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The Fathers' cell gardens of the Charterhouse of Calci-Pisa in Tuscany (Central Italy): pollen and multidisciplinary reconstruction

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***Abstract* – The archaeological investigation of the Charterhouse of Calci-Pisa (Central Italy) is a research project launched in 2018 by a multidisciplinary team of the University of Pisa. Three different monks' gardens (the Prior's, the Apothecary's, and the Master's garden) have been investigated. The study focused not only on their structural transformations, evidenced by flowerbeds, pools, and fountains, but also paid special attention to pedological variations, plants diversity (114 pollen taxa), and the presence of root systems, animals, and microorganisms, to detail changes in use, such as the succession of crops and fertilisation practices. Palynological and archaeobotanical results allowed us to reconstruct the succession of seasons in the gardens, with colourful and fragrant flowers, ornamental, aromatic, medicinal herbs, and fruit trees. The gardens seem to have a functional space organisation strictly related to the monks' peculiar kind of life, their personalities and feelings, and their relationship with nature and divinity.**

***Keywords* – pollen; biodiversity; Medieval Age; landscape reconstruction; garden archaeology; monastery; multidisciplinary approach**

I. INTRODUCTION

Palynology is the science that studies pollen and spores within sediments to reconstruct the history of vegetation and its interaction with environmental and climatic changes and human activities. The application of palynological analysis in archaeological deposits (Archaeopalynology) provides evidence on socio-economic practices (crops, harvested plants, storage), the special use of space within settlements, the relationship between humans and plants, and people's deep knowledge of the plant diversity and properties. Palynological research from gardens offers an opportunity to investigate the traces of the use and introduction of plants. In these contexts, pollen analysis is mainly carried out on sediment samples, but there are also exceptional cases involving the extraction of pollen from plaster attached to structures that face the garden [1]. Previous studies have revealed the great potentiality of this approach to reconstruct details of horticultural trends during Roman times (Villa Arianna-Stabiae in Italy and gardens of Herod the Great-Judea in Israel [1]; Casa dei Casti Amanti-Pompeii [2]) or in Medieval and Renaissance times (Giardino delle Duchesse-Ferrara [3,4]).

The interdisciplinary archaeological research (pollen, anthracological, and carpological analyses) referred to in this paper is primarily aimed at understanding the plant diversity of monks' gardens and horticultural practices in courtyards and orchards implemented during the centuries of occupation of the Certosa di Calci near Pisa, Tuscany-Italy [5]. The Charterhouse of Calci construction began by the end of the 14th century at the behest of the Archbishop of Pisa in a secluded place called Vallis Gratiosa, chosen to foster the Rule of the Carthusian Order, which combined manual labour with solitude and contemplation [6,7]. The monastery was dedicated to the Virgin Mary and St. John the Evangelist. In the second half of the 15th century, new cells and green spaces were built. In 1972, the monks left the Charterhouse of Calci following the closure of the monastic community a few years earlier. Afterwards, the National Museum of the Monumental Charterhouse of Calci was established and managed by the Ministry of Cultural Heritage. In 1979,

the complex was partially entrusted to the University of Pisa, housing the Museum of Natural History.

Charterhouses were intertwined in a complex network of relationships between people, plants, and the environment. For most of the day, Carthusian monks live in their cells, praying, studying, eating, working, and sleeping. However, the word "cell" should not mislead: it is, in fact, a real little house with a garden. Gardens represented spaces for meditation with a relevant role in hermitic life. They were a space of balance between monastic life and the plant world, expressing individual monks' feelings and relationships with nature and divinity [8,9].

We present here what emerged from palynological and archaeobotanical analyses of the gardens of the Father Prior's, the Father Apothecary's, and the Father Master's cells of the Charterhouse of Calci (PG, AG and MG, respectively; **Fig. 1**). The study of pollen and plant macroremains has provided information on the appearance of each garden, ornamental species planted in the gardens, their changes throughout time, and their connections with the local environment.

Fig. 1. Location map of the Charterhouse of Calci-Pisa (Tuscany-Central Italy). Fathers' gardens: PG=Father Prior's Garden, AG=Father Apothecary's Garden, and MG=Father Master's Garden.

II. MATERIALS AND METHODS

Since 2018, interdisciplinary archaeological research has focused on three different monks' gardens (the Prior's Garden, the Apothecary's Garden, and the Master's Garden), in which six sectors have been excavated: i) two areas in the Father Prior's Garden (PG), ii) one area in the Father Apothecary's Garden (AG), and iii) three areas in the Father Master's Garden (MG).

A. Pollen

A total of 12 samples were collected from organic layers excavated in the three monks' gardens: 4 samples from the PG (CerC1-CerC4), 3 from AG (CerC5-CerC7), and 5 from MG (CerC8-CerC12).

Pollen was extracted from samples according to the routine method in use in the Laboratory of Palynology and Palaeobotany of Modena-LPP [10,11]. *Lycopodium* spore tablets were added to calculate concentration (pollen per gram = p/g). The extraction treatment involved sieving and heavy liquid flotation with sodium metatungstate hydrate. Pollen was identified under a light microscope at 400x and 1000x magnification with the help of atlases/keys (e.g., [12,13]) and the LPP reference pollen collection. The pollen diagram was drawn with Tilia 3.0.1 [14].

B. Plant macroremains

Charcoal and seed/fruit analyses were performed on 11 SUs from the PG, 8 from the AG, and 8 from the MG. Each sample was obtained by sieving the sediment in water with a mesh size larger than 1 mm.

Anthracological analysis focused on charcoal fragments larger than 2 mm. Charcoals were identified under a reflected light microscope at 100x, 200x and 500x magnifications by referring to wood anatomy atlases [15-17]. Carpological analysis was carried out under a stereomicroscope at magnifications from 0.5x to 20x. Records were separated from fragments, and each category was identified and subdivided by carpological type based on morphology [18].

III. RESULTS

A. Pollen

At least 300 pollen grains were counted for each sample, for a total of about 3650 pollen grains. A mean of approximately 40,000.00 p/g was found on average in the samples. All over the spectra, the number of pollen taxa is 114 (34 taxa of Arboreal Pollen-AP and 80 of Non-Arboreal Pollen-NAP; **Table 1**; **Fig. 2**), ranging between 24 and 57 pollen taxa per sample. The arboreal plants characterise almost 1/6 of the spectra (AP=15.4% on average), while non-arboreal plants are prevalent in all samples (NAP=86.6%). Among trees, pollen of deciduous *Quercus* (2.4%), *Castanea sativa* (1.5%), and *Alnus* (1.1%) are prevalent, together with shrubs of Ericaceae (1%), *Corylus* (1%), and traces of *Vitis*. Inaperturate *Vitis* pollen grains were observed in the Father Apothecary's Garden (0.3% and 0.9% in samples CerC6-CerC7) and in in the Father Master's Garden (0.3% in sample CerC11). Asteraceae (28.8%, prevalently Cichorieae), and some herb plants belonging to wild Poaceae (8.3%), Apiaceae (6.6%, including *Apium*), Cheno-Amaranthaceae (2.7%), *Plantago* (4.5%), *Ranunculus acris* type (4.1%), Cyperaceae (3.2%), *Urtica* (2.5%), Brassicaceae (2.4%), Rosaceae (2.3%, including *Rosa*), *Anagallis* (2%), Fabaceae (2%), and Caryophyllaceae (1.9%). Cereals are present with *Hordeum* group (0.8%) and *Avena/Triticum* group (0.2%). *Cannabis* is also present in traces (**Fig. 3**).

Table 1. Pollen list of Arboreal Pollen and Non-Arboreal Pollen from the fathers' gardens. The presence of a pollen taxon is indicated by "x".

	Fathers' gardens		
	PG	AG	MG
Juniperus type		x	x
Abies			x
Pinus	x	x	x
Sambucus nigra	x	x	x
Hedera helix	x	x	
Berberis	x	x	x
Alnus cf. *viridis*			x
Alnus undiff.	x	x	x
Carpinus betulus			x
Corylus avellana	x	x	x
Ostrya carpinifolia/Carpinus orientalis type	x		x
Humulus	x		
Cistus		x	x
Erica	x	x	x
Castanea sativa		x	x
Fagus sylvatica		x	x
Quercus deciduous undiff.	x	x	x
Quercus ilex		x	x
Juglans	x		
Tilia		x	
Myrtus		x	
Fraxinus excelsior type	x		
Fraxinus ornus		x	x
Jasminum			x
Olea europaea	x		x
Syringa	x	x	x
Rosa type	x	x	x
Populus		x	x
Salix	x	x	
Acer campestre type		x	
Tamarix	x	x	x
Ulmus		x	x
Vitis vinifera	x	x	x
Vitis (inaperturate pollen)		x	x
Amaranthaceae/Chenopodiaceae	x	x	x
Allium cf.	x		
Apium		x	x
Daucus carota type	x		x
Peucedanum		x	x
Apiaceae undiff.	x	x	x
Aristolochia cf.	x		
Artemisia	x		
Aster type	x	x	x
Carduus		x	
Centaurea nigra type	x	x	x
Cichorieae	x	x	x
Cirsium		x	x
Asteraceae undiff.		x	
Biscutella type	x		
Brassica type	x	x	x
Hornungia type	x	x	x
Raphanus	x		
Thlaspi type	x		
Campanula			x
Cannabis			x
Herniaria type	x	x	x

	Fathers' gardens		
	PG	AG	MG
Caryophyllaceae undiff.	x	x	x
Helianthemum	x	x	x
Convolvulus	x	x	x
Sedum	x	x	x
Scirpus lacustris	x	x	x
Cyperaceae undiff.	x	x	x
Dipsacus	x	x	
Mercurialis		x	
Euphorbiaceae undiff.	x		
Astragalus	x		
Dorycnium		x	x
Lotus		x	
Trifolium	x	x	x
Vicia/Lathyrus		x	
Fabaceae undiff.	x	x	
Geranium type	x	x	
Hypericum	x	x	
Mentha type	x		x
Salvia		x	x
Lamiaceae undiff.	x	x	x
Liliaceae	x		
Malva		x	x
Nuphar	x		
Nymphaea alba type	x		
Oxalis	x		
Fumaria			x
Papaver	x	x	
Linaria		x	
Plantago lanceolata type	x	x	x
Plantago media type		x	
Plantago undiff.	x	x	x
Avena/Triticum group	x	x	
Cerealia undiff.		x	
Hordeum group	x	x	x
Phragmites australis	x	x	
Poaceae wild grass group	x	x	x
Polygonum aviculare type	x		x
Rumex	x		x
Anagallis	x	x	x
Cyclamen			x
Primula	x	x	x
Polygala	x		
Adonis	x		
Helleborus	x		x
Ranunculus acris type	x	x	x
Ranunculus parviflorus		x	
Thalictrum	x	x	x
Aphanes/Alchemilla type	x		
Filipendula	x	x	x
Potentilla	x		
Rosaceae undiff.	x	x	x
Saxifraga hirsuta type	x	x	x
Solanum	x	x	
Sparganium emersum type	x		x
Typha latifolia type	x	x	x
Urtica dioica type	x	x	x
Urtica cf. *pilulifera*	x	x	x
Valerianella		x	

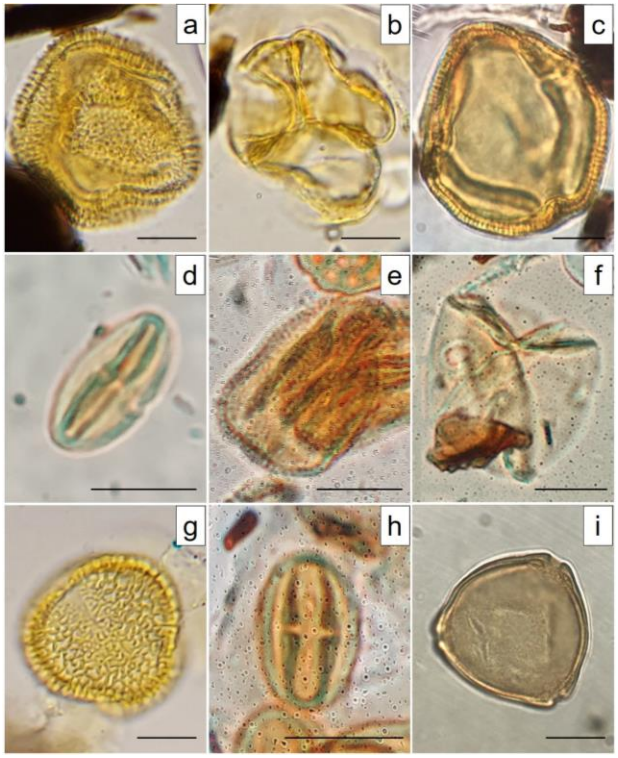

Fig. 2. Charterhouse of Calci-Pisa: pollen microphotographs under light microscope. (a) Geranium *– 38 µm, (b)* Erica *– 37 µm, (c)* Helianthemum *– 45 µm; (d)* Apium *– 15 µm, (e)* Mentha *– 23 µm, (f)* Cannabis *– 31 µm; (g)* Olea *– 25 µm, (h)* Castanea *– 13 µm, (i)* Corylus *– 26 µm. The scale is 10 µm.*

B. Charcoals

Charcoal analysis includes 2159 charcoals (among which 2003 determined records) belonging to 31 taxa (for the complete list of taxa, look at the figure 4 in [5]). Uncultivated plants are prevalent (81.9%). *Quercus* cf. *cerris*, *Fraxinus* cf. *ornus*, *Fagus sylvatica*, *Ulmus* and *Ostrya carpinifolia* are dominant among deciduous broadleaved trees (32.7%). Evergreen sclerophyllous plants (21.4%) are mainly represented by *Quercus* cf. *ilex*, *Rhamnus/Phillyrea*, *Erica*, *Arbutus unedo*, and *Smilax*. *Pinus halepensis/pinaster* (16.2%) is the only conifer tree. Riparian environments are represented by *Fraxinus* cf. *angustifolia* and *Alnus*. Cultivated plants (18.1%) are dominated by *Castanea sativa* (up to 19.8% in the PG), together with *Olea europaea*, *Juglans regia*, *Prunus* cf. *dulcis*, and *Vitis vinifera*.

C. Seeds/fruits

Carpological analyses identified 9 taxa belonging to cultivated fruit plants, *Corylus avellana*, *Olea europaea*, *Malus/Pyrus*, *Prunus avium*, *P. persica*, *Vitis vinifera*, and arable crops, *Triticum aestivum/durum*, *Triticum* sp., and *Vicia* sp.

IV. DISCUSSION

The interdisciplinary archaeological, palynological, and archaeobotanical data allow us to highlight the composition and seasonality of the gardens and the choice of specific plants and flowers adopted by the Carthusians during the centuries of occupation of the Charterhouse. The obtained data show the strongly anthropogenic nature of the gardens, with a wide variety of cultivated herbaceous and woody plants. For this

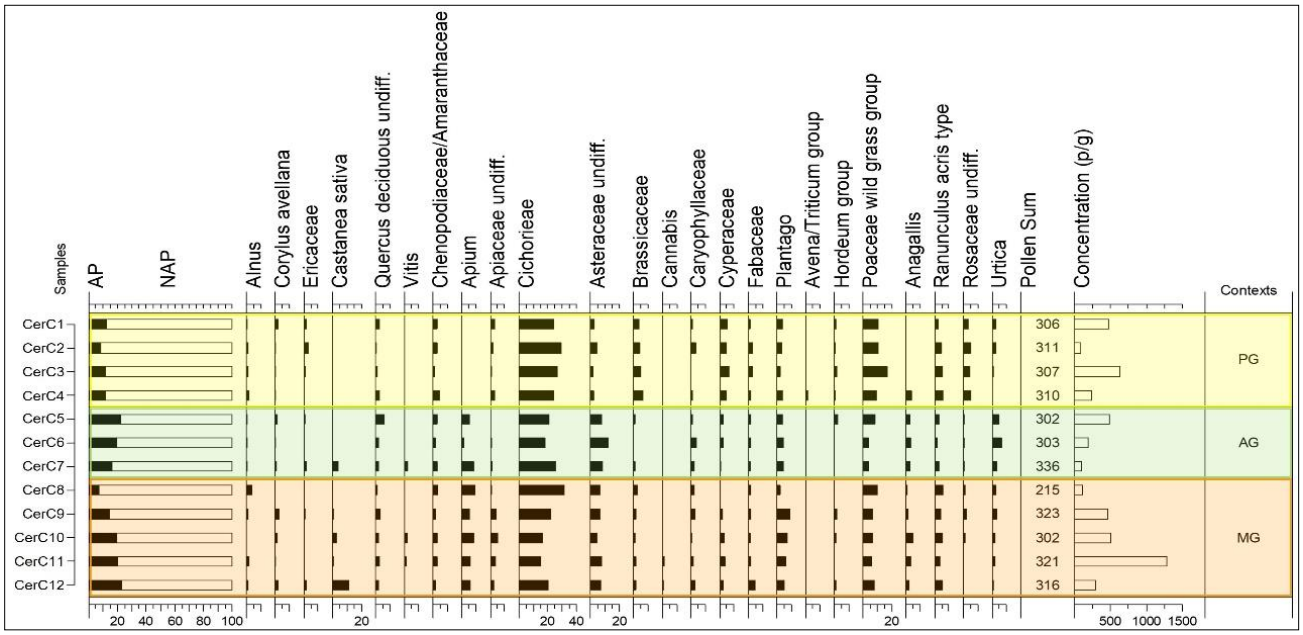

Fig. 3. Charterhouse of Calci-Pisa: synthetic pollen diagram (selected taxa and sums) of the fathers' gardens (contexts: PG=Father Prior's gardens, AG=Father Apothecary's Garden, and MG=Father Master's Garden)

reason, an attempt has been made to divide the plants that characterise gardens into three main groups, discussed in the following paragraphs.

A. Smell and colour of flowers

Palynological analyses of the fathers' gardens have returned significant microscopic biodiversity indicative of showy flowers with beautiful colours and pleasant fragrances. The colour and fragrance of flowers pervaded the gardens and help create the atmosphere of quiet essential to religious life. The Father Prior's Garden was especially characterised by the different presence of flowering and ornamental plants in each season. This garden was probably characterised by a selection of Rosaceae with different colours, such as the pale green-yellow of parsley-piert/lady's mantle (*Aphanes/Alchemilla*), the white of meadowsweet (*Filipendula*), the yellow of *Potentilla* (cinquefoils), and the pink of *Rosa* (rose), the latter possibly planted as hedges and appreciated for their intense fragrance. Other flowering plants with different seasonal blooms were chosen to beautify the garden, for example, *Adonis* (pheasant's eye), *Anagallis* (pimpernel), *Oxalis* (yellow sorrel), *Geranium* (dovefoot geranium), *Papaver* (poppy), and *Polygala* (milkworts) in summer, *Primula* (primrose) and Liliaceae s.l. (lily) in spring, and *Helleborus* (hellebores) in winter. In addition to ornamental grasses, Mediterranean shrubs that produce beautiful and long-lasting flowers in summer have been selected, including especially *Cistus* (cistus), *Helianthemum* (rock rose), and *Erica arborea* (heather). *Herniaria* (rupturewort), *Saxifraga* (saxifrages), and *Sedum* (stonecrops) probably adorned the walls with pretty flowers.

From the mid/second half of the 18th century, the Father Prior's Garden became wetter, as documented by the increased presence of hygrophilous herbs - Cyperaceae, *Sparganium emersum* type, and *Typha latifolia* type. In this context, beautiful water lilies - *Nymphaea alba* and *Nuphar* - probably adorn an octagonal fountain flanked by two rectangular basins [5,8].

B. Medicinal and aromatic plants

Pollen records also attest to daily horticultural activities, evidenced by food, aromatic and medicinal plants, which especially characterised the Father Apothecary's Garden. Here, plants such as *Salvia* (sage), *Malva* (mallow), *Hypericum* (common Saint-John's wort), and *Papaver* could be wild or cultivated and selected for their medicinal properties. In the case of *Salvia*, for example, it is well known that *S. officinalis* has anticancer, anti-inflammatory, antinociceptive, antioxidant, antimicrobial, antimutagenic, antidementia, hypoglycemic, and hypolipidemic effects [19]. Among Apiaceae, an interesting medicinal and food plant family, *Apium graveolens* (celery) was probably cultivated for cooking, medicinal purposes, and preparing digestive and diuretic infusions. The presence of *Peucedanum* (hog's fennel) could also testify to the preparation of medicinal products for cardiopulmonary diseases and microbial infections or liqueurs [20]. In other families, *Valerianella* (lamb's lettuce), a variety of salad greens, and *Cirsium* (common thistle), sometimes used in cooking as an artichoke, were probably cultivated for food. In addition to the species that characterised the Father Apothecary's Garden, *Mentha* (peppermint) and *Cannabis* (hemp) were present in the Father Master's Garden and were probably used for their health beneficial properties.

C. Arboriculture

Woody plants were mainly represented by shrubs with beautiful blooms, such as lilacs and heaths, and autumn fruits such as hazelnuts and chestnuts. *Corylus*, as well as *Olea*, *Vitis*, *Juglans regia* (walnut), *Prunus* cf. *dulcis* (almond), *Malus/Pyrus* (apples/pears), and *Prunus persica* (peaches), may have been cultivated for fruits in the gardens. However, the high presence of chestnut pollen, documented in the Father Master's Garden, could testify to the use of organic acidic soils collected from the surrounding hills and transported to the garden as fertiliser in gardening practices. A noteworthy aspect is the recovery of inaperturate *Vitis* pollen considered an indication of the local presence of wild grapevine with functionally female flowers [21]. The presence of both trizonocolporate and inaperturate pollen grains is a rare record in archaeological samples and in this context it could be interpreted as the breeding of wild vines as a deliberate choice of the monks in garden greening. The ornamental use of this species was probably the same as that of other common climbing plants (*Hedera helix* and *Jasminum*) which probably covered the perimeter walls.

V. CONCLUSIONS

Archaeological, palynological, and archaeobotanical data from the analysis of the cell gardens of the Charterhouse of Calci-Pisa allowed us to describe the care of green spaces as a fundamental aspect of Carthusian monastic life. In Carthusian monasteries, gardens were not just places used for manual labour but, more properly, spaces for meditation and spiritual care. Here the high plant diversity is represented by 114 pollen taxa. The thoughts, choices, and actions of individual monks are evident in the organisation of the gardens. The intended use of the gardens is particularly evident in the choice of ornamental plants with their flowers, colours, and fragrances different for each season, the presence of plants used for medicinal purposes, cooking and preparing infusions, and fruit plants that supplemented the diet of the inhabitants of the Charterhouse. However, rejecting an exclusively anthropocentric view, the gardens arise from an intricate network of human and non-human connections.

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