

Snapshots from the past: Biodiversity of the Vesuvian area before AD 79 from new archaeopalynological studies

A. Florenzano^a, P. Torri^a, G. Bosi^a, E. Clò^{a,*}, P. Caprio^b, A.M. Mercuri^a

^a Laboratorio di Palinologia e Paleobotanica, Dipartimento Scienze Vita, Università Degli Studi di Modena e Reggio Emilia, Modena, Italy

^b Direzione Regionale Musei Del Lazio, Museo Archeologico di Formia, Formia, Italy

ARTICLE INFO

Keywords:

Pollen
Pre-roman age
Pompeii
Cultural landscape
Mediterranean

ABSTRACT

The Vesuvian area is rich in well-studied archaeological sites, in which the exceptional preservation of plant remains has led to an in-depth botanical reconstruction of aspects related to diet, rituals and elements of the local urban landscape. Pollen analyses have been mainly focused on the reconstruction of gardens, providing direct evidence of floristic composition, plant selection and seasonality. With a biological approach, the present study aims to contribute to a broader understanding of the plant diversity that characterised the Vesuvian area through the study of 1st century AD Vesuvian sites, i.e. Stabiae and Pompeii. Forty pollen samples were studied from three sites in the Vesuvian area: the two multipoint sites of Stabiae and Pompeii and the Civita Giuliana site close to Pompeii. At Stabiae (nowadays Castellammare di Stabia), pollen investigation conducted in two *villae* (“Villa Arianna” and “Villa San Marco”) provided important information to reconstruct the plant landscape before the catastrophic eruption of AD 79. In Pompeii, two plaster samples from two houses (“Casa del Menandro” and “Casa del Centenario”) were studied and, in the nearby Civita Giuliana, samples are from an agricultural area. Among the main features common to the studied contexts, it is noteworthy the presence of a large amount of pollen from fruit trees (*Juglans*, *Olea*, *Vitis*, *Castanea*) and evidence of ornamental plants. These elements characterised the rich cultural landscape of the area. Despite some caution due to pollen preservation issues, when a high level of identification is achieved, palynology proves to be a reliable tool for the knowledge of biodiversity and landscape patterns in vulnerable areas exposed to natural events.

1. Introduction

Deeply rooted in life sciences and environmental ecology, palynology is playing an increasingly important role in the study of archaeological contexts (Edwards et al., 2017; Fægri et al., 1989; Mercuri, 2014). In addition to studies that complement environmental archaeology research, pollen analysis has interesting applications in the study of stratigraphical contexts (trenches or walls into the archaeological site – Cremaschi et al., 2016; Florenzano et al., 2022; Mercuri et al., 2019) or in spot samples (such as gut or stomach content, votive offerings, plasters, and tiles – Di Lernia, 1999; Florenzano et al., 2012; Langgut, 2022a, 2022b; Mariotti Lippi and Mori Secci, 1997). Thanks to pollen data, information on flora and vegetation as well as ecological and cultural landscape traits can be obtained by analysing samples from a single structure, a room, a house, a village or a network of sites in a given region. Spatial distribution and chronologies of archaeological (on-) sites and open area (off-) sites can be a formidable knowledge tool

for reconstructing the traits of past cultures and comparing their pollen spectra can help to reconstruct human action and landscape in the studied area (Mercuri, 2014).

Although the interdisciplinary approach is widespread and almost always applied in prehistoric archaeology, less widespread seems to have been the botanical research in the historical periods until now (Kouli et al., 2019), probably due to the extraordinary wealth of written, architectural, and iconographic sources that can provide direct and often unambiguous documentation of useful plants and some environmental data. Nevertheless, interdisciplinary research conducted in recent years on deposits dating back to historical phases has made it possible to document aspects of the human-plant relationship and the plant landscape that are not fully understood and sometimes unexpected. Thus, the study of lacustrine deposits has brought to light traces of hemp retting in the lakes of Latium during the Roman period (Mercuri et al., 2002), while detailed studies on small Roman farms in southern Tuscany have revealed that there was extraordinary expertise

* Corresponding author.

E-mail address: eleonora.clo@unimore.it (E. Clò).

accompanied by great local variability in the exploitation of agrarian landscapes and vegetable gardens by Roman peasants (Bowes, 2020; Bowes et al., 2015). Indeed, the study of off-site contexts can provide interesting environmental reconstructions and represent palaeoenvironmental evolution over a long-time span. For example, long-term palynological studies covering the last ~8200 years depict the palaeoenvironmental evolution in the area of the Garigliano delta plain and describe the landscape context when the *Minturnae* Roman colony flourished since the 3rd century BC (Bellotti et al., 2016; Ferrari et al., 2013). In this area, a gradual increase in anthropogenic forcing occurred after 3000 yrs BP related to the spread of grasslands and wet pastures, although the human impact on the landscape of the Garigliano delta seems limited compared to that of other Mediterranean deltas in the Roman period (e.g., Tiber, Arno, and Rhone; Bellotti et al., 2011, 2016; Di Rita et al., 2010; Giraudi, 2011; Vella et al., 2005).

An important type of archaeological study context is the town, which by its nature and complexity represents a 'multipoint site' (Mercuri et al., 2015a), i.e. one extended site that includes many excavations. As each excavation has different archaeological or historical features, each site can correspond to different past and present environmental traits in the same city. Thus, investigations into the Roman city of Mutina led to the different availability of water, dietary resources, and patches of woodland in different dwelling places, from a *villa* to an agricultural area, all now incorporated within the modern city (Bosi et al., 2015, 2019).

No archaeological site in the world has had a higher resonance than Pompeii: in recent decades, a blend of ancient written sources, archaeological and archaeobotanical evidence, along with geoarchaeological studies, has provided a detailed understanding of the natural environment surrounding and within the city. Jashemski spent several years excavating the gardens of Pompeii, Herculaneum, Oplontis, and other nearby villages, villas, and farms, providing insights into the daily life of the past (Jashemski, 1993). In general, the Vesuvian area is rich in multipoint sites, studied by research groups from different schools, which led to a rich and diverse botanical reconstruction of aspects related to diet or elements of the local urban landscape. The large part of the research has been devoted to plant macroremains (e.g., Allevato et al., 2010; Lodwick and Rowan, 2022; Moser et al., 2013, 2018; Murphy et al., 2013; Rowan, 2017). Besides the particular deposition and taphonomy conditions that have often allowed for the exceptional preservation of plant remains, the botanical identification has often been corroborated by magnificent fresco iconography (Ciarallo, 2019). Pollen analyses have been particularly concentrated to the

reconstruction of gardens, for which they provided direct evidence and details on floristic composition, plant selection and seasonality (Ciarallo and Mariotti Lippi, 1993; Jashemski, 1993; Langgut, 2022b; Mariotti Lippi, 2000; Mariotti Lippi and Bellini, 2006). Mariotti Lippi (1998) discussed the poor preservation of pollen grains extracted from the soil of a Pompeian garden, possibly linked to chemical oxidation or microbial attack. However, a special pollen preservation was also emblematic of high temperatures at Oplontis in the suburban area of Pompeii, also buried by Vesuvius in AD 79 (Mariotti Lippi, 2024). Plaster installations facing the garden were also used for pollen extraction, thus solving some problem of poor preservation or long-distance airborne pollen transport. The use of this unique palynological-archaeological method enabled the identification of the botanical components in prestigious early Roman gardens across the Empire (Langgut, 2022b).

In this paper we present examples of original pollen analyses carried out on different materials and contexts of the Vesuvian area, i.e. Stabiae and Pompeii (Fig. 1). Unlike other palynological research oriented towards the archaeology of gardens (e.g., Langgut, 2022b; Langgut et al., 2024), the perspective of this article is focused on plant biodiversity.

At Stabiae, the two Roman villas of Arianna and San Marco were studied to provide information for reconstructing the rich plant diversity in gardens and landscape surrounding the buildings before the AD 79 catastrophic event. In the Civita Giuliana locality, many samples were taken from large portions of agricultural land that had been found with evidence of plant growing covered by eruptive materials during the AD 79 eruption. At Pompeii, plaster samples from the Menander and Centenary Houses were studied as part of a research aimed at reconstructing the chronology of the buildings' restorations.

Starting from these different contexts, this paper provides a 'snapshot' of the biodiversity in three different Vesuvian sites and contributes to the knowledge of the 1st century AD plant landscape. In modern interdisciplinary and holistic science, in fact, palynology of archaeological sites has gained a new reputation, being now at the center of the studies of environmental transformations and human impact, all hot topics in ongoing research on current biodiversity and nature management and conservation (Floyd and Willis, 2008; Mercuri, 2008a; Mercuri and Florenzano, 2019; Stephens et al., 2019).

2. Material and methods

2.1. Notes on the vegetation of the Vesuvian area

The present climate of the Vesuvian area is Mediterranean with an



Fig. 1. – Location map of Pompeii, Castellammare di Stabia (Stabiae) and Civita Giuliana in the Campania region, Southern Italy (GoogleEarth™). The map shows sites and localities mentioned in the text.

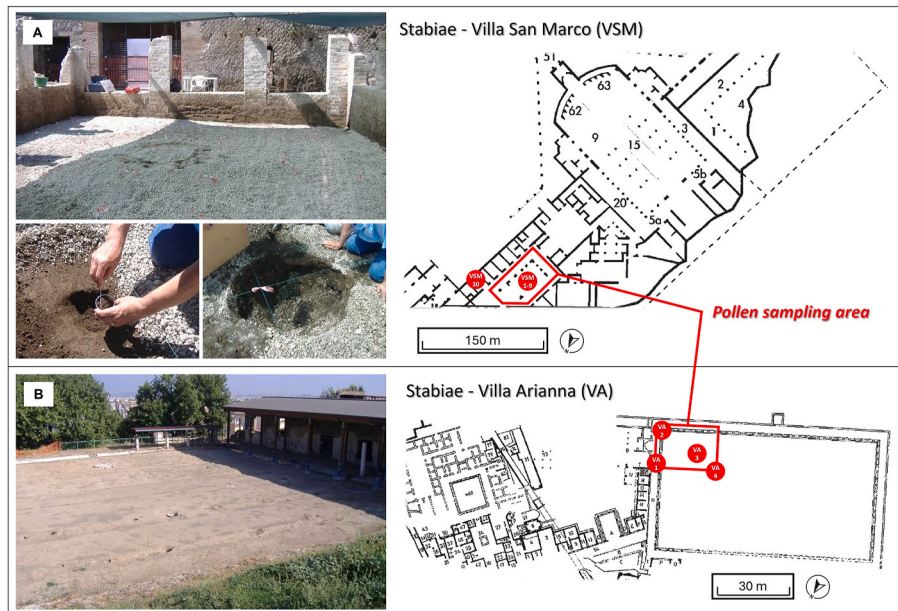


Fig. 2. – Location of pollen samples from Villa San Marco (VSM) and Villa Arianna (VA) at Stabiae. A. Sampling of soil buried from AD 79 lapilli and ash in the Est Portico Garden – VSM (photos by P.Caprio); B. Sampling of soil covered by lapilli in the Peristyle H – VA (photos by P.Torri). The plans of the *villae* are from [Poehler et al. \(2011\)](#), modified.

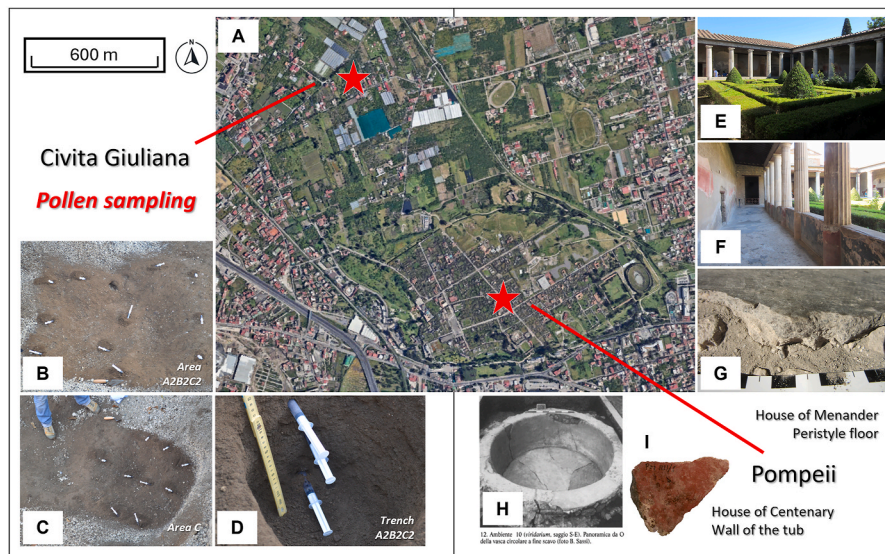


Fig. 3. – Location of pollen samples from Civita Giuliana (CG) and Pompeii. A. Location map of CG and Pompeii (GoogleEarth™); B-D. Sampling of soil in farmland - CG; E-F. House of Menander in Pompeii; G. Peristyle floor detail; H. *Viridarium* (photos B.Sassi); I. Plaster of the wall into the tub.

average annual temperature of 25 °C (min: 13 °C; max: 35 °C) and precipitation of 830 mm ([Foss et al., 2002](#)). The floristic list of Mount Vesuvius counts just over 800 species, a number which highlights a significant impoverishment of the flora of the entire Vesuvian area. Intense anthropisation has affected this area, strongly influencing the composition of spontaneous flora and vegetation. Today, there are few rare and endemic plants, and this seems to be mainly due to the continuous eruptions that have led to the periodic destruction of the flora over time ([Blasi and Biondi, 2017](#)). According to the botanical nomenclature of the [Portal to the Flora of Italy \(2024\)](#), the potential vegetation of the area is characterised by thermophilic woods dominated by *Quercus cerris* L. ([Filesi et al., 2010](#)). The hilly area up to 100–200 m (lower slopes of the Somma-Vesuvius Volcanic Complex) hosts a thermophilic forest dominated by *Quercus* group *pubescens* with

Quercus ilex L., *Fraxinus ornus* L., *Arbutus unedo* L. ([Filesi et al., 2010](#)). In this territory extensive cultivated and urbanised areas are present and most of the Somma-Vesuvius flora comprises annual species and perennial herbaceous plants, while shrubs and trees are rather scarce ([Ricciardi et al., 2016](#)). The potential vegetation of the Sorrento peninsula and Mount Somma is characterised by woods dominated by *Ostrya carpinifolia* Scop., *F. ornus*, *Q. ilex*, *Acer opalus* Mill. subsp. *obtusatum* (Waldst. & Kit. Ex Willd.) Gams and, in the second order, *Quercus pubescens* Willd. and *Alnus cordata* (Loisel.) Duby. These territories are often occupied by extensive chestnut plantations (for coppicing and fruit production); in the Sorrento Peninsula these formations cover large areas, following the need to produce the poles used in the cultivation of citrus groves on the terraces ([Filesi et al., 2010](#)). The fertile soils of the area favored the replacement of the original mixed oakwoods with

chestnut groves, most probably already present also at low altitude since the Roman period (Blasi and Biondi, 2017).

2.2. Sites and pollen samples

Forty archaeo-palynological samples taken from three sites – Stabiae, Civita Giuliana, Pompeii – in the Vesuvian area were studied (Table 1). They are three new sites for the database BRAIN (SCA34: Stabiae - Villa San Marco; SCA35: Stabiae - Villa Arianna; SCA36: Pompeii - Civita Giuliana; SCA37: Pompeii - Casa del Menandro; SCA38: Pompeii - Casa del Centenario) where 9 other sites from the multipoint site of Pompeii already exist (Mercuri et al., 2015b, 2024).

2.2.1. Site 1 - Castellammare di Stabia - Stabiae (villae – a. Villa San Marco and b. Villa Arianna; Fig. 2)

The ancient city of Stabiae was situated approximately 4.5 km southwest of Pompeii, in the territory between the Vesuvian area and the Sorrento Peninsula. It reached its highest population density between its destruction by Sulla (89 BC) and the eruption of Vesuvius (AD 79). During this period, on the northern edge of the Varano hill many luxurious villae (so-called “villae d’otium”) were built. These also include Villa San Marco and Villa Arianna, with beautifully decorated large apartments, thermal baths, and porticoes. Both Pliny the Elder (NH 19, 139–141) and Columella (RR 10, 135) talk about Stabiae to praise the thermal baths and cabbage crops in the area.

Samples for pollen analyses were taken in the framework of the 2007/2008 archaeological excavations at Villa San Marco and Villa Arianna. All samples from Villa San Marco and part of those from Villa Arianna were taken in collaboration with the Applied Research Laboratory of the Superintendency for the Archaeological Heritage of Naples and Pompeii (now Archaeological Park of Pompeii) and handed over for palynological analysis to Professor C.A. Accorsi of the University of Modena and Reggio Emilia. Caprio (2008), as part of her Master thesis, analysed 14 samples, 10 from Villa San Marco and 4 from Villa Arianna; in this paper, the results have been checked and updated.

2.2.2. Site 2 - Civita Giuliana (farmland; Fig. 3a)

The archaeological area of Civita Giuliana is located approximately 700 m north-west of the walls of Pompeii. It was part of the Pompeii suburbs, which was populated by various villae scattered over a territory with both productive and residential vocation (<https://pompeiiisites.org/en/press-kit-en/the-excavations-of-civita-giuliana/>).

Table 1

– List of pollen samples from the three sites of the Vesuvian area studied in this paper: Stabiae (Villa Arianna-VA, Villa San Marco-VSM), Civita Giuliana-CG, and Pompeii (House of Menander-HoM, House of the Centenary-HoC). For each site, the number of pollen samples, their archaeological context and type and chronology of layers are listed.

samples	no.	context	layer
Stabiae - Villa San Marco (VSM)			
VSM-1 - VSM-9	9	villa - E-portico garden	soil 79 AD
VSM-10	1	villa - E-portico room	ash 79 AD
Stabiae - Villa Arianna (VA)			
VA-1, VA-2	2	villa - peristyle H N-side	soil 79 AD
VA-3, VA-4	2	villa - peristyle H garden	soil 79 AD
Civita Giuliana (CG)			
CG-1 - CG-11	11	farmland - area A2B2C2	soil 79 AD
CG-12 - CG-14	3	farmland - trench A2B2C2	soil pre-79 AD
CG-15	1	farmland - area B	soil 79 AD
CG-16 - CG-24	9	farmland - area C	soil 79 AD
Pompeii			
HoM	1	House of Menander - peristyle floor	mortar 79 AD
HoC	1	House of the Centenary - wall of the tub	mortar 79 AD

In the 2018 excavation operation has brought to light the servile-productive sector of a large villa, which had already been partially investigated at the beginning of the 20th century, and the area dedicated to agricultural use. During the archaeological excavations coordinated by the Archaeological Park of Pompeii, farmland with evidence of planting was brought to light. From this area, a total of 24 soil samples were taken for pollen analyses (by P.T.) from surface that showed visible traces of agricultural use and divided into several sectors. Samples were collected from the area A2B2C2 (14 samples: 11 below the lapilli layer of AD 79, and 3 from a trench excavated below) and from the Area B and C (1 and 9 samples respectively, each from below the lapilli layer) (Table 1).

2.2.3. Site 3 – Pompeii (domus – a. House of Menander and b. House of the Centenary; Fig. 3b)

The ancient city of Pompeii was situated close to the sea on a low hill of volcanic origin, referred to as the “Pompeii Hill” and overlooks the terminal, western portion of the Sarno River floodplain. Pompeii was surrounded on three sides by fertile and heavily cultivated agricultural land, as is attested by the large number of villas discovered between Pompeii and the southern slopes of Mount Vesuvius as well as by archaeobotanical and palynological analyses carried out in the area (e. g., Ciarallo, 2002; De Simone, 2017; Mariotti Lippi, 1993; Vignola et al., 2022). Many of the villas show evidence of mixed farming (Flohr and Wilson, 2017).

Two samples of plasters from two domus of Pompeii were analysed: one plaster from the House of Menander (“Casa del Menandro” – Regio I, insula 10, nr. 4/14–17 – sample HoM – from peristyle floor) and one from the House of the Centenary (“Casa del Centenario” – Regio IX, insula 8, nr. 3/6 – sample HoC – from the wall into the tub). In addition to the peristyle, HoM probably featured a hortus-a vegetable garden (Varriale, 2012), while HoC was probably a viridarium-an elite type of Roman garden (Porter, 2020). The insula and house numbers are based on the Neapolis Project Address Book (Giordano, 2012). The usefulness of these materials for pollen analyses was demonstrated by Langgut et al. (2013), partially published in Tirelli (2019), and currently underway on similar samples from other contexts (Tirelli et al., 2021).

2.3. Pollen treatment and analysis

Samples were subjected to pollen extraction with nylon sieving and heavy liquid floatation (Florenzano et al., 2012; van der Kaars et al., 2001). About 2–4 g of sediment/material from each sample were treated through deflocculation with Na-pyrophosphate 10%, sieving (7 µm-mesh nylon sieve), HCl 10%, acetolysis (Erdtman, 1960), heavy liquid separation (Sodium metatungstate hydrate), and HF 40% for 24h. The plasters from Site 3 were treated avoiding the sodium pyrophosphate step and repeating twice the hydrofluoric acid treatment. The final residues were mounted in permanent slides, using glycerin jelly, and sealed with paraffin. *Lycopodium* spores were added to calculate concentrations, expressed as pollen per gram (=p/g).

Identification was made at 1000× magnification, with the help of keys, atlases, and the reference pollen collection. Pollen taxa nomenclature follows Moore et al. (1991), as well as the Northwest European Pollen Flora (Punt, 1976; Punt and Blackmore, 1991; Punt and Clarke, 1991; Punt and Hoen, 2009; Punt et al., 1995, 2003–2009). Cerealia pollen identification was based on Andersen (1979), Beug (2015), and Fægri et al. (1989). About 300 pollen grains per sample were counted. In the Civita Giuliana samples, due to the low pollen content, the results of close samples taken from the same layer were summed; therefore, 3 pollen spectra were obtained from 24 samples treated. The percentage pollen diagrams were calculated on pollen sums including all pollen counted. Pollen taxa were grouped into sums useful for environmental reconstructions: i) bisaccatae (*Abies* and *Pinus*); ii) hygrophilous trees (*Alnus*, *Populus*, and *Salix*); iii) hygrophilous herbs (Cyperaceae, *Phragmites australis*, *Sparganium emersum* type, and *Typha latifolia* type); iv)

mixed oakwood (*Acer campestre* type, *Corylus avellana*, *Fraxinus excelsior* type, *Ostrya carpinifolia*/*Carpinus orientalis* type, deciduous *Quercus*, *Tilia*, and *Ulmus*); v) Mediterranean trees (*Erica*, *Fraxinus ornus*, *Myrtus communis*, *Olea europaea*, *Phillyrea*, *Quercus ilex* type, *Tamarix*, and *Viburnum*); vi) Anthropogenic Pollen Indicators, including *Artemisia*, *Centaurea*, Cichorieae, *Plantago*, cereals, *Urtica*, and *Trifolium* type, that are ubiquitous in archaeological contexts of Italy (Mercuri et al., 2013a). In the studied sites, cereal pollen includes *Avena/Triticum* and *Hordeum* groups, and *Secale cereale*.

Pollen diagrams were drawn with *Tilia* 3.0.1 (Grimm, 2004).

3. Results

Pollen diversity observed in the three sites ranges from 27 (Pompeii) to > 90 pollen taxa (Stabiae and Civita Giuliana) (Table 2; Fig. 4). Herbaceous plants are dominant, almost twice as many as woody plants. In the following paragraphs, the detailed results for each site are reported.

3.1. Site 1 - Stabiae

Samples from the two *villae* of Stabiae contain pollen, except for one sample taken from the portico garden at Villa San Marco. Pollen has generally good state of preservation, with few exceptions, and some pollen clumps were observed (see below, 4.1).

Pollen concentration is low, with an average of 3000 p/g. A total of 4428 pollen grains were counted (340 pollen/sample on average).

The floristic list is rich, including 95 pollen taxa (37 woody and 58 herbaceous plants; Fig. 5). At Villa San Marco the floristic richness is much higher (90 taxa: 35 woody, 55 herbs) than at Villa Arianna (38 taxa: 18 woody, 20 herbs). The arboreal (AP)/non-arboreal (NAP) pollen ratio is 29/71 on average, showing the prevalence of open vegetation. The predominant trees are *Castanea sativa* (mean value: 6.0%), *Juglans regia* (5.2%) and *Olea europaea* (4.9%). In sample VSM-2, *J. regia* pollen was observed in high percentages (20.7%) with very variable sizes (diameter ranging from 26 µm to 54 µm). Low percentages of *Vitis vinifera* characterise only Villa San Marco. Other woody plants are present in low percentages and are representative of different vegetation contexts: mixed oakwoods (*Acer campestre* type, *Corylus avellana*, *Fraxinus excelsior* type, *Ostrya carpinifolia*/*Carpinus orientalis* type, *Ulmus*, and *Tilia*), hygrophilous woods (*Alnus*, *Populus*), mixed evergreen/broad-leaved woods distributed in the hills and at higher altitudinal belts (*Abies*, *Betula*, *Fagus sylvatica*, *Pinus*, and *Taxus baccata*), Mediterranean

Table 2

– Summary of the main results from pollen analyses at Stabiae (Villa Arianna-VA, Villa San Marco-VSM), Civita Giuliana-CG, and Pompeii (HoM, HoC): pollen count, number of pollen taxa, and arboreal (AP)/non-arboreal (NAP) pollen ratio.

<i>samples</i>	<i>count</i>	<i>no. taxa</i>	<i>AP/NAP</i>
Stabiae - Villa San Marco (VSM)			
VSM-1 - VSM-9	2995	89	27/73
VSM-10	119	17	39/61
Stabiae - Villa Arianna (VA)			
VA-1, VA-2	430	20	10/90
VA-3, VA-4	884	35	49/51
Civita Giuliana (CG)			
CG-1 - CG-11	505	61	15/85
CG-12 - CG-14	388	36	3/97
CG-15	–	–	–
CG-16 - CG-24	1068	71	13/87
Pompeii			
HoM	74	26	26/74
HoC	12	7	17/83

trees (*Quercus ilex* type, *O. europaea*, *Myrtus communis*, *Viburnum*, and *Phillyrea*). Ornamental trees such as *Buxus*, *Platanus orientalis*, *Rosa*, and *T. baccata* are also present in some samples. Hygrophilous herbs (*Typha latifolia* type and *Phragmites australis*) are scarce and, together with hygrophilous trees, account for an average of 2.3%. Pollen spectra are dominated by wild Poaceae (42.9%, on average), followed by Cichorieae (12.7%).

Human activities and grazing environments are testified by anthropogenic pollen indicators (API = 17.9% on average). Chenopodiaceae/Amaranthaceae are recurrent in almost all samples (2.1%), followed by *Artemisia*, *Beta vulgaris*, *Plantago*, *Papaver*, *Centaurea nigra* type, and *Urtica*. Cereals (3.7%) are mainly represented by *Hordeum* group; in sample VA-2 the high value of cereal pollen (10%) could also be linked to local plant processing. Pollen of *Cannabis sativa* is present in eight samples (0.7%, on average).

3.2. Site 2 - Civita Giuliana

Most of the 24 processed samples had a low pollen content or were sterile. Therefore, a total of 1961 pollen grains were counted, and partly summed to be attributed to 3 pollen spectra (refer to Table 2 for the summary of the main results from the 3 pollen spectra, and Table 3 for the floristic list). Pollen concentration is low (900 p/g, on average) and spans between ca. 60 and 4000 p/g. The state of preservation is good, only few pollen grains were observed folded or with thinned exine.

A total of 94 pollen taxa (30 woody and 64 herbaceous plants) was identified. Pollen taxa diversity is lower in section A2 B2C2 (pre-AD 79) than in area A2B2C2 and C (soil AD 79). The average percentage of woody pollen taxa is very low (12.5%).

The predominant trees are *Pinus* (3.2% on average), deciduous *Quercus* (1.2%), *P. orientalis* (1.2%), and *O. europaea* (1%), followed by *J. regia* (0.7%). Other woody plants are present in traces and are representative of different vegetation contexts: mixed oakwoods (*Acer campestre* type, *C. avellana*, *Fraxinus excelsior* type, *Ostrya carpinifolia*/*Carpinus orientalis* type, and *Ulmus*), hygrophilous woods (*Alnus*, *Populus*, and *Salix*), and Mediterranean trees (*Erica*, *Fraxinus ornus*, *Quercus ilex* type, *M. communis*, and *O. europaea*). Traces of *C. sativa* and *V. vinifera*, together with olive trees, hazelnuts and walnuts, represent cultivated plants with edible fruits. Ornamental trees such as *Buxus*, *P. orientalis*, *Rosa* and *T. baccata* are quite common.

Among herbs, wild Poaceae (24.0%, on average), Cichorieae (24.5%) and Apiaceae (6.6%) prevailed. Cereals, here represented by *Avena/Triticum* group and *Hordeum* group, show an average of 1.4% with a maximum of 7.2% in sample CG-19 (Area C). In addition, Brassicaceae pollen is almost always present in the samples, reaching 14.3% in sample CG-15 (Area B).

Hygrophilous herbs (Cyperaceae and *Sparganium emersum* type) are low and, together with the hygrophilous trees, amounted to 3.5% on average.

The spectra show high pollen percentage from synanthropic plants that testified human activities (API = 35.8% on average). Chenopodiaceae/Amaranthaceae are present in most samples (2.6% on average) followed by *Urtica dioica* type, *Plantago*, *Papaver*, *Artemisia*, and *Centaurea nigra* type.

3.3. Site 3 - Pompeii

According to the special type of samples, plasters have insignificant (HoC - 63 p/g) to low (HoM - 2569 p/g) pollen concentration, low number of pollen taxa, from 7 (HoC) to 26 (HoM), and the state of preservation was fairly good. Due to the results obtained, HoC pollen data were excluded from the elaborations.

Walnut (*J. regia*) and olive (*O. europaea*) pollen are present in both samples; a peltate leaf hair of olive was also observed in HoC. Another common trait between the two samples is pollen from weeds (e.g., Chenopodiaceae/Amaranthaceae and *Urtica dioica* type). *C. sativa* and

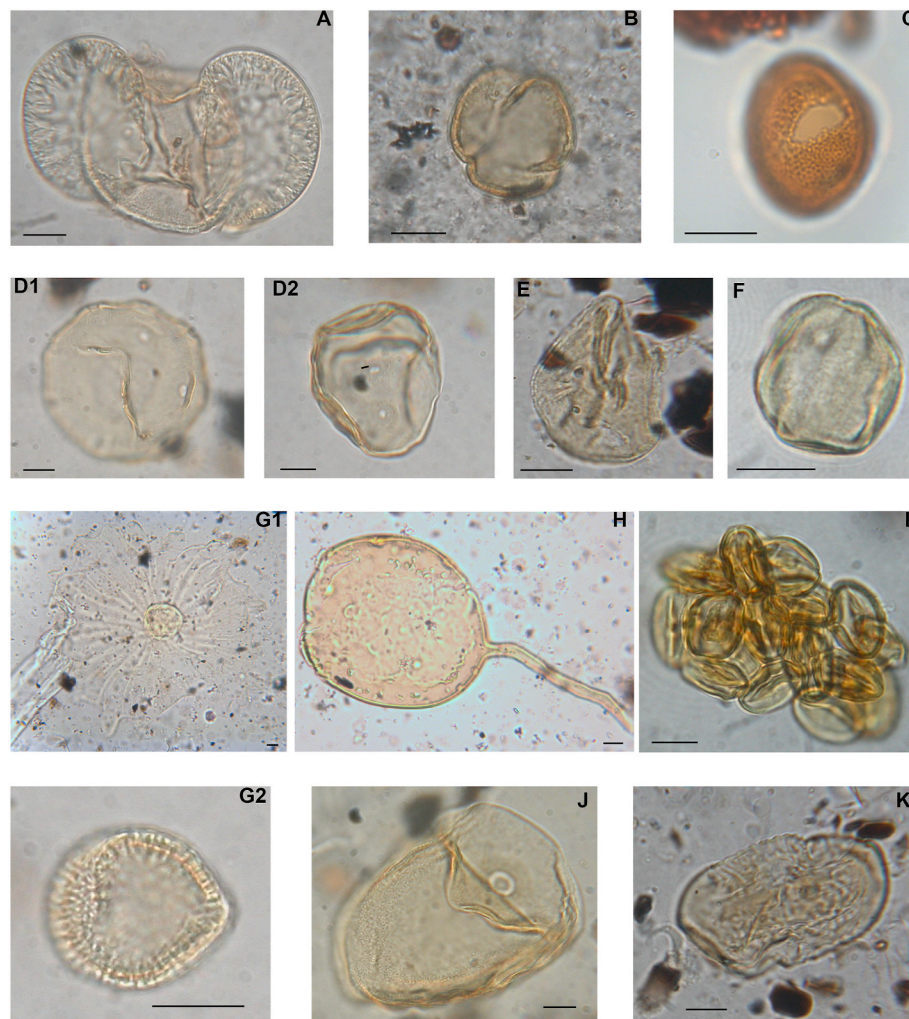


Fig. 4. – Pollen and Non-Pollen Palynomorphs selected from the examined sites: A. *Pinus*-VA (70 μm); B. *Quercus ilex* type-VA (24.5 μm); C. *Platanus orientalis*-CG (23.6 μm); D1. *Juglans regia*-VSM (54.9 μm); D2. *J. regia*-VSM (41.5 μm); E. *Rosa*-CG (32.9 μm) with thinned exine; F. *Vitis vinifera*-VSM (24.4 μm); G1. peltate hair of *Olea europaea*-HoC (182.8 μm); G2. *O. europaea*-VSM (23.3 μm); H. Chlamydospore of *Glomus* type-HoC (98.8 μm); I. Clump of *Castanea sativa*-VSM; J. *Avena/Triticum* group-VSM (73.2 μm); K. *Vicia cf. faba*-CG (47.5 μm). The measurements correspond to the main axis of the pollen. The scale bar is 10 μm .

pollen from hygrophilous trees (*Alnus* and *Salix*) are scarce, only present in HoM. In addition, the presence of roses (*Rosa*) should be noted for HoM; traces of cereals (barley - *Hordeum* group) with some crop weeds (e.g., *Papaver rhoeas* type) were found. A fair number of spores of the mycorrhizal fungus *Glomus* was observed in HoC.

4. Discussion

4.1. The state of pollen preservation in archaeological contexts

Beside disturbance effects of compaction or chemically unfavourable sediment composition that generally affect pollen from archaeological sites (Dimbleby, 1985), in the Vesuvian area, and particularly in the samples presented in this paper, there is the additional complication due to soil composition and stratigraphy disturbance induced by the Vesuvian eruption (Mariotti Lippi, 2024).

In the alkaline soils of the Vesuvian area, pollen is often characterised by a poor state of preservation and highly variable concentration, even in samples collected a few meters apart (e.g., Gröger, 2002; Mariotti Lippi, 2000). Contrarily, pollen preservation in the samples reported in this paper is prevalently quite good. Each site shows different pollen preservation and concentration resulting from different taphonomic processes and depositional contexts.

At VSM and VA of Stabiae, pollen grains show mechanical damage and degradation (according to the deteriorating classes by Berglund and Ralska-Jasiewiczowa, 1986). There is also evidence of corrosion in some pollen grains. For example, some *Juglans regia* pollen has perforated exine: this suggests that the source of sediments where these grains were probably included in different sediments, which were subjected to chemical processes causing damages to the exine. Indeed, the folded Poaceae pollen grains testify that there was some compaction of sediments due to the pyroclastic materials deposited by the eruption of AD 79. Interestingly, the analyses show also some pollen clumps of *Castanea sativa* (Fig. 4I), *J. regia*, Cichorieae and wild Poaceae, as monospecific pollen accumulation typically observed in anthers (Mercuri, 2008b). They can be evidence of local presence of flowers or pollen trapped in some plant parts, or excrement content (Dimbleby, 1985). The latter hypothesis can be applied to the herbs ingested by herbivores and then deposited with dung. This evidence could be interpreted as the presence of some chestnut trees in the garden or at short distance from the site, as also confirmed by direct evidence (macro- and microremains) in neighbouring contexts (Allevato et al., 2016; Mariotti Lippi and Mori Secci, 1997). In the studied context of the villae, these pollen clumps can be regarded as a possible transport of soils containing flowers, especially chestnut and walnut trees, from outskirts and hilly areas, as interesting evidence of walnut cultivation and chestnut forest managed for timber

Table 3

– Floristic list from the pollen samples studied in this paper: comparison of the botanical elements of the Villa Arianna-VA, Villa San Marco-VSM, Civita Giuliana-CG, and Pompeii (HoM, HoC). A1-A2. Woody taxa, and B1-B2. Herbs from the pollen analyses.

A1	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii	A2	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii
Woody plants						Woody plants					
	<i>Abies</i>	x	x	x	x		<i>Ostrya carpinifolia/C. orientalis</i> type	x	x	x	
	<i>Acer campestre</i> type	x		x			<i>Phillyrea</i>	x			
	<i>Alnus</i> cf. <i>glutinosa</i>		x				<i>Pinus</i> cf. <i>halepensis</i>	x			
	<i>Alnus</i> undiff.	x	x	x	x		<i>Pinus</i> cf. <i>pinea</i>	x			
	<i>Betula</i>	x					<i>Pinus</i> undiff.	x	x	x	
	<i>Buxus</i>	x		x			<i>Platanus orientalis</i>	x	x	x	
	<i>Capparis</i>			x			<i>Populus</i>	x		x	
	<i>Castanea sativa</i>	x	x	x	x		<i>Prunus</i> cf. <i>avium</i>	x			
	<i>Corylus avellana</i>	x	x	x	x		<i>Prunus</i> undiff.	x		x	
	<i>Erica</i>			x			deciduous <i>Quercus</i>	x	x	x	x
	<i>Fagus sylvatica</i>	x					<i>Quercus ilex</i> type	x	x	x	
	<i>Fraxinus excelsior</i> type	x		x			<i>Rosa</i>	x		x	x
	<i>Fraxinus ornus</i>	x		x	x		<i>Rubus</i>			x	
	<i>Fraxinus undiff.</i>	x	x				<i>Salix</i>			x	x
	<i>Hedera helix</i>	x		x			<i>Tamarix</i>			x	
	<i>Humulus lupulus</i>	x		x	x		<i>Taxus baccata</i>	x		x	
	<i>Juglans regia</i>	x	x	x	x		<i>Tilia</i>		x		
	<i>Juniperus</i> type			x			<i>Ulmus</i>	x		x	
	<i>Morus</i> cf.	x					<i>Viburnum</i>	x	x		
	<i>Myrtus communis</i>	x	x	x			<i>Viburnum</i> cf. <i>tinus</i>	x	x		
	<i>Olea europaea</i>	x	x	x	x		<i>Vitis vinifera</i>	x		x	
B1	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii	B2	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii
Herbs						Herbs					
	<i>Alchemilla</i> type			x			<i>Melilotus</i>	x			
	<i>Allium</i> type	x		x			<i>Melilotus/Astragalus</i>	x			
	<i>Anagallis</i> type			x			<i>Mentha</i> type	x		x	
	<i>Anethum graveolens</i>			x			<i>Mercurialis</i>				x
	<i>Anthemis</i> type	x	x	x			<i>Muscari</i> cf. <i>comosum</i>			x	
	Apiaceae undiff.	x	x	x	x		<i>Onobrichys</i> type			x	
	<i>Apium inundatum</i> type			x			<i>Ononis</i> type			x	
	<i>Armeria</i>	x					<i>Orlaya grandiflora</i>			x	
	<i>Artemisia</i>	x	x	x	x		<i>Papaver rhoeas</i> type	x	x	x	x
	<i>Asparagus</i>	x					<i>Parietaria</i>	x			
	<i>Aster</i> type	x	x	x			<i>Pastinaca</i>			x	
	Asteroidae undiff.	x	x				<i>Peucedanum</i> cf. <i>austriacum</i>			x	
	<i>Atriplex</i> cf.	x					<i>Phragmites australis</i>	x			
	<i>Avena/Triticum</i> group			x			<i>Plantago lanceolata</i> type	x		x	
	<i>Beta vulgaris</i>	x		x			<i>Plantago major</i>	x		x	
	<i>Brassica</i> type		x	x	x		<i>Plantago</i> undiff.	x	x	x	
	Brassicaceae undiff.	x					Poaceae wild grass group	x	x	x	x
	<i>Bupleurum</i>			x			<i>Polygonum aviculare</i> type			x	
	<i>Callitriche</i>			x			<i>Potamogeton</i>			x	
	<i>Campanula</i>			x			<i>Potentilla</i> type			x	
	<i>Cannabis sativa</i>	x	x		x		<i>Prunella</i>			x	

(continued on next page)

Table 3 (continued)

B1	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii	B2	Pollen taxa	Stabiae - Villa San Marco (VSM)	Stabiae - Villa Arianna (VA)	Civita Giuliana (CG)	Pompeii
	<i>Carduus</i>		x				Ranunculaceae undiff.	x			
	Caryophyllaceae undiff.	x	x	x			<i>Ranunculus acris</i> type	x		x	
	<i>Centaurea nigra</i> type	x	x	x			<i>Reseda</i> cf. <i>lutea</i>			x	
	<i>Centaureum</i>	x					Rosaceae undiff.	x			
	<i>Cerastium</i> type	x		x			<i>Rumex</i>			x	
	Cerealia undiff.	x	x				<i>Ruta</i> cf.	x			
	Chenopodiaceae/ Amaranthaceae undiff.	x	x	x	x		<i>Saxifraga hirsuta</i> type			x	
	<i>Chenopodium</i> cf.	x	x				<i>Saxifraga stellaris</i> type			x	
	Cichorieae undiff.	x	x	x	x		<i>Saxifraga</i> undiff.	x	x		
	<i>Cichorium</i> cf. <i>intybus</i>	x					<i>Scabiosa</i>			x	
	<i>Cirsium</i>			x			<i>Scrophularia</i> type			x	x
	Cyperaceae			x	x		Scrophulariaceae undiff.	x			
	<i>Dianthus</i> type	x					<i>Secale cereale</i>	x			
	<i>Dipsacus</i>			x			<i>Silene vulgaris</i> type			x	
	Fabaceae undiff.	x	x				<i>Sinapis</i> type	x			
	<i>Filipendula</i>			x			<i>Solanum nigrum</i> type			x	
	<i>Galium</i> type	x		x			<i>Sparganium emersum</i> type			x	
	<i>Helianthemum</i>	x					<i>Stachys sylvatica</i> type			x	
	<i>Hordeum</i> group	x		x	x		<i>Stellaria</i> cf. <i>holostea</i>	x			
	<i>Hornungia</i> type	x		x	x		<i>Taraxacum officinale</i> type			x	
	<i>Hypericum perforatum</i> type	x		x	x		<i>Thalictrum flavum</i> type	x			
	Lamiaceae undiff.	x					<i>Torilis japonica</i> type			x	
	<i>Lathyrus</i> type			x			<i>Trifolium</i> type			x	x
	<i>Lemna</i>			x			<i>Typha latifolia</i> type	x			
	Liliaceae undiff.	x					<i>Urtica dioica</i> type	x		x	x
	<i>Linaria</i> type	x					Urticaceae undiff.	x			
	<i>Matthiola</i>		x				<i>Vicia</i> type	x		x	
	<i>Medicago</i>			x			<i>Xanthium</i>			x	

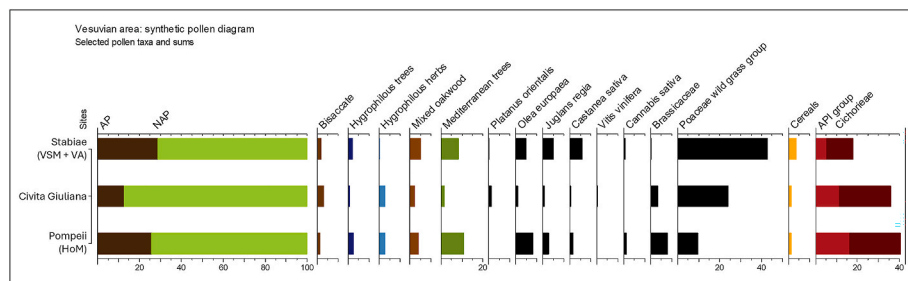


Fig. 6. – Vesuvian area: synthetic pollen diagram (selected taxa and sums) of the three sites: Stabiae (VSM + VA), Civita Giuliana-CG, and Pompeii (HoM; HoC was excluded from the elaboration due to the low pollen content). AP = Arboreal Pollen; NAP = Non-Arboreal Pollen. Pollen sums: Bisaccatae = *Abies* and *Pinus*; Hygrophilous trees = *Alnus*, *Populus*, and *Salix*; Hygrophilous herbs = Cyperaceae, *Phragmites australis*, *Sparganium emersum* type, and *Typha latifolia* type); Mixed oakwood = *Acer campestre* type, *Corylus avellana*, *Fraxinus excelsior* type, *Ostrya carpinifolia*/*Carpinus orientalis* type, deciduous *Quercus*, *Tilia*, and *Ulmus*; Mediterranean trees = *Erica*, *Fraxinus ornus*, *Myrtus communis*, *Olea europaea*, *Phillyrea*, *Quercus ilex* type, *Tamarix*, and *Viburnum*); vi) Anthropogenic Pollen Indicators (API group; Mercuri et al., 2013a) = *Artemisia*, *Centaurea*, Cichorieae, *Plantago*, *Urtica*, *Trifolium* type, and cereals (*Avena*/*Triticum* and *Hordeum* groups, and *Secale cereale*).

largely grown by Romans and their macroremains are common in Italian archaeological deposits (Bosi et al., 2020; Masi et al., 2024; Rowan, 2017), and in the countries of the Empire (e.g., Teira-Brión, 2022).

In VSM-2, walnut pollen is characterised by highly variable size, from <30 to >50 µm, which indicate different morphotypes of walnut (Fig. 4.D1, 4.D2). A brief exposure to heat can have a significant effect on the shape of the pollen grains, beginning with the swelling of most of them (Mariotti Lippi, 2024). However, this size variability is only observed in walnut pollen grains, and this suggests that different

cultivars were probably grown in the site. Pollen morphology can be useful to distinguish cultivars of *J. regia* (Acarsoy Bilgin, 2022), as well as cultivars of *O. europaea* (Messora et al., 2017) or different levels of polyploidy in wild and domesticated cereals (Mercuri et al., 2022). Considering the economic and cultural role of these species in the Roman culture, the hypothesis that a variety of walnut cultivars were present in Stabiae is suggestive and requires further investigation, also considering that today 'Sorrento walnuts', produced in the province of Naples, are among the most prized in the region. In the same site, it is

noteworthy also the finds of *Cannabis sativa* pollen, a textile plant processed in the Latium lakes (Mercuri et al., 2002) whose cultivation is attested for the Roman period in the Vesuvian plain along the Sarno river (Ciarallo, 2007). Probably, there was a small cultivation of hemp in the area surrounding the villas. In Roman times, hemp fibres were used to produce ropes, fishing nets or sails for ships (McPartland, 2020), which were most probably also crafted in the Stabiae area.

Among the non-arboreal pollen, Asteraceae and Fabaceae can be either linked to garden plants or suggests pastoral/livestock farming activities in the area.

Also pollen data from Civita testify to an open landscape witnessing a strong local human impact. The pollen spectra testify to a rich plant diversity with both cultivated/synanthropic taxa and natural elements that were present in the area. The good value of cereals in the spectra (*Avena/Triticum* and *Hordeum* groups) suggests the local cultivation of wheat and barley or the presence/processing of cereals in the housing complex. Also, Brassicaceae were probably cultivated as vegetable plants because their pollen is almost ubiquitous in the samples from the farmland surrounding the villa. Cabbage cultivation by the Romans from the 1st century BC onwards is already attested by palynological studies (Grüger et al., 2002; Mariotti Lippi, 1993; Mariotti Lippi and Bellini, 2006; Montecchi and Mercuri, 2018; Russo Ermolli and Messenger, 2013; Russo Ermolli et al., 2014). Vignola and colleagues (2022) suggest an earlier cultivation (4th-3rd centuries BC?) and their pollen data show high percentages of Brassicaceae (especially *Brassica oleracea* L.) pollen as a strong indication of the local presence of vegetable gardens. Data suggest that cultivated plants in CG were also ornamental (e.g., *Platanus orientalis* and *Myrtus communis*) or fruit trees (e.g., *O. europaea*, *Corylus avellana*, *Prunus*, and *J. regia*).

Accordingly with the particular type of samples, plasters collected at the HoC e HoM of Pompeii trapped few pollen, and their amount was higher in the "trap" placed horizontally (floor in HoM) than in the vertical-oriented surface (wall in HoC). Plasters acted as pollen traps for the flora of the Vesuvian area, and pollen assemblages represent a snapshot of plants diversity in AD 79 that may include surrounding vegetation and garden plants as primary sources. However, the low pollen content supports interpretation based on qualitative rather than quantitative data. Pollen mainly reflects Mediterranean flora with olive trees, which should have been common in the nearby natural Mediterranean macchia, or in olive orchard (Langgut et al., 2019; Mercuri et al., 2013b) or in the gardens within the city walls (Ciarallo, 1992; Jashemski, 1993; Mariotti Lippi and Bellini, 2006; Mariotti Lippi and Mori Secci, 1997). Jashemski (1979) also reports a higher presence of olive pollen in soil samples from "The Garden of Hercules at Pompeii", which suggests that *O. europaea* was cultivated in Pompeii. Also, the peltate leaf hair of olive in HoC supports that these fruit trees were also grown on site (Fig. 4.G1). Indeed, chestnut pollen probably largely arrived from the Vesuvius' foothills (Di Pasquale et al., 2010; Allevato et al., 2012). Pollen grains of chestnut were also found in gardens and on tiles at Pompeii (Mariotti Lippi and Mori Secci, 1997).

The pollen spectra obtained are compatible with the pre-eruption period because no pollen from exotic plants were found (differently from the evidence reported by Langgut et al., 2024), which could suggest modern restorations (post 15th century AD).

The evidence of *Glomus*, a mycorrhizal fungus abundant in soils with strong erosive phenomena or with intense anthropic tillage (Revelles and van Geel, 2016), seems to be linked to the arrival of the spores following the installation on the wall.

4.3. Palaeoethnobotany from pollen

The eruption of Vesuvius in AD 79 destroyed the Vesuvian area with many villas, but at the same time made these sites a unique source of information on many aspects of the everyday life of Roman people including plant uses. In our palynological studies, main features common to the studied contexts are fruit trees such as, e.g., olive, walnut,

chestnut, and grapevine and ornamental plants, both elements that characterised the rich cultural landscape of the area. Indeed, this is what was described in *De Rerum Natura* by the ancient poet Lucretius, who praised the way people had beautified the whole land by planting here and there.

The palynological research carried out in the Casti Amanti building complex, in Pompeii, point out to the use of several plants growing in the natural environment surrounding the city as ornamental species in the gardens (Ciarallo and Mariotti Lippi, 1993; Mariotti Lippi, 1998; Masi et al., 2024). Among them, pollen from Stabiae and Civita showed that evergreen Mediterranean trees and shrubs (e.g., pine and myrtle) were grown in the VSM, VA, and CG gardens. This is in agreement with other data from the area (Mariotti Lippi and Bellini, 2006) and testifies both the favourable environmental conditions of the Vesuvian area and cultural choices in implanting the garden. Other plants (e.g., box, rose, and yew) are known to have been common in gardens, and shrubs could have been grown as decorative hedges modelled using the 'topiary art' widely known to the Romans. The *topiarii*, specialised gardeners and designers, not only fashioned trees and shrubs into geometric shapes, different from those naturally assumed by the plants, but also bred the species into cultivars (e.g., myrtle and cypress; Tally-Schumacher, 2022) as important signs of wealth for the Roman aristocracy. However, there is no clear evidence of topiary art, and probably it was rare in Pompeii. It was likely common in wealthy Roman households during the 1st century AD, but it had not yet reached Pompeii, a commercial provincial town. Roses could also have been elements of the green decoration of the domus.

To support these inferences, it is also important to consider the nature of pollen grains for each taxon identified and the type of pollination adopted by the species. Pollen from plants that are pollinated by insects usually does not travel far from its source. So, plants that are characterised by low pollen-dispersal efficiency, like myrtle and rose (both entomophilous plants), probably grow in the gardens and the presence of their pollen is not associated with long-distance transport. We can assume that these plants were cultivated in gardens, although their pollen has almost always been observed in small quantities.

Oriental plane was probably planted as a shade tree (Rosati et al., 2015). At Stabiae, Villa San Marco, "two rows of large root cavities on each side of the pool are thought to be those of plane trees. The imprint of a leaf found in the volcanic ash was cast in cement and it has the appearance of a plane leaf" (Jashemski, 1993 p. 306). Root casts indicating the presence of plane trees were found in Pompeii, particularly numerous in the Great Palestra (see Jashemski, 1993 p. 92). Plane tree pollen was also found at S. Abbondio (Mariotti Lippi, 1993). The common presence of this tree in the gardens of Roman villas is suggested also by wall paintings and mosaics (Jashemski et al., 2002) and written sources. In fact, Roman authors (e.g., Ovid, Virgil, Martial, Pliny the Elder, Cicero, and Petronius) reported on plane tree as a kind of *genius loci*, the protective spirit of a place (Curbera and Galaz, 1995). The same evidence has already been described in many sites in Naples (Grüger and Thulin, 1998; Grüger et al., 2002; Russo Ermolli et al., 2014) and in sites destroyed by the AD 79 eruption in the Vesuvian area that show a sporadic but fairly continuous presence of *P. orientalis* (Jashemski, 2012; Mariotti Lippi, 2000; Mariotti Lippi and Bellini, 2006; Mariotti Lippi and Mori Secci, 1997; Moser et al., 2013).

Similar pollen spectra resulted from the plasters installations facing the Great Peristyle Garden at Villa Arianna, which shows a high diversity of taxa related to the humid Mediterranean environment and the Mediterranean forest (Langgut, 2022b). It is not easy to distinguish the outdoor environment from the floristic components of the garden because pollen from wind-pollinated plants may have arrived in the garden from distant sources. The new data from the VA peristyle garden samples provide further details on the natural floristic composition and possible ornamental and utilitarian plants. The high pollen percentages (up to 20.8%) of walnut, a wind-pollinated species characterised by a very low pollen dispersal efficiency (Bottema, 2000; Langgut, 2015),

reflect the presence of this species in the garden, as previously suggested by Langgut (2022b). It can be also suggested that mulberry, another woody plant cultivated for its fruit in Italy during the Roman time (Bosi et al., 2015, 2020), was planted in VSM, even pollen was only observed in traces. *Morus nigra*, native to Western Asia, was quickly adopted and cultivated for its fruit in the Mediterranean area (Gelorini and Bourgeois, 2005), so much so that it was described by Pliny the Elder in *Naturalis Historia* (AD 77) as *sapientissima arborum*, the wisest of trees.

It is not always easy to trace the genus/species of herbaceous plants, and this makes it complicated to identify the presence of herbs cultivated as ornamental or vegetable garden plants. However, species of the cabbage and daisy family may also have been cultivated as ornamentals in the garden. Pollen of *Matthiola* was present in VA of Stabiae; this genus includes species of flowering plant with ornamental values for a richness of shapes and colours. The early presence of this type of pollen leaves open the possibility of whether it was grown in the garden or transported from the coastal area of the Gulf of Naples: *M. sinuata* (L.) W. T. Aiton is characteristic of the marshy and sandy coastal environment of the Italian regions bordering the Tyrrhenian Sea (Portal to the Flora of Italy, 2024).

In addition, there are many taxa in the pollen spectra (e.g., *Artemisia*, *Plantago*, and *Urticaceae*; Table 3) that represent ruderal plants, common in urban contexts, growing at the edge of gardens (Mercuri et al., 2013a). *Artemisia* includes hardy herbaceous plants and shrubs, usually growing in arid or semi-arid habitats. Pollen, observed in all the contexts investigated, could also originate from sandy coastal vegetation. In particular, *A. caerulea* L. is a species native to Mediterranean Europe, which grows in coastal saline environments of the Italian peninsula and Sardinia (Portal to the Flora of Italy, 2024). Over the centuries, the *Artemisia* species have been linked to a number of therapeutic and cosmetic benefits (Polito et al., 2024), and some of them have also been cultivated.

5. Conclusions

Much is known about the food plants of the Vesuvian area during the 1st century AD thanks to the long history of archaeobotanical studies in the area (e.g., Murphy et al., 2013; Rowan, 2017). The exceptional state of preservation of plant remains from the ancient cities destroyed by the catastrophic eruption of Mt. Vesuvius in AD 79 tells us of the presence of a great plant diversity and a wealth of food, confirmed by figurative, historical, and written sources (Ciarallo, 2019; Jashemski et al., 2002). Palynological studies have also contributed to this knowledge (e.g., Langgut, 2022b; Mariotti Lippi, 2000; Vignola et al., 2022), although the state of preservation of pollen sometimes prevents useful information from being obtained. Indeed, palynological research requires, as and more than other findings, a deep knowledge of the sources of the finds, as problems of conservation and interpretation make their study more complex.

Based on the new data from forty pollen samples studied from three sites in the Vesuvian area (the two multipoint sites of Stabiae and Pompeii and the Civita Giuliana site), similarities and dissimilarities emerged from the different contexts highlighting local biodiversity and landscape patterns.

Main details can be summarised as follows.

- Pollen spectra from the Stabiae *villae* attest to a significant plant diversity and delineate a strongly anthropised open landscape with tree cultivation (olive, walnut and chestnut trees were prevalent) and presence of cereal crops in a Mediterranean landscape.
- Also pollen data from Civita Giuliana testify to an open landscape with strong human impact; pollen assemblages are characterised by both natural and synanthropic taxa, that witness human activities such as cereal-growing and local presence of vegetable gardens, with also ornamental or fruit trees.

- Similarly, pollen from plasters of the installations facing the garden of the Pompeii houses (HoM, HoC) attests to diversity of taxa related to the Mediterranean environment surrounding the city as well as to the ornamental species in the gardens. Again, fruit trees are well documented as evidence of their important role in the cultural landscape of the area.

In this study, pollen collected from three Vesuvian sites provides further details on plant composition of the Roman gardens (ornamental and utilitarian plants), but also testifies to the past plant diversity in the area and gives new insights on the natural landscape of the area right before the catastrophic Vesuvius eruption.

CRedit authorship contribution statement

A. Florenzano: Writing – review & editing, Writing – original draft, Validation, Investigation, Data curation. **P. Torri:** Writing – original draft, Methodology, Formal analysis. **G. Bosi:** Writing – original draft, Methodology. **E. Clò:** Writing – review & editing, Writing – original draft, Visualization, Validation, Data curation. **P. Caprio:** Methodology, Formal analysis. **A.M. Mercuri:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization.

Data availability

All the data is included in the article and available on request.

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.

Acknowledgements

We are grateful to Marta Mazzanti for analysing pollen samples from Pompeii plasters and for contributing to the study of Civita Giuliana samples; thanks also to Carla Alberta Accorsi for supporting pollen analyses of Stabiae samples. The use of the data of Civita Giuliana was communicated to Maria Rispoli (Ufficio UNESCO Sito 829) and Valeria Amoretti (Tutela del Patrimonio Culturale - Beni Demoetnoantropologici) by e-mail in January 2024.

The authors thank Stefano Lugli and Giulia Tirelli for involving LPP in the analysis of Pompeian plasters (provided by Maria Stella Pisapia and Antonella Corralini).

Warmful thanks to Grete Stefani for her precious support during the sampling at Civita Giuliana. Many thanks also to Luigi Buffone and Vincenzo Sabini for their active contribution to the sampling in the *villae* of Stabiae.

The position of E.C. was funded by the project “National Biodiversity Future Center—NBFC”, implemented under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4—Call for tender No. 3138 of December 16, 2021, rectified by Decree n.3175 of December 18, 2021 of Italian Ministry of University and Research funded by the European Union—Next Generation EU. Project code CN_00000033, Concession Decree No. 1034 of June 17, 2022 adopted by the Italian Ministry of University and Research, CUP E93C22001090001.

We also express our sincere thanks to Prof. Gaetano Di Pasquale and Alessia D’Auria (University of Naples “Federico II”) and the Organizing Committee of the Conference “79 d.C., Il contributo della botanica alla più grande avventura archeologica della storia” (Reggia di Portici, Naples, 22–24 June 2023) that gave us the opportunity to present this study.

We thank the anonymous reviewers, whose comments helped

improving the clarity of the manuscript.

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