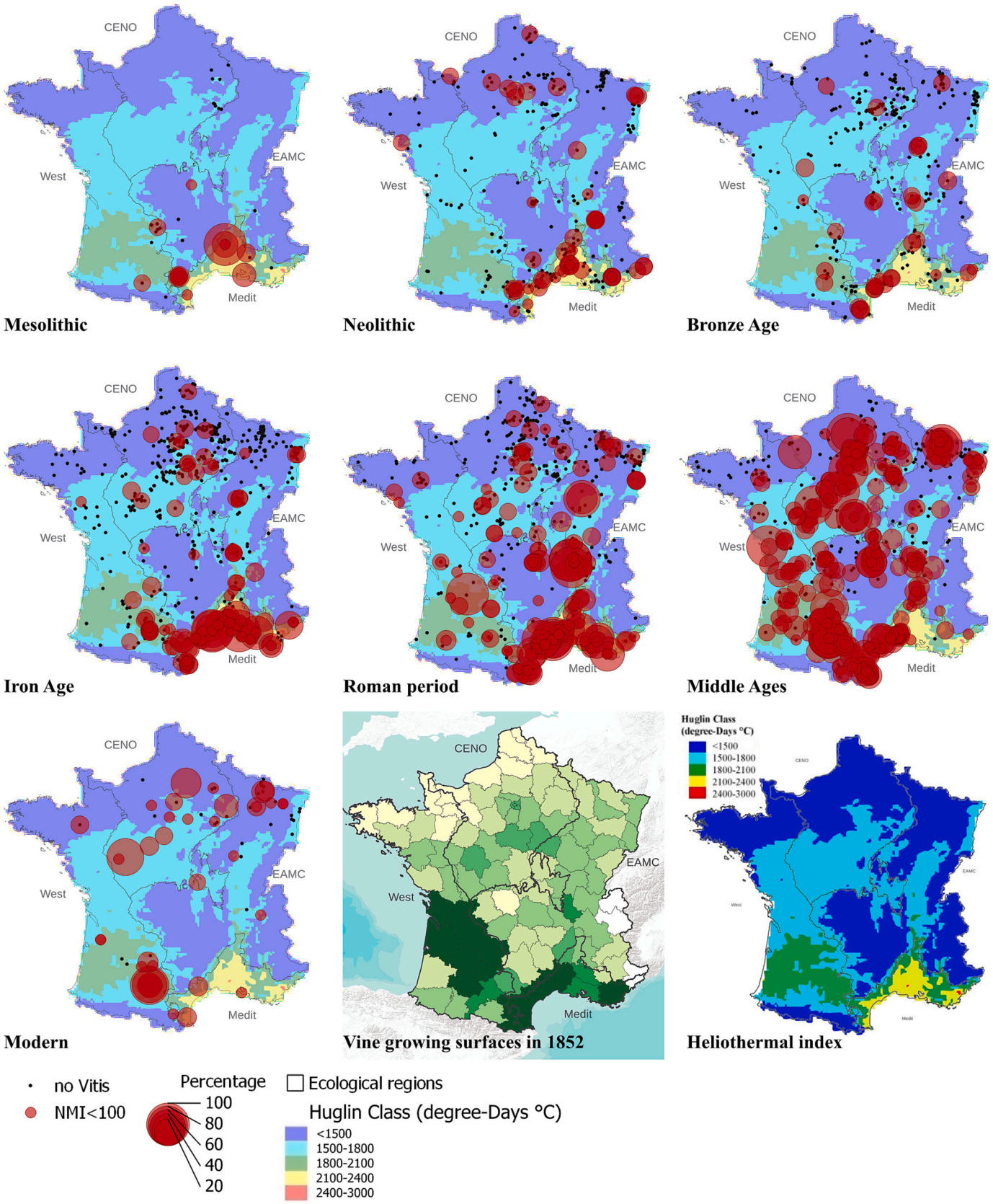

Fig. 3. Maps showing the distribution of charred *Vitis* pips according to the main chrono-cultural periods and Huglin's Heliothermal zones calculated from present-day temperatures. Maps showing vine surfaces in the 1852 agricultural inventory (Marin and Marraud, 2011) and Huglin's Heliothermal Index (Quénol et al., 2017) are provided for comparison. The Heliothermal Index of Huglin is calculated using a day length coefficient and daily average and maximum temperatures from the 1st of April to the 30th of September (Huglin and Schneider, 1998). It presents a strong relationship with the potential sugar content of the grape and therefore expresses the climate suitability for vine growing (IH 2400–3000: warm, 2100–2400: warm temperate, 1800–2100: temperate, 1500–1800: cold, ≤1500: very cold).

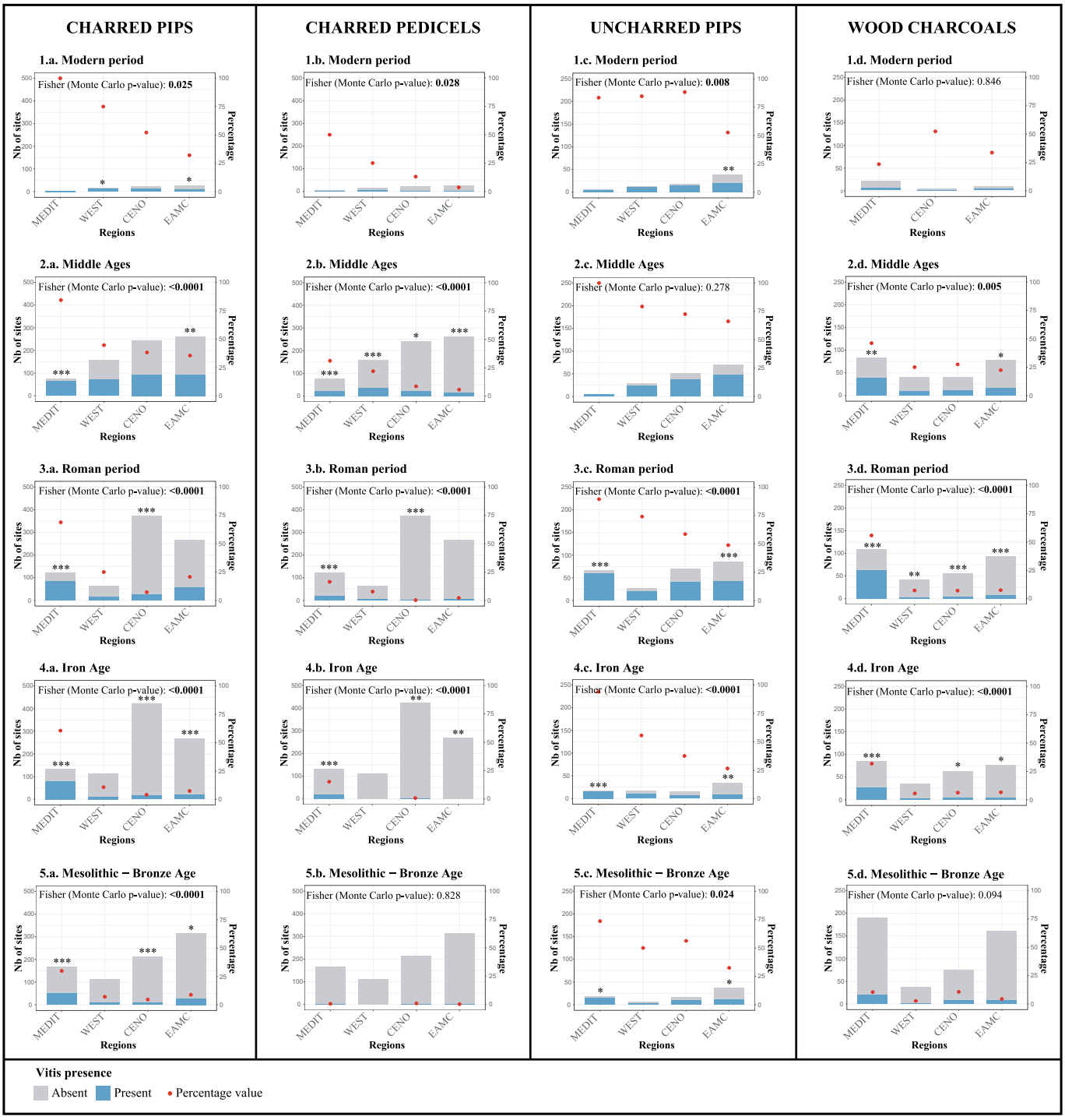

Fig. 4. Frequency of occurrence of Vitis macroremains in relation to chrono-cultural periods and ecological regions. Statistical significances of the Fisher's exact tests are indicated on the barplots, only when the result is significant (*: $p \leq 0.05$; **:$p \leq 0.01$;***:$p \leq 0.001$). The results of Fisher's exact tests are detailed in Supplementary Table 1.

Charcoals are more frequent in urban contexts during the Iron Age (Fig. 5, 4d), but are significantly less frequent in cities during the Roman times (Fig. 5, 3d). Most of the urban Iron Age sites with *Vitis* remains are located in the Mediterranean area (Fig. 6). Actually, in this region, charred pips are significantly over-represented in urban sites while no effect of context on their occurrence was detected in other regions (supplementary Table 2).

Overall, in Roman times, *Vitis* pips are still more frequent in urban sites but with a reversed geographical pattern to that of the Iron Age, when examined at the regional level. Charred pips are significantly overrepresented at urban sites only in the EAMC region ($p < 0.0001$). Uncharred pips are overrepresented in urban sites of the EAMC ($p = 0.008$) and CENO ($p = 0.001$) regions while in the MEDIT they are significantly more present in rural settlements ($p = 0.022$; Supplementary Table 3). Charcoal is also more frequent at rural sites in the Mediterranean but the Fisher's test is not significant ($p = 0.079$). During the Middle Ages, *Vitis* pips are more frequent in urban contexts in all regions outside the Mediterranean (mostly significant for uncharred remains) and tend to be equally represented in all contexts in the Mediterranean. In fact, *Vitis* is recorded at nearly every site in the area for this period.

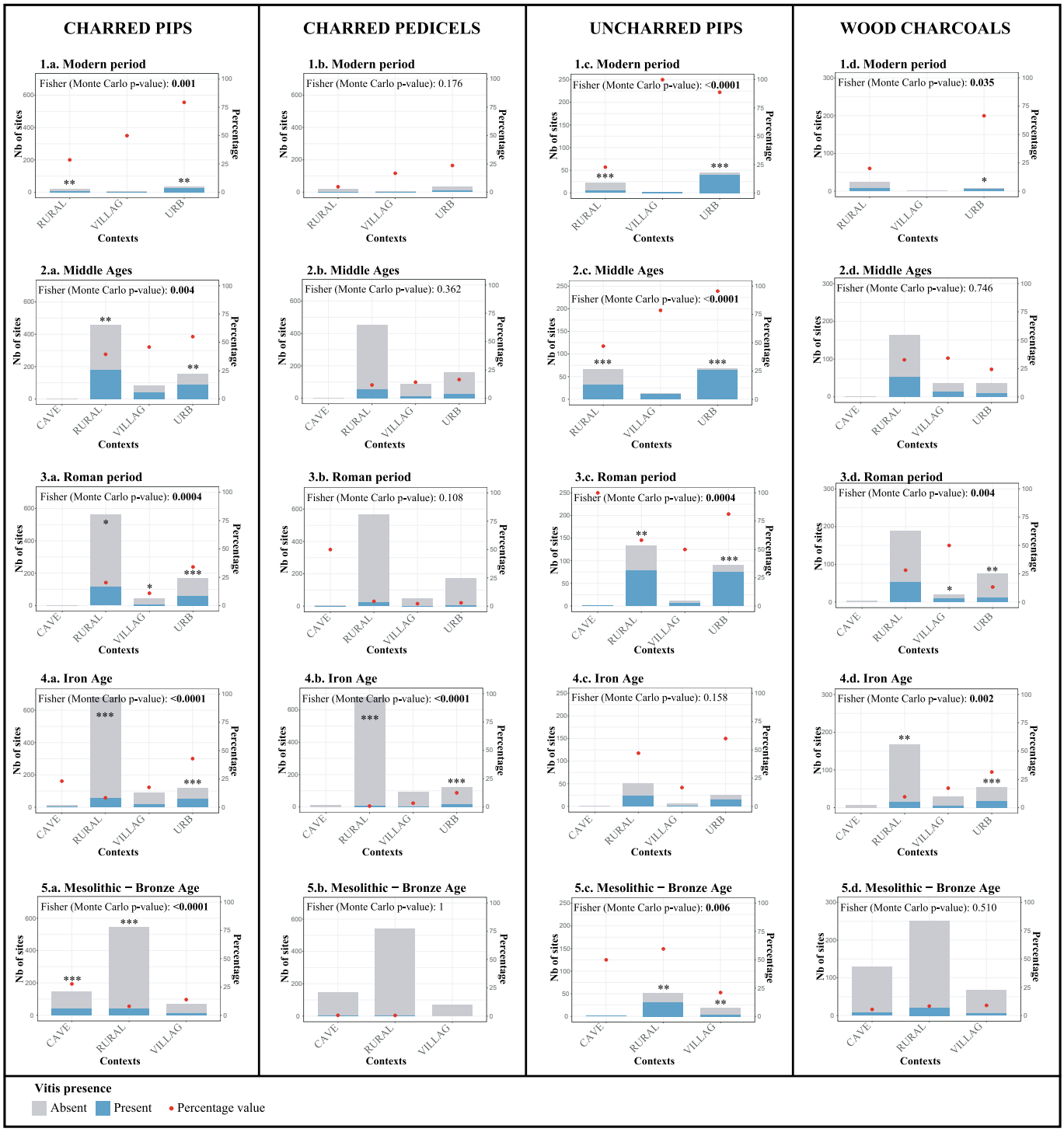

Fig. 5. Frequency of occurrence of Vitis macroremains in relation to chrono-cultural periods and site contexts. Statistical significances of the Fisher's exact tests are indicated on the barplots, only when the result is significant (*: $p \leq 0.05$; **: $p \leq 0.01$; ***: $p \leq 0.001$). Fisher's exact tests results are detailed in Supplementary Table 2.

There is no identifiable impact of context on the distribution of pedicels and charcoals during the Medieval period.

Site function has less incidence on the presence of *Vitis* remains. In any case, there is no consistent pattern valid for all types of remains and all periods. *Vitis* remains are equally represented in natural and anthropogenic sites throughout the chronology (Supp Fig. 2, Supp Table 2, 3 & 4).

We notice however that charcoals are better represented in natural sites during the Mesolithic-Bronze Age period. When a pattern emerges, it highlights the lesser recurrence of grapevine in ordinary settlements compared to sites with a more distinctive function. This is the case for charred pips and pedicels, which are significantly better represented during the Iron Age and Roman period in harbour sites than in habitats (Supp Table 2 & 4). Charred pips are also more frequent in ritual sites than habitats in Roman times in the CENO and EAMC regions (significant only in CENO; $p = 0.019$).

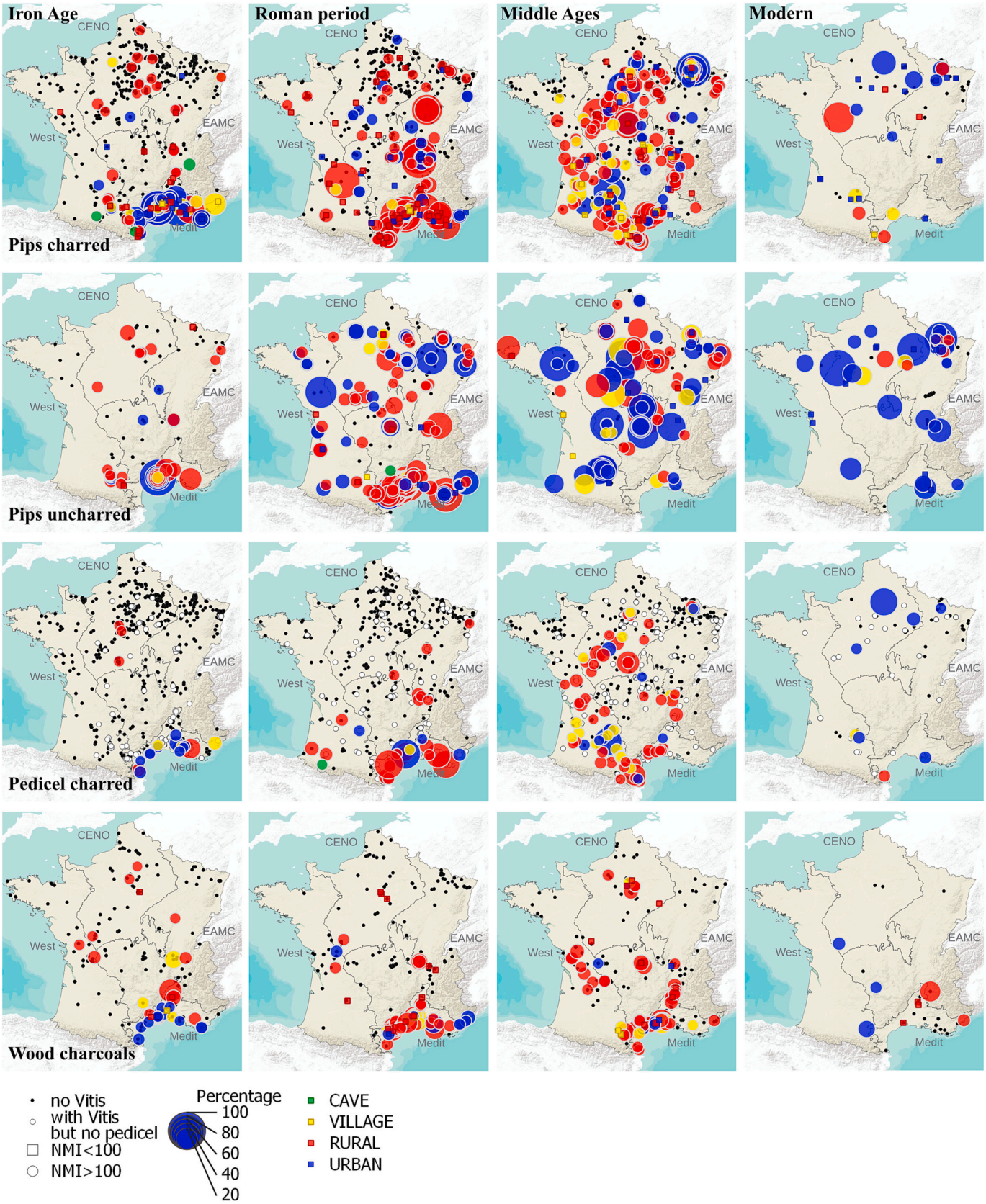

Fig. 6. Maps showing the distribution of charred and uncharred *Vitis* pips, charred pedicels and *Vitis* charcoals records in relation to chrono-cultural periods (Iron Age - Modern period), and site contexts.

4. Discussion

4.1. *Vitis* macroremains as indicators of grapevine exploitation and cultivation

As expected, preservation conditions have a strong impact on the record of *Vitis* remains, which show higher frequencies and proportions when waterlogged or mineralized compared to charred assemblages. However, and regardless of preservation, plant remains show consistent patterns through time and space, indicating that the variations must be related to changes in the spread of grapevine and its uses rather than mere taphonomic effects. With respect to plant organs, pips are much more common than pedicels – or any other fruit part- and wood remains (Fig. 2). The fact that the same unbalance between pedicels and pips is observed in the waterlogged material leads us to conclude that the over-representation of pips in the charred material is not due to taphonomic issues. In addition, charring experiments have shown that pedicels preserve well compared to the seeds, even at high temperature (Margaritis and Jones, 2006). As most of the samples come from dwelling sites, the predominance of pips is consistent with the fact that most assemblages represent domestic and daily food wastes rather than by-products of more specialized activities, such as wine making or other grape juice preparations. Scattered pips should be considered as mere indicators of consumption. It is impossible to know if they indicate local cultivation or reflect long-distance transport. Nevertheless, the common patterns observed between pips, on one hand, and pedicels and charcoal, on the other hand, indicators of local production, suggest that changes in grape consumption mirror changes in cultivation and local spread of grapevine. Firstly, during all periods, there is more archaeobotanical *Vitis* evidence in regions where climate is the most favorable for vine cultivation, particularly in the Mediterranean. Secondly, the map of charred pips records in medieval archaeological sites matches fairly well with that of areas under vine cultivation in 1852 (maximum extension of vineyards) (Fig. 3). This is in agreement with, and supports, written evidence which suggests that by the 13th–14th century CE, vineyard surfaces had reached an extension close to that of the mid 19th century (Lachiver, 2006). The main results that arise from the consistent patterns observed in time and space between different types of *Vitis* remains lead us to identify four major stages in the history of grapevine and viticulture in France. The following discussion will be organized on the basis of these four main points.

4.2. A wild resource extensively available to human populations since the Early Holocene

From the beginning of the Holocene to about 500 BCE *Vitis* macroremains are found sparsely but consistently at archaeological sites. This pattern is supported by pollen records as *Vitis* is first detected after the Late-Glacial period around 7500 BCE becoming more frequent from 6500 BCE onwards (Brewer et al., 2017). According to genetics, western Eurasian populations of wild vine (*Vitis vinifera* subsp. *sylvestris*) split into a Near-eastern/Caucasian ecotype and a western European ecotype during the Pleistocene. After the last glaciation, wild vines colonized Europe from refugia located in the Caucasus, the eastern Mediterranean, central Europe, the Italian and Iberian peninsulas and possibly southern France (Dong et al., 2023; Grassi et al., 2008). In fact, data based on seed and charcoal show that, *Vitis* was present in southern France at the onset of the Holocene and even during the Lateglacial, as noticed at La Balma de l'Abeurador (Félines-Minervois, Hérault). In this site, charcoal and seeds of *Vitis* were identified ca. 11,000–10,000 BCE, when the local forest-steppe vegetation was dominated by *Pinus* type *sylvestris*, *Juniperus* spp. and deciduous *Quercus* (Chabal and Heinz, 2021; Heinz, 1991; Vaquer and Ruas, 2009). Our data also show that the species reached the Paris Basin and northern France at least by 7000–6500 BCE. From the Neolithic period onwards (about 5000–4000 BCE), grape pips are occasionnally found in northwestern France, in a zone where vine growing is hazardous or even impossible today. Although an early spread by humans cannot be ruled out, it is likely that wild grapevine benefited from the warmer and more humid conditions of the Atlantic period (Marcott et al., 2013) to extend northwards. Pollen and macroremains evidence for a further northern spread in Europe during the Neolithic and Bronze Age is however very scarce (Brewer et al., 2017; Jones and Legge, 1987).

Wild grapevine is a woody heliophilous liana that grows on the edges of deciduous and semi-deciduous alluvial and colluvial forests (Arnold, 2002). The fact that alluvial forests are today the main habitat of the wild grapevines has probably favored the frequent recovery of macroremains at natural sites – chiefly paleochannels- since the Mesolithic. It is impossible to know how widespread the plant was in other forest habitats. Anthropogenic pressure and the spread of *Phylloxera* and other pests and diseases of American origin since the middle 19th century BCE are generally considered as the main causes for the loss of many wild populations since the last century (Ocete et al., 2015; This et al., 2006). Populations outside alluvial habitats may have been affected more heavily as *Phylloxera* cannot survive in sandy and temporarily flooded soils. The recurrence of *Vitis* macroremains in archaeological settlements demonstrates that the wood was occasionnally used as fuel and the fruit regularly collected. However, there is no evidence that the plant was cultivated or that the fruit was anything more than occasional food. The archaeobotanical data do not support the hypothesis formulated very recently by Dong et al. (2023), based on modern genetics, according to which the domesticated grapevine spread to western Europe during the Early Neolithic. Pedicels, which might indicate wine making, are very scarcely found at the sites. Nothing in the macroremains record suggests that wine could have been made from wild grapes, as it was the case in northern Greece in the Late Neolithic (Pagnoux et al., 2021; Valamoti et al., 2007). Thus, given the scarcity of pedicels and the recurrence of grape seeds in dwelling sites, generally mixed with other food waste (more especially fruit remains, cereals and cultivated pulses from the Neolithic onwards), we conclude that wild grapevine berries were a regular part of the diet of the populations at least from the Mesolithic onwards. The frequency of pips clearly shows that the fruits were more commonly used in the Mediterranean region than in temperate France, possibly because the plant was more widespread in this area. Today, the wild grapevine is present as small populations in various parts of France, but more especially in the South (André et al., 2017; Lacombe et al., 2003). On the other hand, although pips are more common in the Mediterranean region, the same does not happen with charcoals. Then, this may also indicate that wild grapevines were not that widespread but that grapes (food) were especially attractive to Mediterranean people.

4.3. The beginnings of viticulture during the Iron Age in the Mediterranean region

The sharp increase in the ubiquity and proportion of *Vitis* remains in the Mediterranean area during the Iron Age (around 500 BCE), testifies to the beginning of viticulture. By then, local populations were purchasing important quantities of wine from Etruscan and Greek merchants, especially the Phoceans who, by 600 BCE, had founded Marseille on the French Mediterranean coast (Dietler, 2010; Py, 1993). The simultaneous increase in the ubiquity of charcoals, pedicels and seeds is evidence that the fruits were not simply imported, as wine, but illustrate the development of local cultivation. Moreover, as *Vitis* remains become more frequent, morphometric analyses of pips show a shift from the wild to the domesticated morphotypes in most sites of the Mediterranean zone (Bouby, 2014). This evidence shows that, from the start, viticulture in France was based on domesticated vines. Cultivated varieties may have been either imported through contact with Mediterranean populations, or domesticated locally. Paleogenomic results obtained on pips from the Mediterranean site of Nîmes-Mas de Vignoles XIV, dated to the 2nd-1st c BCE, show kinship relationships with modern varieties from the Eastern Mediterranean (Ramos-Madrigal et al., 2019), thus

suggesting the introduction of foreign varieties. On the other hand, within the archaeobotanical assemblages, seeds of the wild morphotype are consistently associated with those of the domesticated type, leaving open the possibility that local wild vines may have been cultivated or even entered a domestication process. Recurrent finds of pedicels show that the grapes were used for winemaking. Several sites located in the coastal area have provided archaeobotanical assemblages characteristic of wine-pressing residues (Bouby et al., 2014). These include numerous grape remains, such as pips, pedicels and less frequently grape skins, which means that indigenous populations made their own wine while also purchasing wine from Mediterranean merchants. Table grapes may also have been cultivated by the end of the Iron Age. Indeed, morphometric analyses of pips from Nîmes-Mas de Vignoles XIV show that their shape is typical of modern eastern table varieties (Bonhomme et al., 2021a).

It is difficult to assess the extent of local grape production during the Iron Age in Mediterranean France. Data suggest that it may have been widespread, *Vitis* remains being almost as frequent as during Roman times. However, there is no archaeological trace of specialized facilities, such as wine cellars or local wine amphorae production, which could indicate the existence of large-scale viticulture. It seems that this first wine production occurred primarily at a domestic scale (Bouby et al., 2014). All kinds of *Vitis* remains are better represented in proto-urban (rather than rural) contexts of the Mediterranean Iron Age. This is where the majority of the population lived during most of this period and it is probably here that agricultural products were mainly processed. Biomolecular evidence on a stone pressing platform at the proto-urban harbour site of *Lattara* (425–400 BCE) suggests that it was used to press wine (McGovern et al., 2013) and all traces of vineyards dating to before the Roman conquest are located near urban centers (Boissinot, 2001; Jung, 2007; Pomarèdes et al., 2012). There is no doubt that the proximity of viticultural activities and dwellings favored the preservation and recording of *Vitis* macroremains, which may lead to some overestimation of the importance of viticulture.

This work confirms that Iron Age viticulture was clustered near the Mediterranean shores (Py and Buxo Capdevila, 2001), although by the 5th c BCE it may have spread some 150 kms north, along the Rhone river (Limier et al., 2018). Nevertheless, no significant increase in the ubiquity and proportions of *Vitis* macroremains was detected in the three regions outside the Mediterranean. Contrarily to the scenario suggested by biomolecular analyses of ceramic contents (Cherel and Frère, 2020) archaeobotanical data obtained up to now do not support the hypothesis of wine production far from the Mediterranean shores, even though it cannot be ruled out. Outside the Mediterranean region, archaeobotany does not detect changes in human practices related to the grapevine, when compared to earlier periods, even if wine was imported from the Mediterranean, in modest quantities during the Early Iron Age (6th–5th c BCE) and at large scale from the 2nd century BCE onwards (Laubenheimer and Marlière, 2010; Rageot et al., 2019).

4.4. First spread of viticulture outside the Mediterranean region in the Roman period

Although the evidence is still limited, archaeobotanical data suggest that the extension of viticulture outside the Mediterranean region started during the Early Roman period. However, the increase in the *Vitis* record is mainly confined to the southern half of the country and concerns mostly pip remains. Pedicels only increase in the southwest while no significant change is detected for charcoal. It is possible that our data may reflect above all a surge in the consumption of grapes which may partly explain why pips are found mainly in urban contexts. In any case, we cannot consider that grapes were only imported from the South in Roman times. Today, multiple archaeological findings, including traces of vineyards and amphorae production workshops, show that viticulture was being practiced in many areas of temperate France, up to the Paris basin and northwestern France, as early as the beginning of the 1st century CE (Laubenheimer and Marlière, 2010; Poux et al., 2011). In the city of Troyes (Champagne region), wine-pressing residues, composed of pips, pedicels, grape skins and rachis fragments, were recovered from a well dating to the 2nd century CE (Zech-Matterne et al., 2011). The likely wine production in the surroundings of the city is also supported by the local manufacture of wine amphorae (Zech-Matterne et al., 2011). Based on paleoclimatic data, a spatial modeling analysis established that a large part of the French territory was potentially favorable for viticulture in the 1st century CE, thus suggesting that its early extension benefited from the Roman Climatic Optimum (Bernigaud et al., 2021). The archaeobotanical data put the whole process into perspective by showing that evidence from the three north-western regions, stays far behind that of the Mediterranean. The spread of viticulture outside the Mediterranean from the 1st century CE onwards, was therefore gradual and limited, reaching the southern zones first and concentrating around urban areas, for the production of wine and possibly table grapes. Why was this expansion not more substantial? Wine from the Mediterranean area was still massively imported into the North in the Roman period, especially from south-eastern France (Narbonnaise province) (Laubenheimer and Schmitt, 2009), emphasizing the existence of lucrative local markets. Long distance inland transport of wine was very expensive before the advent of the railway and it would have been more lucrative to keep the production areas close to the consumption centers (Dion, 2011). Firstly, the expansion of viticulture may have been constrained by socio-political factors. Many scholars have commented on Emperor Probus autorization (end 3rd century CE) to plant vines in the northern part of France, possibly relieving a ban by Emperor Domitian in 92 CE (Brun and Laubenheimer, 2001; Dion, 2011). Based on recent archaeological evidence supporting the role of viticulture in the northern half of France, it has been often considered that the measures taken by Domitian and Probus did not have a significant effect on the development of local viticulture (Brun, 2011). However, the existence of regulatory constraints nonetheless remains a possibility, which could explain why the first spread of viticulture to the north was so limited. Secondly, we may recall the hypothesis once formulated by R. Dion, who argued that the spread of viticulture outside the Mediterranean area required the selection of new varieties able to adapt to different environmental and climatic contexts (Dion, 2011). During the 1st century CE, latin authors mention the adoption of new varieties resistant to adverse climatic conditions in the outer periphery of the Mediterranean area; examples include the allobrogica variety in the Alpine foreland (Dauphiné region) (André and Levadoux, 1964). However, it is questionable whether the range of varieties available at the time allowed extensive viticulture to flourish in all temperate zones. Paleogenomic results have highlighted the presence in Alsace (north-eastern France) of a variety also identified in Languedoc, by the Mediterranean (Ramos-Madrigal et al., 2019). This may indicate either the importation of fruits or the exchange of varieties between regions with very different climates, and thus possibly their introduction from the Mediterranean. Morphometric analyses of pips from Troyes (Champagne) show that the domesticated specimens from the first two centuries CE have strong morphological affinities with modern varieties regarded as typical of Southern France (Bonhomme et al., 2021b). These results suggest that viticulture could indeed have started in northern France with varieties introduced from the South, poorly adapted to more continental or oceanic climates, unable therefore to provide good and steady yields. This would have been instrumental in limiting the development of viticulture, despite the favorable conditions of the Roman Climate Optimum. Grapes were nevertheless regularly consumed and charged with symbolic significance, as shown by their greater representation in ritual contexts than in habitats, in northern France.

As we already pointed out, *Vitis* remains are much more common in the Mediterranean region during the Roman period, but compared to the Iron Age, the increase of its representativity is not as spectacular as might be expected, even though viticulture becomes massive in rural

areas, during the first two centuries CE. We have argued that some disconnection between dwellings and specialized wine production areas is likely to have contributed to a lesser representation of *Vitis* in the archaeobotanical record of the Roman period. The impact of viticulture in the Mediterranean countryside is nevertheless well reflected in the fact that *Vitis* remains reach their best representation in rural contexts at this period. This can also be seen in the progression of the frequency of charcoal records compared to the Iron Age.

4.5. Viticulture in full bloom during the Middle Ages

The Middle Ages is the period during which the archaeobotanical evidence of *Vitis* is the most important in the whole of France. The increase is most striking in the three northwestern regions, especially in CENO. This progression is not restricted to grape pips but also concerns pedicels and charcoals, which confirms the spread of *Vitis* cultivation and not only of grape consumption. This agrees with the historical sources which document a great expansion of viticulture in western Europe in the Middle Ages (11-13th century CE) (Bligny, 1978; Lachiver, 2006; Mane, 1991). The combined action of the Clergy and aristocracy to promote the development of medieval viticulture is well documented. Wine was needed for religious services, for the hospitality of the rulers, and was a commercial good valued by north European societies. This expansion most certainly benefited from the Medieval climate optimum (Graham et al., 2011) in a prosperous economic and commercial context. It was probably also facilitated by the availability of a range of grapevine varieties adapted to the terroirs of western and northern France. It is only from the 14th century onwards that historical sources begin to mention variety names. These names often correspond to varieties that, by the 19th–20th centuries CE were regarded as characteristic of the wine regions of northern France, such as Pinot noir or Gamay in Burgundy (Grillon et al., 2019). It must however be kept in mind that it is impossible to know whether the names used from the 14th century onwards correspond exactly to the varieties known today (Galinié, 2019). Written sources do not provide information on the situation during the Central Middle Ages, but thanks to paleogenomics we know that a variety now characteristic of the northern Alpine area, Savagnin blanc, was present at Orléans (Paris Basin) during the 11th–12th century CE (Ramos-Madrigal et al., 2019). In addition, morphometric analyses of the archaeological pips from Troyes (11-12th century CE) identify various shapes with similarities to current varieties typical of north-eastern and south-western France (Bonhomme et al., 2021b). Therefore, it seems very likely that by the mid medieval period, winegrowers of temperate France had a range of varieties adapted to their terroirs. But the characteristics, origins and pathways of these varieties are not yet well known. The take-off of viticulture in temperate France certainly benefited from the medieval warming, but archaeobotanical macroremains suggest that, in some areas, it started earlier, probably already at the transition between the Roman period and the Middle Ages. It is worth mentioning the accounts of certain authors, such as Ausonius (late 4th century CE) and Grégoire de Tours (6th century CE). The first reports on the vineyards he contemplated around the city of Bordeaux (Southwestern France) and in the Moselle valley (North-eastern France), while the second describes the damage inflicted by the Bretons on the vineyards of the lower Loire Valley in 579 (Brun, 2001). It is difficult to trace precisely the temporal fluctuations of viticulture during historial times based on archaeobotanical data alone. In all temperate regions, a possible decrease in the frequency of charred pips may be related to the cooling of the Early Middle Ages (Büntgen et al., 2016), but this trend needs to be more strongly supported by further evidence. In certain areas, such as Burgundy, written sources mention a decline in viticulture at the end of the Roman priod (Kasprzyk, 2016), but records are scarce. In the same way, archaeobotanical data are also too limited to consider the possible effect of the Little Ice Age. In fact, they suggest a further increase in *Vitis* evidence in all regions, during the Modern period. Concerning written sources, they record a decline in vineyards in the northernmost areas compared to the Middle Ages; however, in the whole, they also show an expansion of viticulture in Modern times, in connection with both population growth and increasing wine consumption among the lower classes. Written sources attest that between 1500 and 1800 the surface area occupied by vineyards in France increased by >60%, even though these underwent fluctuations according to local conjuncture (Lachiver, 1991).

In Medieval and Modern times, pip remains are mainly associated with urban sites, especially in the regions outside the Mediterranean. This is not only a consequence of the consumption of grapes as food, but is probably also evidence of a viticulture centered around towns. Charcoal and pedicels are found in both urban and rural contexts, in most cases with no significant difference in ubiquity between the two. Many peri-urban vineyards were known in the Middle Ages, particularly in the northern half of France (Lachiver, 2006). In the 12-13th century CE, vineyards were mainly located around large cities and waterways, both of which provided a commercial outflow for wine (Le Mene, 1991). In medieval Bordeaux, vine plots were located within the city, vineyard owners and workers often resided in town, where wine was stored, probably pressed, and viticultural implements kept in or near the houses (Lavaud, 2003). This may help explain the frequency of pips, pedicels and charcoal in urban contexts.

In spite of the Medieval bloom of viticulture in northern and western France, grape remains are still more frequent in the Mediterranean, as the climate allows the cultivation and good productivity of grapevines virtually everywhere in the region. Indeed, grape pips were found in 81 to 100% of Medieval Mediterranean sites, depending on context and state of preservation. In other regions, climatic reasons prevent viticulture from being so widespread: in many areas of northern France, vineyards would be confined to the best exposed slopes to benefit from the best sunlight and avoid the risk of frost. In other areas, viticulture is even more risky, if not impossible. This is why, even in the Middle Ages, *Vitis* remains are less common in the EAMC region, which has a cold continental or mountain climate in most of its territory. The medieval climatic optimum is credited with allowing an exceptional northwards progression of viticulture. Nevertheless, our data show that *Vitis* remains are still rare in northwestern France, which shows that progression remained very limited in this region least favorable for viticulture. The written and archaeological sources show that vines were already cultivated in northwestern France during the High Middle Ages, reaching their maximum extension in the 13th century. Vineyards were scattered mainly around religious establishments and towns, to satisfy local wine needs, but written sources confirm that they were confined to the most favorable locations (Bachelier, 2020; Le Mene, 1991).

In the Mediterranean region, plant macroremains do not register a decline in viticulture in the Middle Ages, compared to the Roman period. However, while wine was massively exported in the first two centuries CE, historical sources mention the difficulties faced by the Mediterranean merchants to sell their wine during the Middle Ages and early Modern period. The transportation costs were higher than those of more northern vineyards and they had to pay customs fees on the way to northern European markets (Dion, 2011; Lachiver, 2006). Regardless of these problems, these sources also testify to the viticulture expansion of the 13th century CE, in relation to the demographic growth. In the Languedoc, vineyards enjoyed a period of great prosperity between 1250 and 1350 CE. The wine was exported, in particular to Italy, and much of it fed local demand in the towns and countryside (Le Roy Ladurie, 1990). In the Mediterranean region, people in the countryside drank wine more frequently than in northern France. According to archaeobotanical data, grapes are the most common fruit throughout the Early Middle Ages in the sites of southeastern France (Ruas, 2005), just as it was in the Iron Age and in the Roman period (Bouby et al., 2022).

5. Conclusion

This work offers the first complete panorama of the history of

grapevine in France, its spatio-temporal dynamics from the Early Holocene to the Modern period, based on plant macroremains found primarily in archaeological contexts. The collection of an extended database of the occurrence of *Vitis*, organized by site-phases, was made possible by the involvement the majority of present-day archaeobotanists in France. Records of the different types of fruit remains (seeds, pedicels, berries, stalks) and wood (charred or waterlogged), provide coherent patterns concerning the spread of the grapevine, the fluctuations in viticulture, grape consumption and wine production. The confrontation of the regional presence and abundance of the different types of vine remains with the socio-environmental and functional contexts of the sites, allowed us to investigate the spread and uses of the grapevine in each period. The spatial and temporal schemes recognized are generally in good agreement with previous knowledge based mostly, according to chronology, on archaeological data or written sources. But, in contrast to this earlier information, they provide a more comprehensive and global picture encompassing the entire Holocene period, although some chronological phases and regions are still less well documented.

The distribution of *Vitis* remains in space and time allows us to distinguish four main chronological stages in the history of grapevine in France: the first part of the Holocene, the Iron Age, the Roman period, and medieval/modern times. *Vitis* macroremains are regularly recorded from the beginning of the Holocene onwards. This supports the hypotheis of an early spread of wild grapevine after the last glaciation and probably of the existence of refugial areas in southern France. Their frequency is higher in the Mediterranean area from the Mesolithic to the Bronze Age. Records of grape remains (seeds, pedicels and charcoal) increase in frequency and proportions from the Iron Age onwards in the Mediterranean area, as a result of the consumption of grapes and the development of viniculture. Our data do not support a decline in viticulture in southern France during the Middle Ages. Grapes are the most common fruit throughout the Middle Ages in southeastern France, just like it was during the Iron Age and the Roman period. Outside the Mediterranean, the frequency of *Vitis* increases first during the Roman period and more significantly in the course of the Middle Ages, especially in northern France. In these areas, viticulture remained limited during the Roman period. Our data show that *Vitis* remains are consistently better represented in urban contexts, which points to the prevalence of food consumption residues in the cities. However, the presence of pedicels and charcoal also attest to viticultural and vinicultural activities involving the cities.

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CRediT authorship contribution statement

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Declaration of Competing Interest

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

Data availability

The archaeobotanical data on which this study is based have been deposited in InDoRES under the reference https://data.indores.fr:443/privateurl.xhtml?token=d277b78e-a06a-4a55-8819-747edc451908.

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