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# Mummy Labels: A Witness to the Use and Processing of Wood in Roman Egypt

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## Abstract

Mummy labels are relics found in large quantities in Egypt, often in an excellent state of preservation (like most woods preserved in arid environments). As a result, they are widespread in Roman Egyptian collections of many museums. These labels reflect funerary practices that possess Egyptian and Roman influences and are an important

source of historical and archaeological information. These corpora of mummy labels offer several possibilities for investigation. The inscriptions on these labels have been the subject of an international project (Death on the Nile) in which all accessible objects were recorded in a database. However, the potential of these funerary objects extend beyond the inscriptions to the methods of manufacturing and cutting, the choice of species used, and their dendrochronological potential to better define their chronology and possibly their provenance. The study of mummy labels allows us to propose a new typology, some forms of which seem to be limited to certain necropolises. Mummy labels, whether made by the family of the deceased or by specific workshops, show that their realizations vary greatly, ranging from coarse specimens to others with beautiful detailing. They are made from endemic as well as imported species, which are symbolic of long-distance trade, especially for conifer trees, which are well represented. Their dendrochronological potential has also been demonstrated in numerous studies, some of which have allowed the identification of labels from the same tree, supported by inscriptions attesting to the same family relationship.

### Keywords

dendrochronology – endemic and imported wood – funeral practice – provenance – typology

## 1 Introduction

Archaeological wooden artifacts from Egypt are generally in a good state of preservation because of the arid environment in which they are found (Bouchaud *et al.* 2018) and thus constitute a perfect corpus to be studied. Although most wooden artifacts from Egypt are from funerary contexts, sometimes they also relate to a range of aspects such as domestic, public, or artisanal life (Gale *et al.* 2000). Their analysis, whether technological, typological, xylological, or dendrochronological, can provide valuable insights on cutting and shaping techniques, uses, deliberate or random selection of species, whether endemic or imported, and the provenance of wood, in addition to chronological, environmental, and climatic insights. Trees are natural archives whose growth rings store valuable environmental information that can then be linked to the societal context in which they are felled (Creasman 2015).

The study of historical wooden objects and timber from Egypt has focused on several periods of the past, mostly Pharaonic, and was restricted primarily to the analysis of inscriptions on wooden artifacts (Asensi Amoros 2003).

However, despite the remarkable state of preservation of archaeological wood in Egypt, virtually no research has been undertaken to investigate the functional and technological uses of wooden objects. Likewise, the current knowledge on tree species that were selected and harvested in Egypt remains rather fragmentary. Species identification was based on textual sources before applications were extended to identifications based on wood anatomical observations. Recently, the study of numerous collections of wooden objects has offered insights into the main species used in Egypt, explaining the relevance of timber imports from other, sometimes distant, territories (Asensi Amoros 2003; Asensi Amoros & Détiennes 2008; Bouchaud *et al.* 2018; Cartwright 2021).

Likewise, dendrochronological studies relying on timber and objects from ancient Egypt have hitherto mainly yielded floating tree-ring chronologies (Kuniholm *et al.* 2014; Creasman *et al.* 2015), mostly built from imported timber. The focus has been on conifers, particularly cedars (*Cedrus* sp.), as their annual rings are clearly visible and are relatively easy to measure. In contrast, endemic species from Egypt have received minimal attention because of their complex ring structures (Cichocki *et al.* 2004; Cichocki 2006). Some of the Greco-Roman (332 BCE–395 CE) material found in Egypt has been compared with floating oak (*Quercus* sp.), cedar (*Cedrus* sp.), and juniper (*Juniperus* sp.) chronologies from the eastern Mediterranean (Kuniholm *et al.* 1996). There is a critical need for more chronologies and greater sample depths to complement these records and to close the dendrochronological gap persisting in eastern Mediterranean chronologies during the Greco-Roman period, to build a securely dated chronology for this critical time window.

Thus far, wood from the Ptolemaic (332–30 BCE), especially the Roman (30 BCE–395 CE) period, has remained much less documented than that of the Ancient Egyptian (3150–332 BCE) period. However, rich collections of hitherto unexplored Greco-Roman wood objects are preserved in many museums worldwide. A study of these collections is therefore key for the construction of absolutely dated conifer chronologies, but is also considered to have a high potential to enhance our understanding of practices and customs during the Roman period in Egypt. Considered a pivotal time, the Roman period experienced large-scale transformations and external threats (i.e., military anarchy, civil wars, galloping inflation, famines, raids, and invasions; Alföldi 1938; Blois 2002); epidemics (Elliott 2016; Huebner 2021) and a succession of droughts (Manning 2013; Harper 2017). However, there is a dearth of relevant information regarding how wood was used and how forest resources were exploited in Greco-Roman times, including its availability and provenance. At the same time, these wooden artifacts could also be used as a natural archive to reconstruct climate. The study of wooden archaeological objects is thought to have

great potential in improving our understanding of past societies, their organization, and evolution.

A rich source of wooden archaeological objects preserved in large quantities is funerary furniture, particularly mummy labels. Although mummy labels have been studied for their inscriptions as they contain information on funerary practices; however, their functionality, shaping technology used, wood anatomy, or dendrochronology is yet to be analysed. We posit that the great diversity of shapes, different shaping techniques, and wood species used, both from Egypt and the entire Mediterranean basin, would allow an exhaustive assessment of the origin of the wood and the context in which it started being used. In this study, we (1) analysed existing typologies of mummy labels to distinguish between specific procedures at workshops and practices of wood-working, (2) distinguished endemic from imported specimens to improve our knowledge on the use and selection of wood, and (3) evaluated the dendrochronological potential of the mummy labels used to measure tree-ring widths to introduce a dendroarchaeological research approach to the mummy label collections.

The dendrochronological analysis of mummy labels made of endemic species and imported wood represents a real challenge. However, it also offers a unique possibility to provide information on wood supply networks, taxonomic variety, and wood uses (finished objects, semi-finished products) in addition to having dendrochronological potential.

## 2 Material and Methods

### 2.1 *Mummy Labels: A Vast, Unexplored Corpus*

Mummy labels are small wooden labels (rarely made of stone, ivory, or enamelled glass), which were attached to a mummy prior to its transport to the necropolis. Although their use is known from the New Kingdom onwards, mummy labels became part of funerary practices during the Ptolemaic period. Their use became very common during the Roman period and with the advent of Christianity (Aubert *et al.* 2008) (Fig. 1). Therefore, a majority of existing mummy labels are from the second to fourth century CE.

Concerning labels and their inscriptions we disregarded whether they were designed by the embalming workshop or the family of the deceased when the body was handed over to the workshop. Mummy labels usually contain bare inscriptions providing information on the affiliation of the deceased, their age, profession, hometown and region, mummification method, and burial location (Gaudard *et al.* 2009; Wallis Budge 2010). Inscriptions on mummy labels are mostly in Greek, Demotic, or both (Bornemann 2010; Kipfer 2021), written



FIGURE 1 Presentation of mummy labels from the Bibliothèque Nationale et Universitaire (BNU) of Strasbourg (France) collection

with black (rarely red) ink, or sometimes engraved. Mummy labels had two main functions. First, they were used to identify the body as it was received in the embalming workshop and then moved through a series of holy places to finally be buried in the necropolis (with the latter being mostly inscribed in Greek; Aubert *et al.* 2008). Second, they were also meant to accompany the deceased to the afterlife as they also featured a short inscription, frequently written in Demotic (Aubert *et al.* 2008), or a religious symbol (e.g., sacred animals, gods, vegetal elements; Gaudard *et al.* 2009) intended to ensure the welfare of the deceased in the afterlife.

With regard to the quality of writing of labels, wide variations are observed. In some cases, carelessness is evident, attesting that expert skills are not always present in funeral establishments or families. By contrast, other labels show perfect mastery of both woodworking and writing, or even drawings. It may be inferred that the latter group of labels were used for individuals belonging to a higher social strata they are found on bodies that underwent a long and expensive mummification process that not everyone could afford (Firon 2020), contradicting the idea that these mummy labels were used for members of the lower social class.

Many mummy labels are preserved in museums worldwide. They range from a few in some collections to several hundred — the Louvre has no less than 852 mummy labels. Indeed, a recent inventory of mummy labels has identified more than 3000 pieces in different collections (Gaudard *et al.* 2009; Worp 2017).

## 2.2 Archaeometric Approaches

### 2.2.1 Morphological and Technological Observations

Archaeometric approaches cannot be implemented easily when working on museum collections (Lavier 2013), because of the invasive nature of some of the sampling techniques, the fragile nature of the objects under study, and the complex technical setup required for quantitative analysis. This limits the handling of mummy labels, depending on the degree of fragmentation and fragility. However, they have the advantage of being light, small, and therefore easier to handle. Besides measuring basic label dimensions (i.e., length, width, and thickness measured in mm), with a ruler and caliper, we recorded their shape (i.e., rectangular, square, trapezoidal) and various arrangements (i.e., number of suspension holes, single or double handle) to allow a typological approach. These qualitative and quantitative approaches were adapted to wooden furniture (Blondel 2018) but relied on methods that were originally used for metal furniture or *instrumentum* analyses (Fort & Tisserand 2013). Thus, without having to handle objects excessively, several archaeometric approaches are possible simply by observing label surfaces. Tool marks are often visible on wooden objects, depending on the degree of finish, and provide valuable information on craft practices (Bláha *et al.* 2008). A carefully finished object will have fewer tool marks, whereas others will have many. Two types of marks have been recorded (Fig. 2). In the first type, marks are made with a sharp tool, recognizable by a slight incision on the wood surface or through the removal of material, rendering the surface somewhat “wavy” — yet it is difficult to specify the actual tools used. The second type are, saw marks which can be recognized in the form of regular “striations” left on the wood. In this study, we assembled series of photographs taken with a grazing light to enhance the visibility of the saw cuts. During the observations, it was possible to determine the cutting method used to shape the labels (i.e., on slab, mesh, quarter, strand, half strand;



FIGURE 2 Comparison of two mummy labels. The label on the left (H0163) has a neat finish with a flattened inscribed surface, clean ends and an outline with a chamfer (BNU Strasbourg). The label on the right (F1949/4.2) has traces of sawing and a knot is present. Also, the corner cuts are different, and the left end is not straight.

Blondel *et al.* 2020). The cutting mode used can be determined by observing either the end of the label based on the orientation of the wood rays or the curvature of the growth rings. This information is important to ascertain the original position of the wood piece within the tree and thereby gain insights into shaping practices and dendrochronological potential.

### 2.2.2 Anatomical Identifications

In addition to morphological and technological observations, anatomical identification was essential to determine the species used for the production of mummy labels. Depending on the state of preservation, accessibility of the object, and sampling opportunities, the botanical species can be determined based on observable wood anatomical features, provided that the anatomical profile that is visible allows such identification (Schweingruber 1990). However, species identification remains a challenging task with regard to museum collections (Lavier 2013) because of conservation policies that usually prohibit or at least limit invasive analyses of mummy labels owing to their small size and the presence of inscriptions. However, the use of a completely non-invasive approach limits the direct analysis of an object to visual observations with a hand lens or microscope, thereby offering the possibility of identifying the tree species (Lavier 2013). Further, the surface of mummy labels is not always legible owing to paint, tool marks, patina (plant or animal residue), or even the remains of linen strips stuck to the wood because of its extended contact with the mummy. Except for the collections at the British Museum, Marseilles, and a few individual pieces from the Louvre for which anatomical identification has already been realized (Barakat 1993; Asensi Amoros 2003; Asensi Amoros & Détiennes 2008), we employed two different approaches to identify wood species used in mummy labels. The first is an optimal approach in which a small sample is taken and a thin section is prepared for comparison of its anatomical features (Fig. 3) with wood anatomical reference collections and the primary reference atlases (Schweingruber 1996; Gale & Cutler 2000; Neumann *et al.* 2000). The second approach is limited to surface observations with a hand lens or microscope, where certain anatomical criteria are recognized on the surface of the object, but do not allow the species to be identified with certainty. In the worst case, no observation is possible, and only the family can be identified, that is, conifers or broadleaves. For broadleaves, it is sometimes possible to differentiate genera with distinct anatomical characteristics, such as ring porosity or wide rays. In this study, we could identify oak (*Quercus* sp.), ash (*Fraxinus* sp.), elm (*Ulmus* sp.), and beech (*Fagus* sp.). Simultaneously, a differentiation between conifer and broadleaved wood is an important marker for the Egyptian collection. Even if it remains difficult to differentiate imported



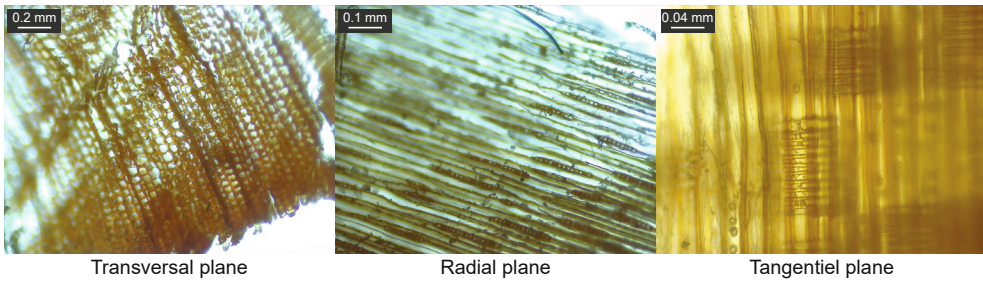


FIGURE 3 Anatomical identification of fir (*Abies* sp.) based on the anatomical planes (transverse, tangential, and radial) obtained from label HO60, BNU collection, Strasbourg

broadleaved wood from that endemic to Egypt without anatomical identification, we can be sure that conifer wood was all imported, thereby underlining the importance of wood trade during the period.

### 2.2.3 Tree-Ring Analysis

In the last step, we performed dendrochronological measurements, but in the absence of a sufficiently large section or the possibility of surfacing, the only possibility to obtain ring-width series on mummy labels was through measurements at the end grain of the wood sample or on a perfectly oriented radial section (far less ideal and dependent on the wood species) (Fig. 4). Here again, as with anatomical identification, the state of preservation of the wood and the presence of tool marks or coating (i.e., paint, wax, ink, and patina) defined the possibilities, but also limitations, for precise measurement. In the case of endemic and imported broadleaves along with the absence of visible tree-rings across the transverse plane, it was often impossible to carry out such measurements. Therefore, tree-ring analyses were restricted to conifer labels with well-defined earlywood and latewood boundaries (Creasman *et al.* 2015). Measurements were performed on all conifer mummy labels exhibiting at least 20 growth rings. Two methods were used: we measured the ring widths either directly on the object at a resolution of 0.01 mm using a measuring table (Lintab or Velmex) equipped with a binocular microscope connected to a computer system and TSAPWin software (Rinn 1986); or the rings were measured on images (with a resolution of at least 300 dpi) from databases or catalogs available for different museums using the CooRecorder measuring software (Larsson 2017). Growth patterns were then synchronized using TSAPWin before tree-ring series from individual mummy labels were cross-matched to build a mean chronology. Thereafter, the latter was used to attempt absolute dating of the mummy label chronology with existing reference chronologies using the Sylphe software (Meignier, © GNU-GPL 2001). The software (Lambert 2006a)



FIGURE 4 Mummy labels of different quality from the BNU collection in Strasbourg were used to acquire dendrochronological measurements. Top left: Growth rings on mummy label H087 cannot be measured easily due to tool marks and surface coating. Top right: Mummy label H066 has a clean surface and perfectly readable rings. Bottom left: growth rings on label H059 are only partly visible as a result of the cutting method applied and tool marks, the central part is illegible. Bottom right: Growth rings on the transverse plane of mummy label H043 as seen on a x-ray tomography image with perfectly legible rings

transforms raw data into indexed data based on Besançon E (Lambert 2006b). The series were compared in pairs (Kaennel & Schweingruber 1995), with a minimum of 20 years of overlap, using Student's *t*-test applied to the interannual correlation coefficient with a probability threshold  $\geq 0.9999$ . Statistical results were then checked visually to examine interannual variation in the indexed data (Lambert & Lavier 1992). The synchronous series made it possible to calculate several average chronologies, which were then compared to the floating and reference chronologies available for Gaul and the Mediterranean basin.

In addition, a third, more innovative approach has been used to acquire ring widths using x-ray computed tomography (Grabner *et al.* 2009; Dominguez *et al.* 2021). By scanning the wood internally, ring-width measurements can be realized directly from the transverse plane of the x-ray images with a resolution ranging from 11 to 42  $\mu\text{m}$  (Fig. 4). However, this approach remains limited because of the constraints of moving museum collections to laboratories able to produce tomographic imagery and the cost that this may entail. We analyzed 38 mummy labels from the Bibliothèque Nationale Universitaire (BNU) Strasbourg using an EasyTom 150/160 tomograph (RXsolutions) at the Charles Sandron Institute (Blondel *et al.* data not shown). The approach is innovative

and broadens possibilities or dendrochronological approaches, whereas acquisition of ring widths is identical to that of conventional photographs. X-ray computed tomography has the advantage of allowing insights from more accurate transverse planes and not just radial planes as on conventional photography.

### 3 Results

#### 3.1 *The Corpus of Mummy Labels Used in This Study*

A total of 1741 mummy labels were either studied in museums or analysed online using readily accessible databases. A total of 490 mummy labels were analysed in different museums: 255 mummy labels in the BNU Strasbourg (France); 4 in the Musée de Picardie, Amiens (France); 170 in the Neues Museum, Berlin (Germany); 11 in the Rijksmuseum van Oudheden, Leiden (The Netherlands); and 50 in the Musée d'Archéologie Méditerranéenne (MAM), Marseille (France). An additional 1251 mummy labels were examined online: 862 from the Louvre (France), 283 from the British Museum (UK), 36 from the Liverpool Museum (UK), and 70 from the Nationalbibliothek, Vienna (Austria) collections.

For obvious reasons, the details of the information obtained varied between the samples analysed directly in museums and those studied online. All mummy labels were subjected to typological analyses based on their particular shape and arrangement; however, only those analysed directly in museums were used to study the mode of cutting and tool marks. Moreover, the lengths and widths could be measured for all samples, and thickness was obtained for 1270 out of the 1741 mummy labels. Wood anatomical analyses were performed on 451 labels due to physical access to the sample and, above all, the possibility of minimally destructive sampling. Some of these analyses were carried out by the British Museum Research Laboratory and are available on its web page, or published previously for some mummy labels from the Marseille and Louvre collections (Asensi Amoros 2003; Asensi Amoros & Détiennes 2008). In the framework of this study, some identifications were made in the collections of Amiens, Berlin, Leiden, and Strasbourg.

#### 3.2 *Typological Indications*

The shapes of analysed labels varied greatly; most often, they were close to square, rectangular, or trapezoidal, with one or two straight ends, sometimes cut at the corners in a more or less pronounced manner, pointed or rounded, and had one or two holes for hanging. Others had a type of handle at one end, simplified or elaborate, straight, round, rounded, wide, or short, and were pierced to be suspended. Finally, some mummy labels, referred to as *Tabula*

Ansata, are quadrangular in shape and flanked at both ends by a pierced dovetail. The labels with one hole were oriented vertically to the neck or body of the deceased, whereas those with two holes were attached horizontally. Some labels were without holes, and it remains unclear how they were attached to the mummy.

The first typology of mummy labels was established by Quaegebeur (1978), the main forms of which were taken up by Gaudard *et al.* (2009) in the framework of the “Death on the Nile” project. They classified labels into three basic categories: stele-shaped, Tabula Ansata, and rectangular or “arbitrary” shapes, and relied on a characterization of the ends (i.e., angled, rounded, with one or two rounded or pointed handles). However, their typology did not account for the diversity in shapes displayed on mummy labels and thus needs to be complemented in this study with other distinguishing characteristics.

From the dimensions and shapes of the 1730 mummy labels analysed, a more elaborate typology emerged (Fig. 5). We include three basic shapes (stele-shaped, Tabula Ansata, or rectangular), but adjust the term rectangular as it is not always appropriate, as many labels are not rectangular, but rather trapezoidal or, more rarely, close to square. Therefore, we replace the term “rectangular” with “quadrangular.” Other distinguishing features are found at the ends: the end opposite to the suspension hole can be cut straight, slightly curved, or with blunt angles. The other end is more varied: we distinguish labels with a handle (or strip) from those without a handle. The latter group exhibits a straight end with pronounced sloping angles, rounded in the form of a straight point, or even curved. For those with a handle, the latter can be short or wide (making the entire width of the label) with a rectangular, round, oval, or dovetail shape. Finally, in our case, Tabula Ansata only includes rectangular labels with dovetails at both ends, unlike the typology of Quaegebeur (1978), which also includes labels with a handle. This shape is a known element in architecture and ornamentation and has a specific morphology (Giroire & Roger 2007) that includes only labels with dovetails at both ends. Thus, five types of mummy labels can be identified (without counting the variations in end shapes): simple quadrangular (Type I), trapezoidal (Type II), close to square (Type III) shapes, mummy labels with a handle (Type IV), and Tabula Ansata type (V) labels. Note that some labels are too fragmented to be assigned to a type.

### 3.3 *Shaping Techniques with Dimensions*

Observations on the shaping techniques used are limited to 490 mummy labels that could be analysed directly in museums. The source material from which the labels were shaped may have resembled a board, obtained by splitting or sawing. Although this first stage of cutting is difficult to characterize, the

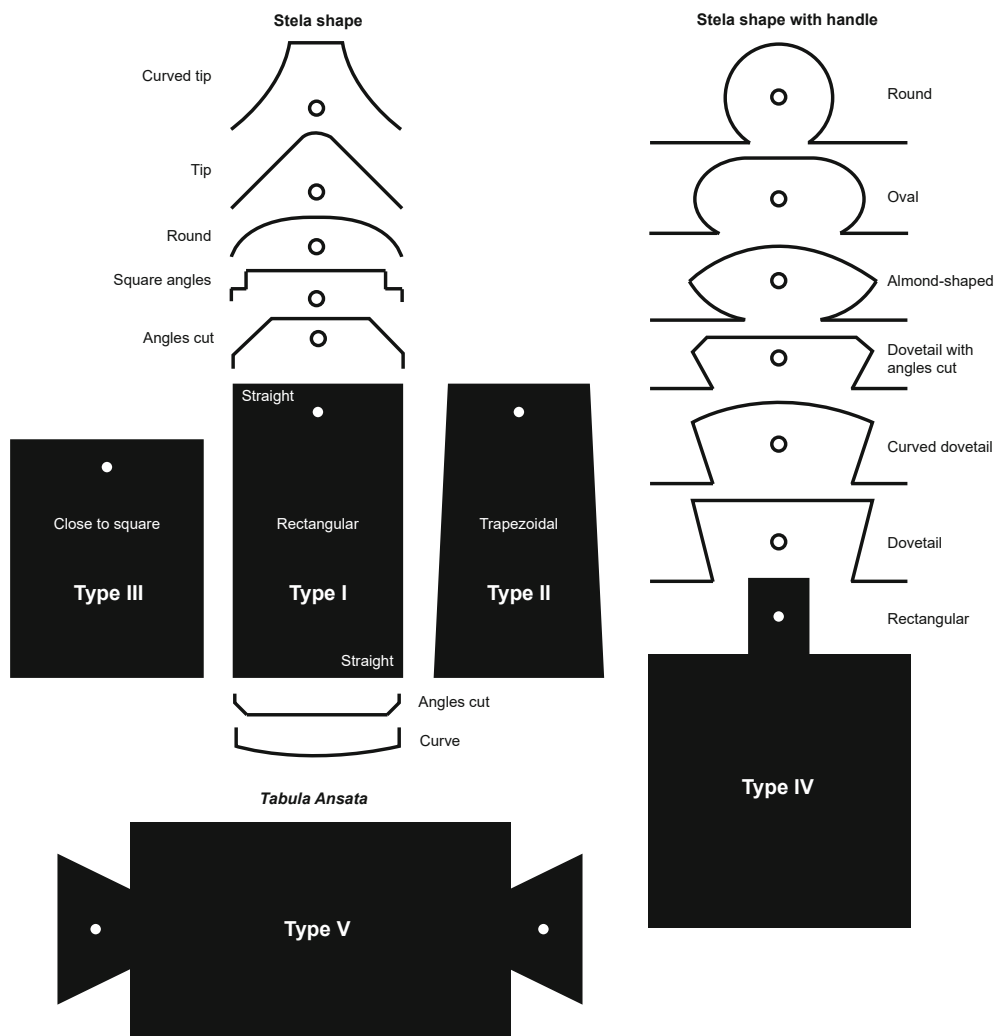


FIGURE 5 Representation of the five main types of mummy labels, with the most frequently encountered variants

second stage has been recognized on many labels from the obvious saw marks. Therefore, two shaping actions are easily identifiable: sawing observed on 61 labels and shaping with sharp tools on 113 labels (Fig. 6). However, this last category can correspond to many different tools, including chisels, scrapers, short and wide adzes, and even planes. It can also correspond to the reshaping of a sawn surface to make it flat, thus facilitating the writing of inscriptions. All these tools were known and used in the Empire (Ulrich 2007), even if certain craft practices and tools seem to be more dominant in certain territories than



FIGURE 6 Two main tool marks can be recognized on mummy labels: (left) long and slightly curved marks from a cutting tool observed on label HO141 and (right) oblique and irregular sawing marks observed on HO106 (BNU, Strasbourg)

in others (Lucas 1948; Bruwier *et al.* 1981). The small size of the mummy labels limits the use of axes or adzes unless it is used for initial cutting in the form of a large board before being cut into small plates or tablets.

No link can be established between the typology of a label and the cutting method; however, some tendencies emerge when labels are categorized by wood type. From the 380 labels with legible tool marks, the majority were cut on slabs (45.5% of all broadleaves and 34.5% of all conifers) (Fig. 7). Mesh cutting was more widespread in conifers (12.6%) than in broadleaves (7.1%). Only one individual was derived from a half-strand, retaining the raw form of the broadleaf branch collected (0.3%); however, this is an exceptional case. The number of processing steps is minimal because many labels retain saw marks. In most cases, the side(s) to be inscribed is flattened using a sharp tool. Conversely, rough sawn faces rarely contain inscriptions (43 labels with ink and 8 with engraved inscriptions). Although difficult to prove, it seems that the most suitable tools for shaping label surfaces is probably a scraper or a planer. The other fittings, especially for the ends, are either rough sawn or have clean cuts from a sharp tool (chisels) for the shaping of felled, pointed, or rounded corners, or for the shaping of handles. The combined use of saw and sharp tools is common in Egyptian craftsmanship. The rough appearance of certain labels sometimes shows that the number of gestures is limited to give the labels their shape without any particular finishing.

Mummy label dimensions are also highly variable, but relatively clear trends emerge according to their shape (Fig. 8). The largest labels belonged to the *Tabula Ansata* type. To date, 60 individuals of this type of label have been inventoried, accounting for approximately 3.5% of the corpus analysed. They were, on average, 17 cm long, 7.5 cm wide, and 1.5 cm thick. The simplest labels have

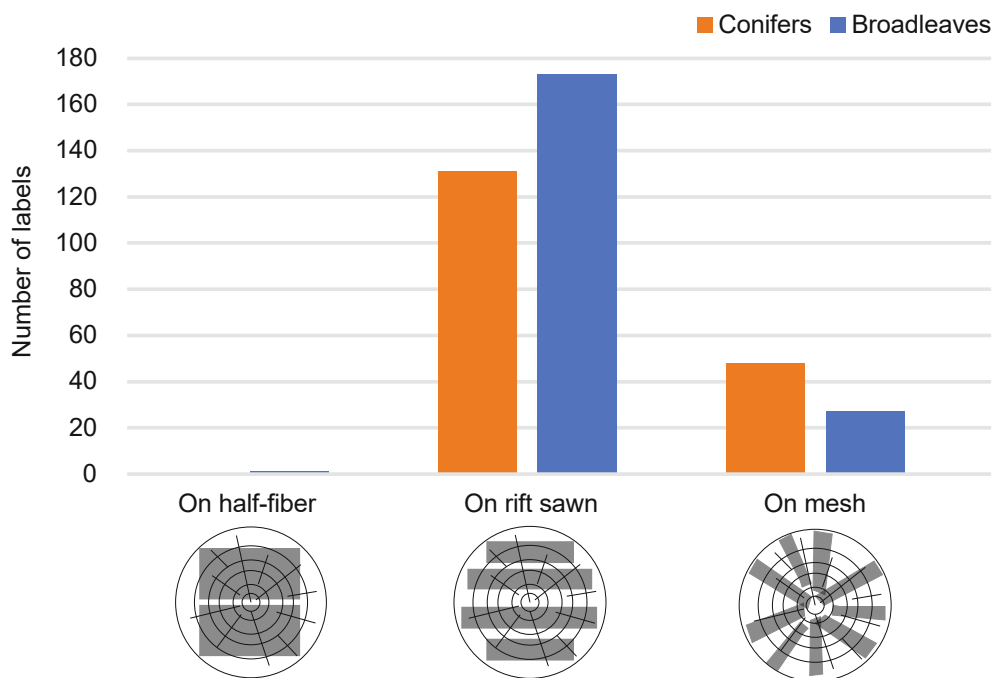


FIGURE 7 Different types of cutting observed on a corpus of 380 labels from the collections of Strasbourg, Berlin, Amiens, and Marseille

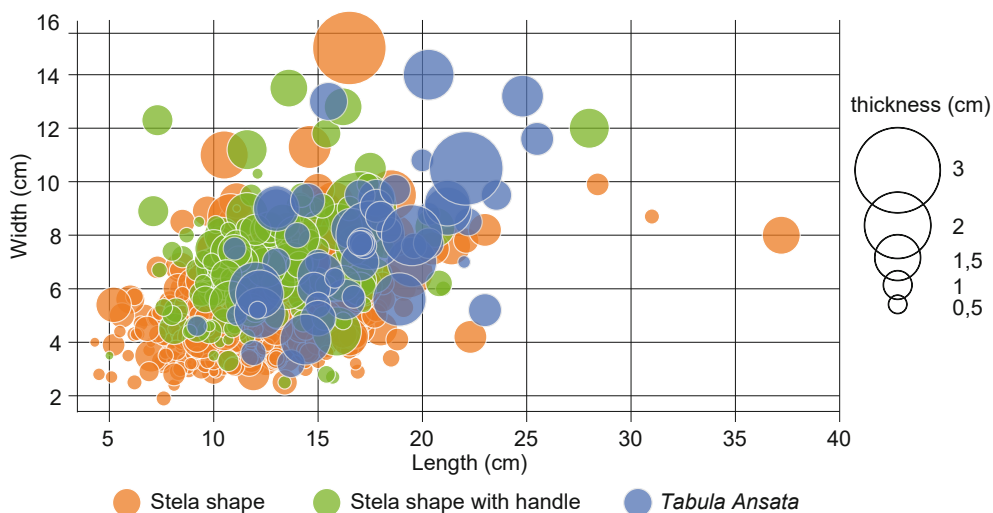


FIGURE 8 Dimensions of mummy labels according to the three main shapes (from a corpus of 1270 labels)

a quadrangular shape; they are also the most numerous with 1446 individuals (83.5%), with rectangular labels being the most common (977 labels, 56.5%). They were, on average, 12 cm long, 5 cm wide, and 1 cm thick. Trapezoidal labels were less numerous, with 432 individuals (25%), but relatively similar in size. Labels with a shape close to a square were much fewer in number, with only 41 labels inventoried (2.4%). They were, on average, 9 cm long, 6 cm wide, and 1 cm thick. Their length-to-width ratios were approximately  $2/3$  and  $1/3$ . They are not specifically square but closer to squat rectangles. The designation “close to square” is mainly used to differentiate them from the others in the typology. Labels with a handle or strip at one end account for 169 individuals (10%). The handle type has an impact on dimensions; on average, they are 13 cm long, 7 cm wide, and just over 1 cm thick.

Mummy labels vary in terms of their finish or how well made they are, so the finish is not a typological criterion, as all types present a range of variables, such as an off-axis suspension hole, cutting of the ends, or the shaping of coarse handles that are not necessarily symmetrical. The ones that do not have a hole, raise the question of how they were attached to the mummies. In comparison, others may have more than one hole. Some 14 labels showed clear evidence of reuse, such as the presence of a peg hole, groove, molding, or nail hole. These are few in number in the corpus as a whole but provide clear evidence of the practice of recycling.

### 3.4 *Wood Species Used*

Species identifications could be realized on 451 mummy labels and allowed distinction of 26 different taxa that we categorized in four groups: imported conifers with 7 taxa, endemic broadleaves with 5 taxa, imported broadleaves with 8 taxa, and broadleaves whose origin could not be confirmed as the species can grow both locally and in a wider geographical region, with 6 taxa (Gale *et al.* 2000; Asensi Amoros 2003). In contrast, individual species are sometimes difficult to distinguish because of the absence of distinguishing anatomical markers. This is, by way of example, the case for willow (*Salix* sp.) with several Euro-Mediterranean species and one endemic to Egypt, *Salix subserrata* (Neumann *et al.* 2000; Asensi Amoros & Détienne 2008). Other species may have been established for cultivation since ancient times in Egypt, including laurel (*Laurus* sp.), carob (*Ceratonia siliqua*), and olive (*Olea europaea*) (Lucas 1948; Gale *et al.* 2000). For these species, the endemic or imported origin cannot be determined.

The use of endemic species is important, particularly in the case of tamarisk (*Tamarix* sp.), which accounts for 16.2% of all mummy labels for which taxa



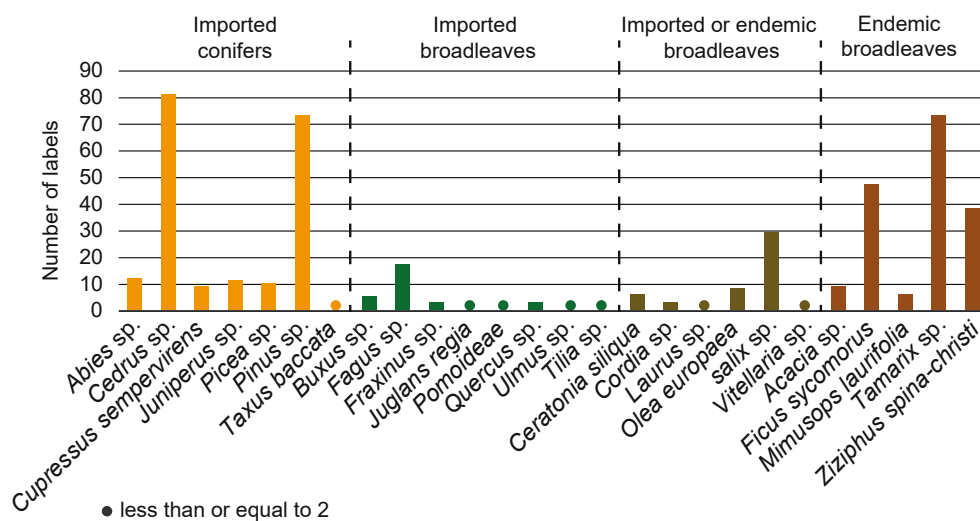


FIGURE 9 Overview of main wood species used for the production of mummy labels, grouped by genera and origin (from a corpus of 451 identified labels)

can be determined (Fig. 9). Fig (*Ficus sycomorus*) is also well represented with 10.4%, jujube (*Ziziphus spina-christi*) accounts for 8.4%. Two other species were represented in lesser numbers, acacia (*Acacia* sp.) with 2%, and mimusops (*Mimusops laurifolia*) with 1.3%.

Imported broadleaves were poorly represented by oak (*Quercus* sp.), ash (*Fraxinus* sp.), elm (*Ulmus* sp.), lime (*Tilia* sp.), walnut (*Juglans regia*), or pomoid (*Maloideae* sp.), each with less than 1%, and some were only represented by one individual (lime, walnut and pomoid). Boxwood (*Buxus* sp.) was slightly more prevalent (1.1%), whereas beech (*Fagus* sp.) was the most common among imported broadleaves (3.8%).

Broadleaves with unclear origin are poorly represented, often less than 1%. These include laurel (*Laurus* sp.), cordia (*Cordia* sp.), and shea (*Vitellaria* sp.). Olive (*Olea europaea*) or carob (*Ceratonia siliqua*) samples represented between 1 and 2%, whereas willows (*Salix* sp.) were the most common (6.4%).

Conifers were very well represented, accounting for 43.7% of the mummy labels for which taxa determination was possible. Cedars (*Cedrus libani* or *Cedrus atlas*) made up 18% of the corpus. Pines (*Pinus* sp.) accounted for 16.2%, whereas fir (*Abies* sp.), cypress (*Cupressus sempervirens*), juniper (*Juniperus* sp.), and spruce (*Picea* sp.) accounted for approximately 2–3%. Yew (*Taxus baccata*) had the least amount with only one individual (0.2%).

Although it was not possible to go further in identifying other mummy labels, the first assessment realized on the whole corpus of 1730 mummy labels

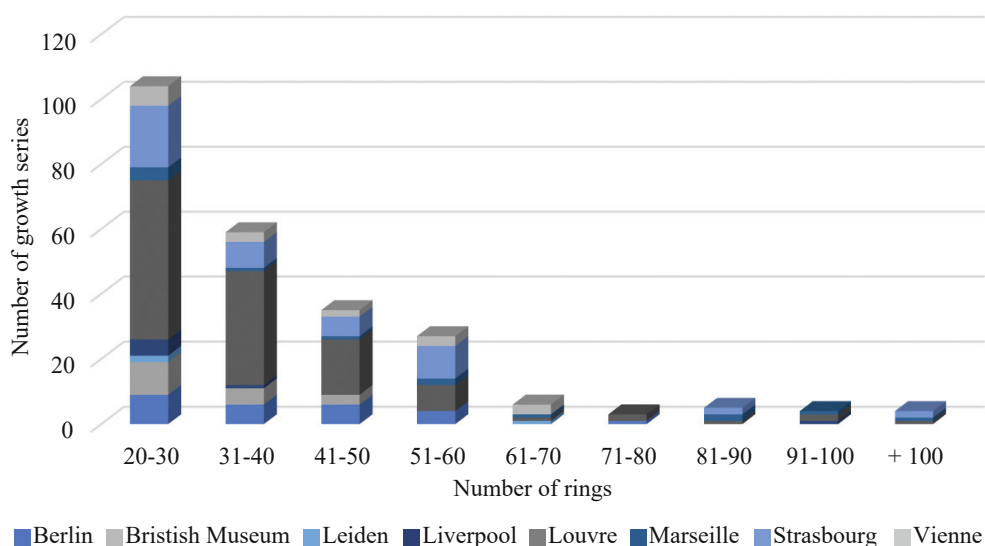


FIGURE 10 Overview on the number of growth series with their number of rings as obtained from different museum collections

allowed us to estimate that conifers are frequently used for the manufacture of mummy labels with about 44%.

### 3.5 *Dendrochronological Assessment*

The tree-ring pattern was analysed on 242 mummy labels (the conifer mummy labels from the Musée de Picardie in Amiens all had less than 20 rings), of which 80% had less than 50 rings, 18% had 50–100 rings, and only 2% had more than 100 rings (Fig. 10). However, the contribution of these dendrochronological series, even short ones, should not be underestimated, as they exist in very large quantities. As such, if combined, it is the accumulation of all of these short series that will add to the long master series. However, the prevention of anatomical identification is an obstacle in this dendrochronological approach, as it is difficult to evaluate and validate the statistical correlations of series for which the species is unknown. Of the 242 series analysed, species determination was possible in 49 cases (20%): 23 of these series were from pines (*Pinus* sp.), 17 from cedars (*Cedrus libani* or *atlas*), 4 from cypress (*Cupressus sempervirens*), 3 from junipers (*Juniperus* sp.), and 2 from firs (*Abies* sp.).

Although a visual correspondence of growth curves may still be relevant between the same or different species (Guibal 1992; Kuniholm *et al.* 1996), high correlation values between a series of identified and unidentified species will, at best, allow cautious attribution of a probable taxonomic correspondence.

Despite the absence of anatomical identification for 193 of the dendrochronological series, several strong correlation values (i.e., a  $t$ -value  $\geq 6$  and  $r$ -value  $\geq 0.7$ ) were obtained with strong visual correspondence. These correlations leave no doubt about a close or maybe even common origin for at least five batches of two labels whose morphological similarities, high correlation values (expressing similarity of growth patterns), and (or) parental linkage were established from the inscriptions, indicating that they may be labels fashioned from the same parent timber (Fig. 11). In all five examples, the morphology was close or almost identical, suggesting longitudinal cutting of the initial piece of the tree into two distinct elements. Most of the inscriptions report obvious family links through the mother, father, grandmother, or between siblings, except for two labels (MAM collection: Inv. 99 and 117), in which the presence of the first name alone does not allow a family link to be validated. However, all exhibited strong correlation values. However, there is an obvious gap between  $t$ -value  $\geq 10$  and an  $r$ -value  $\geq 0.8$  for labels H066 and H0156, 13354 and 13435a, as well as 11828 and 11833, and  $t$ -values around 6 and  $r$ -values around 0.7 for labels H046 and H0159 as well as inv.99 and inv.117. It is noteworthy that the cutting in the length is very pronounced, resulting in strong differences in the ring widths, which become more pronounced closer to the pith, which most certainly lowers the correlation values. It is also interesting to note that these strong correlations only concern collections from the same museum. No strong correlations ( $t$ -value  $\geq 6$  and  $r$ -value  $\geq 0.7$ ) were observed between collections from different museums.

The possible role of differences in the acquisition of ring-width measurements (i.e., direct measurement on labelled faces, on-screen using photographs, and x-ray computed tomography imagery) need to be evaluated, especially regarding the reliability of cross-dating between series to synchronize the newly gained records with floating chronologies available for the eastern part of the Roman Empire. As shown before, for the label batches from parent timber, differences in ring widths are more or less important depending on the cutting and the original position of the wood sample in the tree. The examples of label batches are the first test to highlight the quality of cross-dating between series acquired directly from label faces and photographs. The differences in the widths of the same ring after synchronization show that cutting affects the quality of the measurements (Fig. 12). The first rings of the labels were cut on the slab near the pith (e.g., H046, H0159, Inv. 99, and Inv. 117) showing the greatest differences in the ring widths. The other series showed deviations inherent to the method of acquiring ring widths, but these remained small (or insignificant), rarely exceeding a difference of 0.4 mm. The averages obtained for all ring width differences highlight that, overall, the growth curves are similar, in contrast to those previously mentioned, which can show differences of

| Label number | Label morphology                                                                    | Translation of the inscription                                                                                                     | Nbr. of rings | Correlation values |       |          |
|--------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|---------------|--------------------|-------|----------|
|              |                                                                                     |                                                                                                                                    |               | t value            | r     | Overlaps |
| HO66         |    | «(The mummy of) Thermouthis, daughter of <b>Polycarpus</b> . Her mother is <b>Besoûs</b> . She lived 18 years.» (Spiegelberg 1901) | 53            | 11,203             | 0,858 | 53       |
| HO156        |    | «Apollon, son of <b>Polycarpus</b> . His mother is <b>Besoûs</b> . He lived 25 years.» (Spiegelberg 1901)                          | 58            |                    |       |          |
| HO46         |    | «Psentausis, son of <b>Psen-thmesis</b> , son of <b>Tatripis</b> .» (Spiegelberg 1901)                                             | 47            | 6,054              | 0,736 | 39       |
| HO159        |    | «Psentatripis, son of <b>Psen-thmesis</b> , son of <b>Tatripis</b> .» (Spiegelberg 1901)                                           | 41            |                    |       |          |
| 13354        |    | «Apollo(s), son of <b>Pachom</b> .» (Möller 1913)                                                                                  | 50            | 11,302             | 0,875 | 47       |
| 13435a       |   | «Ponkh, son of <b>Pachom</b> , his mother Tshenpetempkhem.» (Möller 1913)                                                          | 55            |                    |       |          |
| 11828        |  | «(Mummy) of Pamuthes, son of Pabaioûs. The mother of the father (his grandmother) is <b>Hierakiana</b> .» (Krebs 1894)             | 54            | 19,816             | 0,948 | 52       |
| 11833        |  | «Horion Pbekis, husband of Tbaise, the son (daughter?) of <b>Hierakiana</b> .» (Krebs 1894)                                        | 54            |                    |       |          |
| Inv. 99      |  | «Sénéponyx» (Le Blant 1844)                                                                                                        | 59            | 6,795              | 0,716 | 52       |
| Inv. 117     |  | «Orion» (Le Blant 1844)                                                                                                            | 84            |                    |       |          |

FIGURE 11 Overview of pairs of mummy labels with marked morphological similarity, similar inscriptions, and growth patterns, supporting their common origin

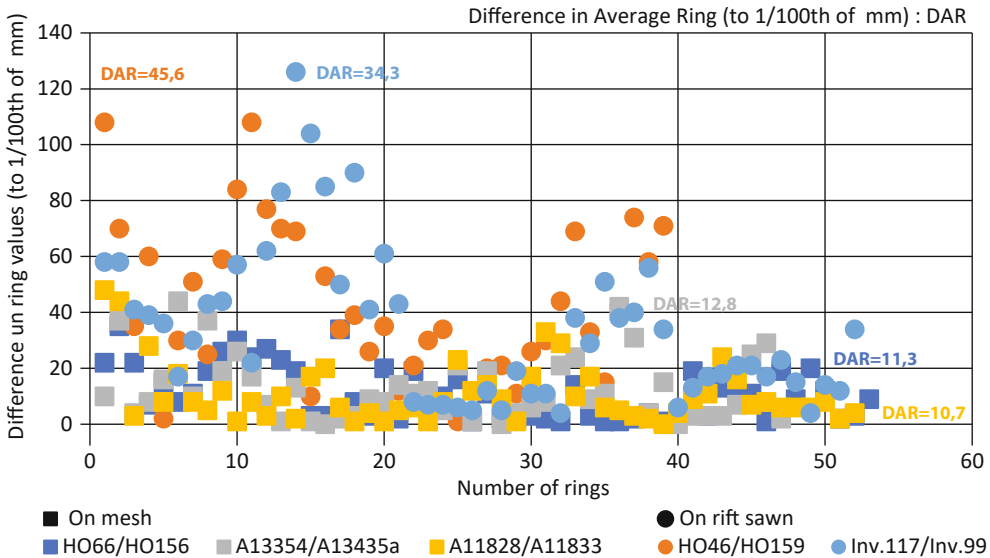


FIGURE 12 Comparison of differences in ring widths between batches of mummy labels from the same origin

more than 1 mm. We conclude that correlation values, despite being very satisfactory, could be higher if ring-width differences were less affected by the cutting method and if dendrochronological acquisition was carried out on the transverse plane of the rings, rather than on the flat side of the labels.

Each of the approaches used in this study has its advantages and disadvantages. While the quality of photographs impacts the accuracy and precision of the ring width measurements, they have the advantage of offering adjustments of brightness and contrast, or even conversion to black and white, which can ease measurements. However, narrow rings can induce measurement errors, especially if the resolution of the photographs is  $\leq 300$  dpi or the visibility of ring boundaries is unclear because of the roughness of the wood surface, even after cutting or polishing. The same is true for measurements on radial label surfaces, where thin or absent rings increase the risk of error. Another disadvantage of measuring rings on the radial plane of an object is that the true difference in ring widths (on which the dendrochronological method depends) can be skewed, depending on the cutting method used and proximity to the pith. The tests presented earlier, using labels from the same trees between the measurements made on the flat side of labels, show that uncertainties vary depending on the orientation of the rings and the original position of the object within the tree. In the absence of visible rings in the transverse

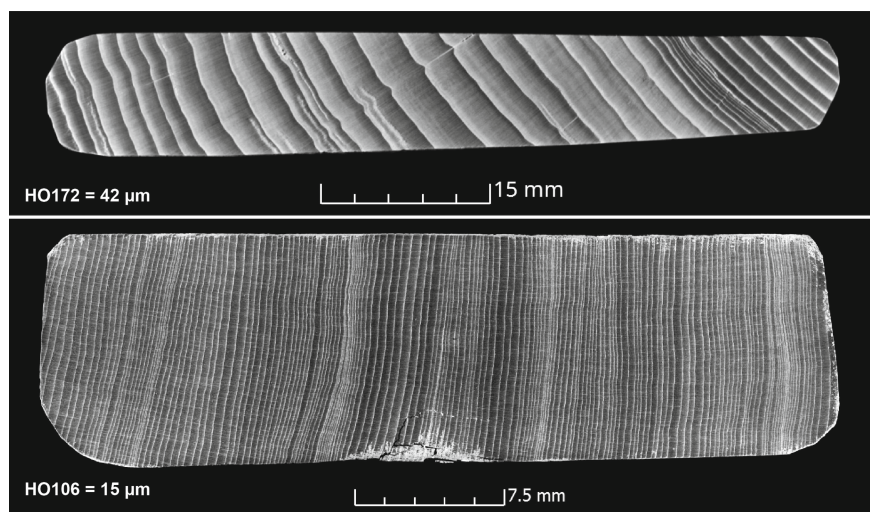


FIGURE 13 Comparison of two x-ray computed tomography images from softwood labels: HO172 is 6.9 cm wide and 1.2 cm thick for a resolution of 42  $\mu\text{m}$  and HO106 is 4.1 cm wide and 1.15 cm thick for a better resolution of 15  $\mu\text{m}$

plane on the ends of the labels, x-ray computer tomography imagery is the best approach for the acquisition of dendrochronological series, especially in the case of museum collections. The first test, performed on 38 mummy labels from BNU Strasbourg, shows the potential of x-ray computed tomography imagery acquisition (Fig. 13). The disadvantages of this method, the costs of laboratory services, and the transport of excluded collections, are centered on the size of the labels. The larger the labels in terms of width and thickness, the lower the image resolution owing to a loss of signal between the x-ray source and the detector (Conchon & Badel 2018). For measurements made in the transverse plane, there was no distortion because of the orientation of the rings, in contrast to the measurements made on the flat surface of the objects, as shown above.

## 4 Discussion

### 4.1 *Distribution of Findings: Identification of Workshops*

Whether it is the shape of the labels, their inscription, or the choice of wood species, the question arises as to where, by whom, and how these labels were created. Traditionally, the creation of wooden mummy labels has been attributed

to embalming workshops (Wallis Budge 2010). However, the diversity of forms, types of inscriptions (i.e., ink or engraved), the use of Greek and Demotic, sometimes with linguistic errors, and the realization of different drawings render this assumption questionable. In this study, we hypothesize that it could indeed have been the family of the deceased who prepared the label and/or wrote part of the text, which may have been completed by the scribes of the embalming workshops when the body was handed over. Alternatively, the family would have at least given the workshop the wood needed to make the label. This hypothesis remains unconfirmed and does not allow for an objective answer. However, this new approach, focusing mainly on wooden evidence from the labels and not on their inscription, offers new reflections.

The inscriptions on some labels allow the localization of the burial and(or) living places of the deceased (Gaudard *et al.* 2009). Although information on the location where the mummy labels were found is available and provides insights into the main necropolises, as many of the labels were found and acquired in the past, the information is not always reliable and should be treated with caution. There was reliable information on only 599 label finds, thus allowing a partial evaluation of the geographical distribution of the corpus. The highest concentrations of label finds are from the necropolises of the cities of Panopolis and Sohag, whose surroundings also include numerous villages (Bompae, Psonis, and Pollinariados Nesos). Together, they form 80% of the referenced finds (Fig. 14). Other localities yielding a few dozen labels were Thebes (58 individuals), Pathyris (12), and Elephantine (10). All other localities had few finds, ranging from one to seven labels. To assign label shapes to a specific region or to highlight potential workshop concentrations, the main types (Tabula Ansata, Stele shape with handle, Stele shape rectangular, trapezoidal, or close to square) were plotted on a map of label finds (Fig. 14). The high concentration of finds around Panopolis and Sohag somewhat blurs the interpretation of the results, but some trends can be observed. The most common type of label (296 individuals), Stele rectangular shape (Type I), did not show any particular geographic concentration. This shape seems to be common in many embalming workshops. Types II and III (Stele shaped trapezoidal and close to square) are mostly concentrated in interior Egypt, with no labels recorded north of Panopolis and Sohag. This may be a bias in the findings, but other types seem to be more evenly distributed over the Egyptian territory. Type II seems to be particularly represented in Panopolis and Sohag, with 120 localized labels, while Type III is common to Sohag and Thebes. However, the numbers were too small to be relevant, with only nine individuals. Type IV (Stele shape with handle) is more interesting, with 82 labels, of which 57% are from Thebes. This strong presence is all the more interesting, as the main place of discovery (around the Panopolis) is less represented. The Tabula Ansata (Type V) labels

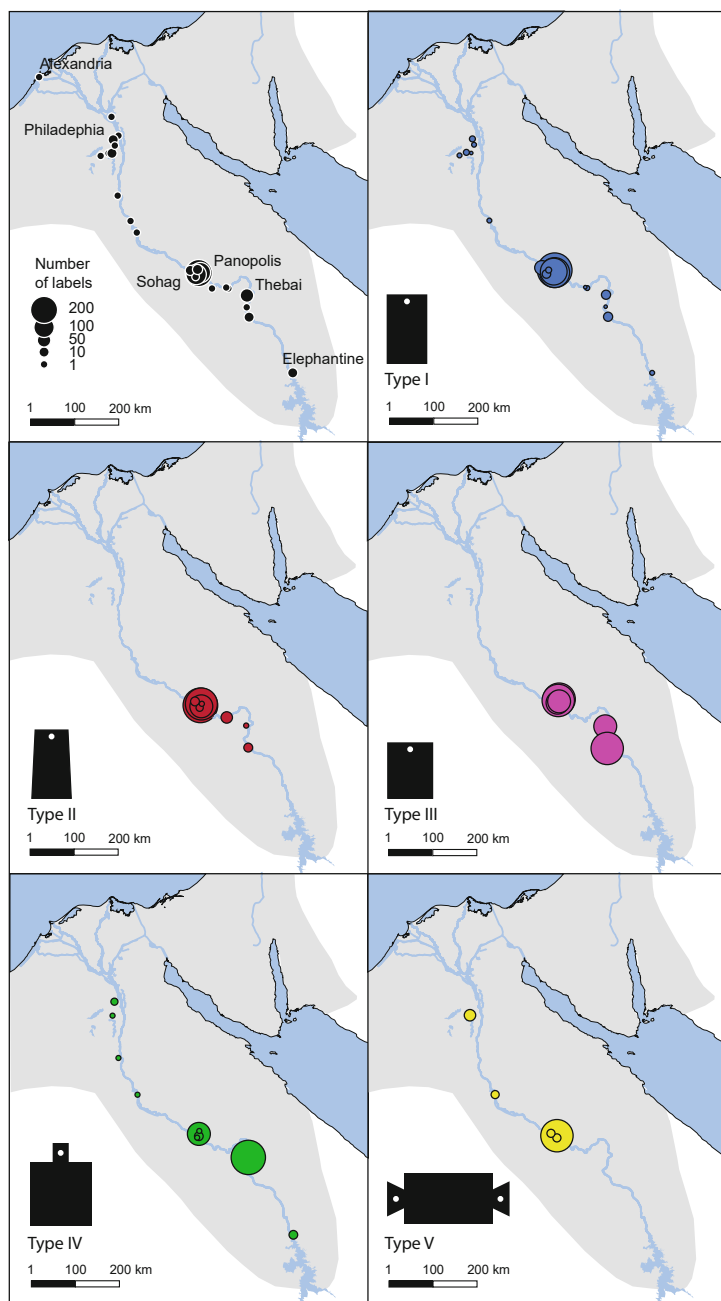


FIGURE 14 Distribution of the 599 labels for which the location of finds is known, as well as the distribution by label type: Type I, Stela shape rectangular; Type II, Stela shape trapezoidal; Type III, Stela shape close to square; Type IV, Stela shape with handle; Type v, Tabula Ansata



were mainly found around Panopolis but were absent farther south; they remained poorly represented with only 21 labels recorded in Egypt.

Research by mummy label type would benefit from a more substantial corpus and by considering more variants to perceive the production types of particular workshops. However, this approach must be qualified because the burial site is not necessarily close to the place of embalming nor is it close to the place of residence of the deceased's family. As the choice of burial place is very important, mummies could have been transported over long distances, mainly by boat, to the place of burial (Kipfer 2021). A reassessment would thus need to include three steps: reading of texts, form of labels, and selection of species. In addition, the dendrochronological approach can provide further information that can be complementary to other analyses.

#### 4.2 *Distribution of Findings by Species Family*

The relationship between the different shapes of mummy labels and the species used cannot yet be established because of the small number of individuals for which provenance is known. Therefore, it is too early to formulate a precise relationship from the typology alone. The only trend that can be observed for the moment is a preference for broadleaves with almost 60%, and potentially the use of endemic species for shaping Stele shape trapezoidal (Type II) labels. Despite the lack of data on species by label type, it was possible to sketch an initial distribution map with imported conifers, imported broadleaves, endemic broadleaves, and broadleaves that could be either imported and endemic (Fig. 15).

The number of labels with both anatomical identification and place of discovery amounted to 175, compared to 451 labels for which the species could be identified, and 599 with known provenance. Therefore, a breakdown by family is relevant in view of the quantities of exploitable data. Therefore, the quantities by group for which the origin is known are slightly different: 39% for imported conifers (against 44% for the whole corpus identified), 9% for imported broadleaves (instead of 7%), 42% for endemic broadleaves (instead of 38%), and 10% for imported or endemic broadleaves (instead of 11%). When plotted on a map of Roman Empire, we could not differentiate the specific sourcing practices for one group of species. Sourcing appears to be as important for endemic as for imported species, broadleaves, and conifers. Imported species account for almost half of the corpus and have a special place in this type of artifact. Conifers are mostly found around the two main settlements of Panopolis and Thebes. Cedar (*Cedrus libani* or *Cedrus atlas*), pine, and, to a lesser extent, cypress are well represented, showcasing the complex economic

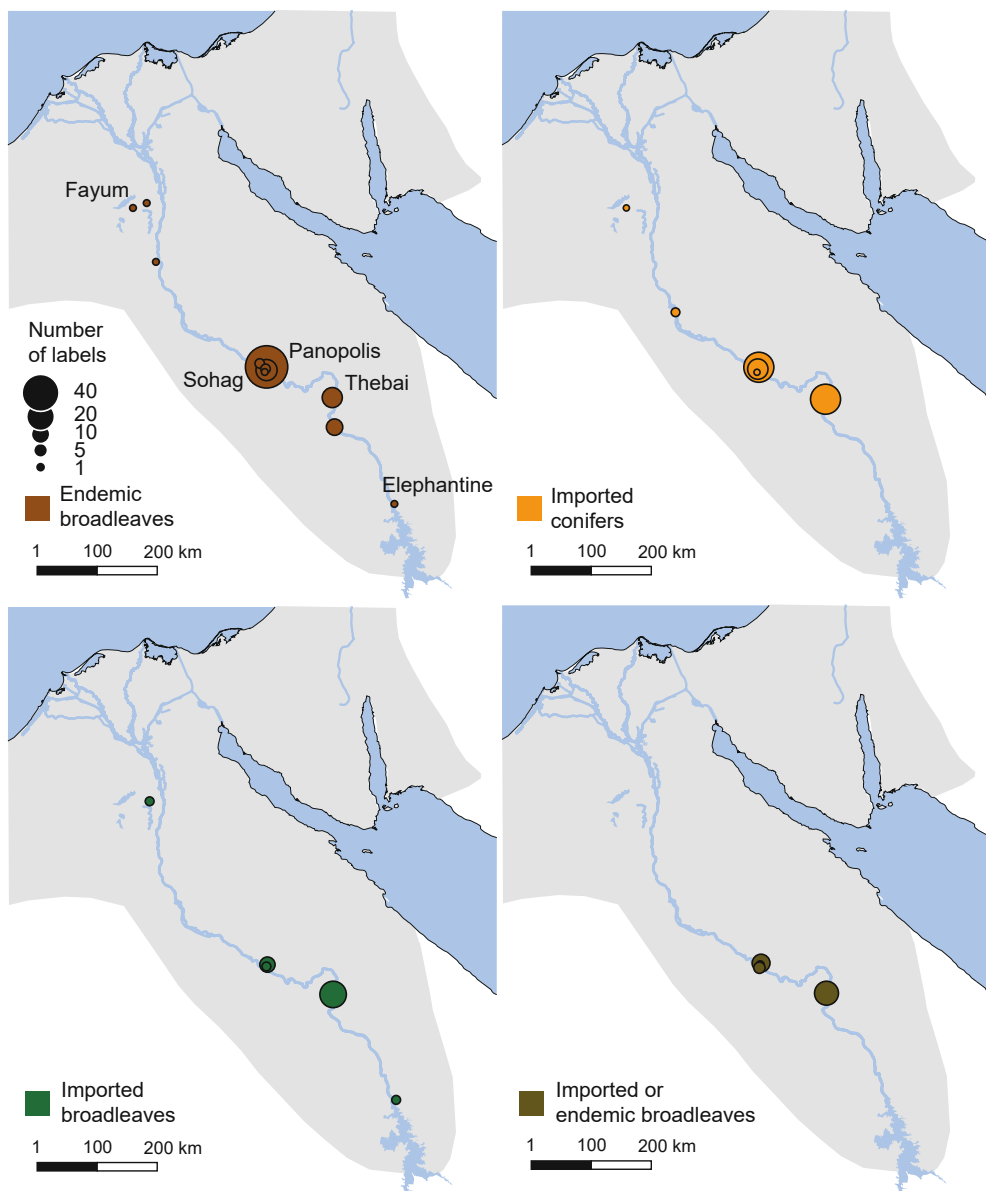


FIGURE 15 Overview of the 175 labels with origin and anatomical identification: imported conifers, imported broadleaves, endemic broadleaves as well as broadleaves that can be endemic or imported

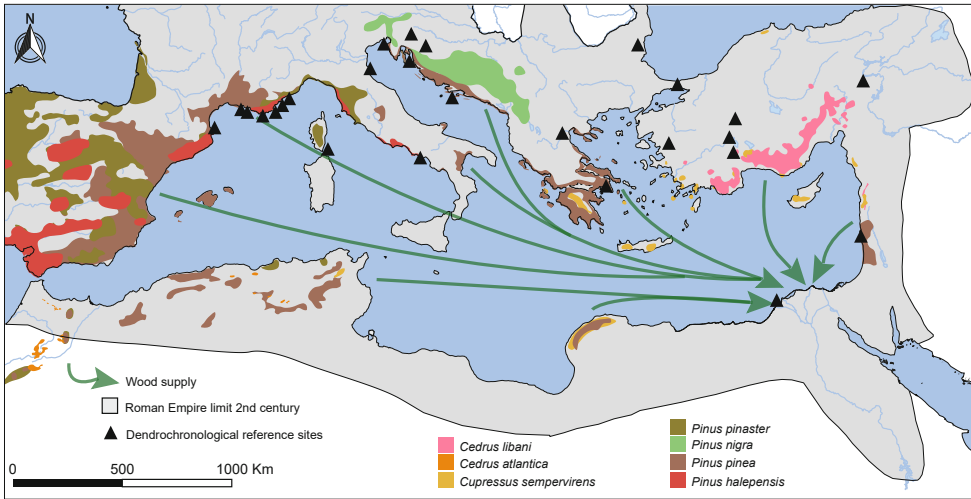


FIGURE 16 Distribution areas of conifers imported into Egypt (from current distribution areas: see [www.euforgen.org](http://www.euforgen.org)) as identified from mummy labels, as well as the main dendrochronological reference sites used to establish or enrich dendrochronological references for these species

circuits of imported wood (Fig. 16). The same applies to imported broadleaves, with one label even found in Elephantine necropolis. This indicates that imported wood could have been transported to the southernmost tip of the Roman Empire. Species whose provenance is difficult to determine (endemic or imported) are poorly represented and are only found in Panopolis and Thebes. Therefore, it is difficult to establish relevant hypotheses. In contrast, endemic species are well-represented at many sites along the Nile and demonstrate that they must have been relatively available. This also demonstrates that endemic species (tamarisk, fig, and jujub) are readily available close to dwelling places, probably growing on the banks of the Nile and in the main oases (Deglin 2011). Conversely, acacia (*Acacia torilis* or *Acacia nilotica*), although widely exploited in the Eastern Desert of Egypt, both as fuel and for domestic wood (Bouchaud *et al.* 2018), are poorly represented in the funerary wood collections inventoried, at least during the Roman period (Kuniholm *et al.* 2014). This observation remains difficult to explain. The exploitation and supply of endemic species probably have different uses over time, depending on the availability of the resource.

These initial results allow us to perceive a complex supply from the prism of mummy labels. They showed that wood resources were available locally from endemic species and that the transport of imported species was not impossible, even over long distances.

## 5 Conclusion

Mummy labels are perfect candidates for a comprehensive approach to maximize the archaeological value of an artifact using wood technology and dendrochronology. Combined qualitative and quantitative analyses of this artifact yielded numerous results.

Mummy labels have numerous forms with various distinguishing criteria and dimensions. The proposal for a new typology allows the classification of these labels into five types: quadrangular, trapezoidal, close to square, equipped with a handle, and Tabula Ansata. Typological analysis provides opportunities for further investigation, including the place of production and the signature of certain workshops. A wide variety of forms may allow for such investigations in the future. The distribution of finds by type supports this initial analysis, particularly for the trapezoidal and close to square-shaped types, as they appear to be concentrated primarily in the necropolises of Sohag, Panopolis, and Thebes. The rectangular and one-handle mummy labels are more widespread across sites around the Nile, whereas those in the form of Tabula Ansata do not occur beyond Panopolis.

The analysis of tool marks and cutting methods provides information on the production process of labels, often limited to a minimum of strokes, especially for those inscribed that are still rough sawn. Edged tool traces are the most numerous as they are easier to create. However, the finish on some labels showed remarkable care.

The wide range of species identified (26 taxa), including endemic and imported broadleaves, broadleaves of undetermined origin, and imported conifers, also opens new possibilities for research. Imported wood occurs in large numbers and demonstrates long-distance trading for many species. It is possible that certain species may have had an ostentatious appeal, as they were prized for having been commonly used for the sarcophagi of the elites, such as cedar, which is a particularly important imported species. The practice of reusing wood also suggests that some elements, perhaps previously used as sarcophagus elements, were recycled for their origin for the persistence of funerary attributes. Endemic species are also well-represented and demonstrate their availability on the banks of the Nile.

A combination of morphological, philological, and dendrochronological approaches has made it possible to verify the use of the same wood source for 10 labels. In most cases, two labels are created from the same piece of wood. The correlation of the shape of the labels, a family link proven by analysing the inscriptions, and the strong similarity of the tree-ring growth patterns indicate that at least two labels were made at the same time, probably following the

death of several people from the same family, such as during an epidemic. Even if dendrochronological dating has to be justified, certain replications tend to validate the hypothesis of death occurring during an episode of plague, such as those occurring at the end of the second century and around the mid-third century CE (Huebner 2021).

In addition to the purely chronological information offered by the dendrochronological potential of these objects, as well as that of other collections to be recorded, the climatic signal obtained from their growth pattern can be representative of a large territory, as demonstrated by a recent study on the climatic signal response in the eastern Mediterranean (Touchan *et al.* 2014). This acquired data, which is necessary to perceive climatic trends over a large territory, is key to a better understanding of the various events that marked the history of the Roman Empire, both in its episodes of prosperity and crises.

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