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Aging mulberry trees (*Morus nigra* L): The Charterhouse, London, UK

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ABSTRACT
Black or Common Mulberry (*Morus nigra*) was introduced into Britain in the late sixteenth – early seventeenth centuries and has since had limited success as an ornamental and fruit-producing tree. Older specimens survive in a limited number of locations including at The Charterhouse in central London. Four of these trees were investigated with the aid of standard dendrochronological techniques, historic images, including an early postcard and a painting by Edward Ardizzone, and with the application of expert knowledge of the forms and ages of contemporary mulberry trees. Results included the creation of a new ring-width chronology (CH_Mulberry) and dating that suggests the two oldest trees may well have been planted to commemorate either Queen Victoria's Golden (AD 1887) or Diamond Jubilee (AD 1897). The research represents a first known dendrochronological investigation of the species, highlighting issues associated with sampling "tortuous" growth forms and the poor visibility of sapwood rings, as well as the potential for the use of branch ring-widths to facilitate dendrochronological dating of fruit and other trees.

KEYWORDS
Branch wood; dendrochronology; image analysis; increment borer; ring-width measurements; sapwood

Introduction

Fruit trees have long been important sources of food growing naturally or under cultivation, the latter at least since 6500 BC (Jackson, 2003). The wood of fruit trees has been used in buildings where other native timber species have been depleted (Biger & Liphschitz, 1992), and specialist uses included the "teeth" of wooden cogs in the machinery of corn mills (Anon, 2021; Watts, 2002). In recent years concern over losses in biodiversity (global, national and local) has rekindled interest in the history, ecological value, re-discovery and propagation of old fruit tree cultivars (Cheshire Orchard Project, 1994; Eccher & Pontiroli, 2005; Robertson & Wedge, 2008; Rotherham, 2008).

Dendrochronological investigations of fruit and orchard trees are however relatively few, focussing primarily on apples and pears. Attempts have been made to confirm the identity and origins of nationally and regionally important specimens such as "Newton's apple tree" located at Woolsthorpe Manor, Yorkshire (Keesing, 1998), and the "Lord Combermere" apple variety growing in the Combermere Estate, Cheshire (Lageard & Gentil, 2003). Other research has determined cambial ages of up to 69 years for remnant orchard trees (*Pyrus communis*

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"Angelica") growing as standards in central Italian agricultural landscapes, building a regional ring-width chronology dating back to the mid-1930s (Neri, Urbinati, Savini, & Sanchioni, 2005), whilst veteran apples and pears at Croxteth Hall, Merseyside are thought to date back to the late nineteenth century (Lageard & Billington, 2008). The technique of dendrochemistry was applied to pears, cherries and plums in Canada, but tree-ring chemistry was thought not to have established a sufficiently accurate temporal record of arsenic uptake from pesticides (Martin, Tomlin, & Marsello, 2000). More recently, wild pear trees (*P. pyraster*) were investigated using standard dendrochronological techniques in northwest Poland creating a ring-width chronology back to AD 1934, highlighting similar growth responses to *Quercus pubescens*, and also the potential of pear in reforesting drought-affected areas (Antkowiak, Cedro, Prajs, Wolko, & Michalak, 2012). Natural apple populations (*Malus sieversii*) were used to construct ring-width chronologies of up to 129 years in southeast Kazakhstan, also establishing dendroclimatological relationships (Panyushkina et al., 2017).

The White Mulberry (*Morus alba*) occurs wild in central and northern China and has been cultivated for centuries in east Asia for its fruit and properties of its leaves, including its utility as a fodder crop for the silkworm, *Bombyx mori* (Samami et al., 2019). *M. alba* was introduced in Britain in AD 1596, but the climate is thought to create leaf chemistry incompatible with silk thread production and the tree has subsequently assumed an ornamental and fruit-producing role (Leathart, 1991). Black or Common Mulberry (*M. nigra*) is a deciduous "round-headed" tree reaching heights of around 12 m, producing dark purplish-red fruit in late summer or early autumn (Brickell, 1994), with older individuals having twisted branches and stems leaning or procumbent, or sometimes buried in soil leaving a low spreading mass of branches (Mitchell, 1978). Its natural origins are thought to be in tropical south-west Asia (Wiersema & León, 1999), and it was present in England by the early sixteenth century where it was planted widely (also *M. alba*) following recommendation by King James I. Earlier Roman introduction of *M. nigra* has also been speculated (CABI, no date; Grieve, 1931). Whilst there is an extensive academic literature centred on the horticulture of *Morus* sp (e.g. Karlidag, Pehluvan, Turan, & Eyduran, 2012; Samami et al., 2019), there is a complete absence of dendrochronological investigations attempting to establish the age or to investigate the properties of Mulberry wood.

Materials and methods

Study site

The Charterhouse was originally a Carthusian Monastery dating back to AD 1371, functioning subsequently as a Tudor mansion, a hospital/school and an alms house, the latter being its primary present-day purpose. The site today is a collection of Grade I listed buildings centred around 3 main rectangular courtyards – northern, Preacher's Court and Master's Court (Historic England, No date); (Figure 1). There is no public access to the courtyards.

Sample collection & analysis

Field sampling at The Charterhouse was undertaken on 12 February 2020 and focussed primarily on two old established mulberry trees (M1, M2, circumferences at their trunk bases circa 250 cm and 180 cm respectively) located in Preacher's Court, as well as two additional trees (M3, M4, circumferences both 130 cm) growing in the southern-most courtyard adjacent to Charterhouse Square (Figure 1).

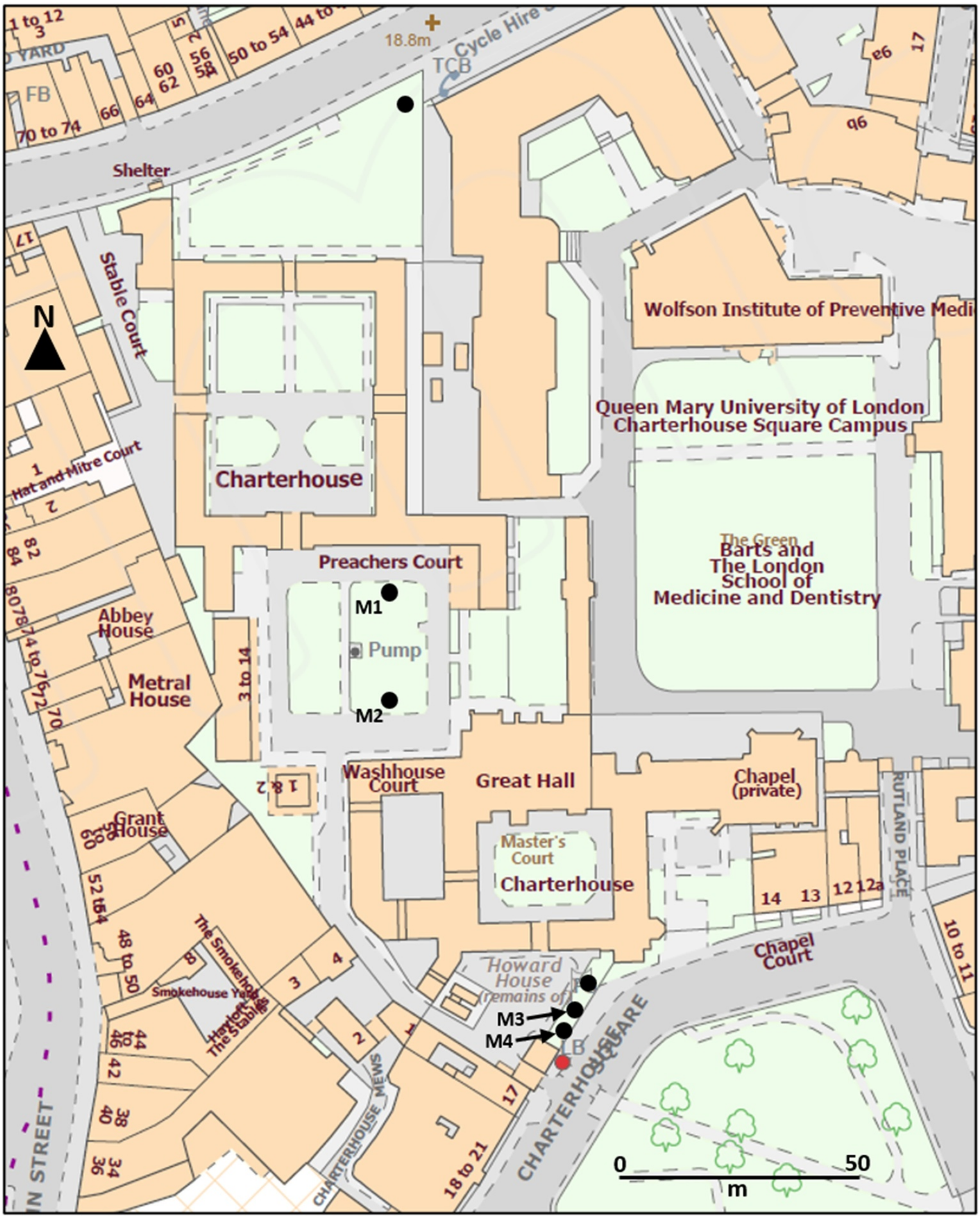

Figure 1. Locations of Mulberry trees (black circles – M1-M4 sampled in this study) in February 2020 at The Charterhouse, a former Carthusian monastery, located between the Barbican and Smithfield Market in central London. Base map: Digimap © Crown copyright and database rights 2021 Ordnance Survey (100,025,252).

Both trees in Preacher's Court were thought to be the oldest, experiencing trunk inclination and more recently collapse under their own weight, despite some previous attempts to prop them up (Figure 2). These growth forms were challenging for standard dendrochronological sampling (Speer, 2010, pp. 77–83), as illustrated by the increment core locations in Figure 2(a) (Lower trunk – cored from above and containing central rot with only 40 rings remaining; base of trunk – inclined and coring access limited by undergrowth).

Similar challenges were also faced with tree M2 (Figure 3), with cores retrieved from north and northeast-facing locations on the inclined lower trunk. Additionally, it was possible to take digital images of pruned cross-sections of larger branches (Branches A-D, see Figures 3 and 4).

All tree increment cores (5 mm diameter), were taken using a teflon-coated Haglof borer (length 540 mm – see Figure 5). Extracted cores were inserted within paper art straws (Speer, 2010, p. 80) and transported in a purpose-built core carrying case containing rigid polythene tubes to prevent deformation during drying. Cores were subsequently mounted in wooden channels or "core mounts" using wood adhesive prior to surfacing by sanding using a Bosch GBS 100A belt sander (sandpaper grits P60-320) to ensure ring and ring boundary visibility, and to facilitate standard ring-width measurements (Lageard, Chambers, & Thomas, 1999; Speer, 2010, pp. 88–95).

Results

Initial computer-assisted comparison of ring-width records (cf Lageard et al., 1999; Tyers, 1999) for the cores retrieved from mulberries M1-4 revealed a good statistical correlation between M3b and M4 ($t = 6.70$). Visual comparison of the tree-ring curves confirmed this cross-match, and these measurements were combined to form an initial 95 year site chronology (CH_Mulberry). CH_Mulberry could not be assigned a calendar age as sapwood rings immediately adjacent to the bark were indistinct and only heartwood rings were therefore measured (see Figure 6).

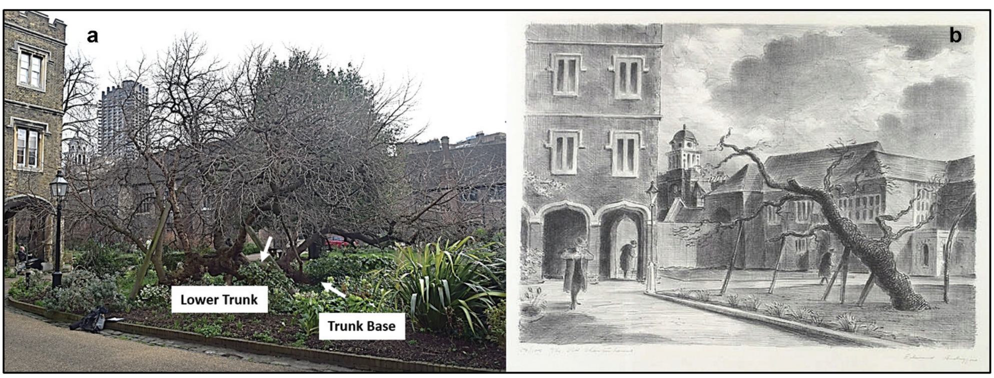

Figure 2. Collapsed Mulberry tree M1 at the northern end of Preacher's Court. **A** – image taken in February 2020 with white arrows indicating locations of increment cores taken from the lower trunk and trunk base. **B** – Lithograph by Edward Ardizzone illustrating the tree's already recumbent form in 1964 (Source: Bonhams.com).

Figure 3. A second collapsed Mulberry tree M2 at the southern end of Preacher's Court. M2 had previously fallen under its own weight and a number of branches were subsequently pruned on 11 July 2019. Digital images were taken of four branches (Branches A-D) in addition to tree increment coring on 12 February 2020. The pruned end of Branch C was only visible from a westerly direction – back left of main image.

Figure 4. Image of Branch D (Mulberry M2). All tree ring boundaries including sapwood (not clearly distinguishable) were clearly visible following loss of moisture caused by natural drying and these were highlighted on the image using short blue lines in Microscoft Powerpoint (bark also evident adjacent to ring number 69). Ring-width measurements were subsequently made from this annotated image.

Figure 5. Mulberry M4 growing against the south-west wall of The Charterhouse, adjacent to Charterhouse Square. An increment core was taken from the base of the inclined trunk indicated by a white arrow (**A**) and the blue handle of the Haglof borer still inserted within the tree during sampling (**B**). The red-handled device (**B**) is a borer starter that facilitates initial engagement of the borer into the bark.

In an attempt to date CH_Mulberry, this chronology was compared with ring-width measurements of pruned branches from mulberry M2. Although branches A-C demonstrated some consistency in their growth patterns, they comprised relatively short sequences (19, 45, 18 years respectively) which were unsuitable for dendrochronological comparisons. Branch D however produced a 69 year ring-width record with the most recent ring formed in AD 2019 (see Figure 4). Cross-matching of the ring-width records of Branch D and CH_Mulberry produced a relatively low correlation (t = 4.91 –

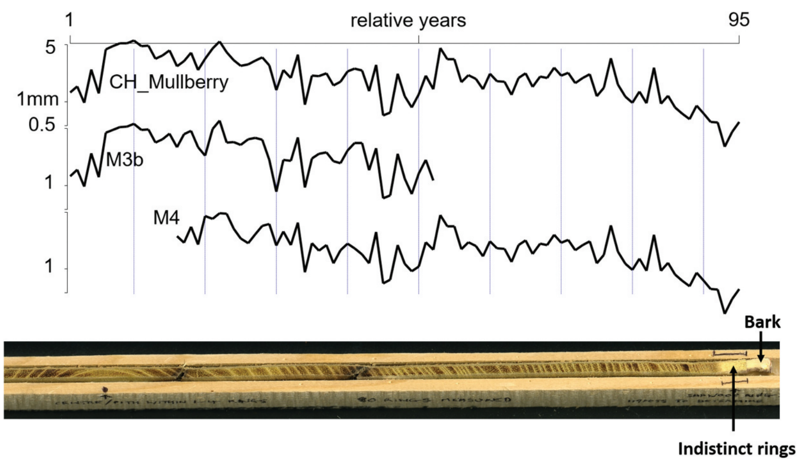

Figure 6. Initial tree-ring chronology CH_Mulberry, an averaged growth record based on ring-widths from trees M3 (core M3b) and M4. The image of core M4 illustrates indistinct sapwood rings adjacent to the bark.

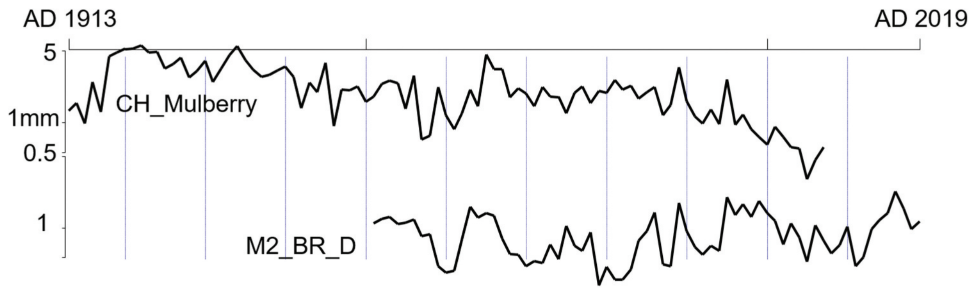

Figure 7. Chronology CH_Mulberry dated from AD 1913 to AD 2007 with reference to M2 Branch D (AD 1951–2019).

comparisons of branch and trunk wood, even for trees growing in relatively close proximity with similar growth environments/factors are expected to have lower correlation values than for tree-ring widths from trunks alone – see Discussion). However manual comparison of these tree-ring curves demonstrated a good fit between the two growth responses, with key wide and narrow rings perfectly aligned throughout the growth sequences (see Figure 7), allowing CH_Mulberry to be assigned the dates AD 1913 – AD 2007.

Ring-width measurements of two cores from mulberry M2 (M2_N and M2_NE_R2) gave both a good statistical agreement (t = 6.09) and a good visual agreement, and these were therefore combined to create a mean growth record for this tree (M2_M) – Figure 8(a). M2_M was then dated from AD 1901 – AD 1981 by comparison with M3b (t = 5.25; Figure 8(b)). Both M2_N and M2_NE_R2 were previously undated due to poor ring visibility, including the recurring issue of indistinct sapwood rings.

Discussion

Accurate aging of living trees using dendrochronology is dependent on coring at the base of the trunk to sample a complete growth series from germination (Thomas, 2000, pp. 37–39; Smith & Lewis, 2007, p. 992), but this is rarely possible due to the presence of the ground surface and requirement to turn the rigid handle of an increment borer at 90° to the borer shaft (recent advances in borer design have added flexible/articulated handles to some borer types, but these were not available for this research). If an increment core contains the centre of the tree or pith (strengthening tissue formed by the tree as it extends) it is possible to provide an exact age for the tree, but only at the height above the ground that the tree was cored (Speer, 2010, p. 50). Accordingly, the dates achieved by dendrochronology for the Charterhouse mulberries must be considered under-estimates of tree age, even though most cores were taken as close as possible to the base of the trunks. M3 and M4 for example were dated to circa AD 1909 and circa AD 1923 respectively based on their tree-ring series, but their germination potentially occurred a decade or more prior to these dates as they were sampled 32 cm and 30 cm from the base of their trunks respectively (Table 1 provides details of the cores and images retrieved from mulberry trees M1-4, their subsequent dendrochronological analyses and dating).

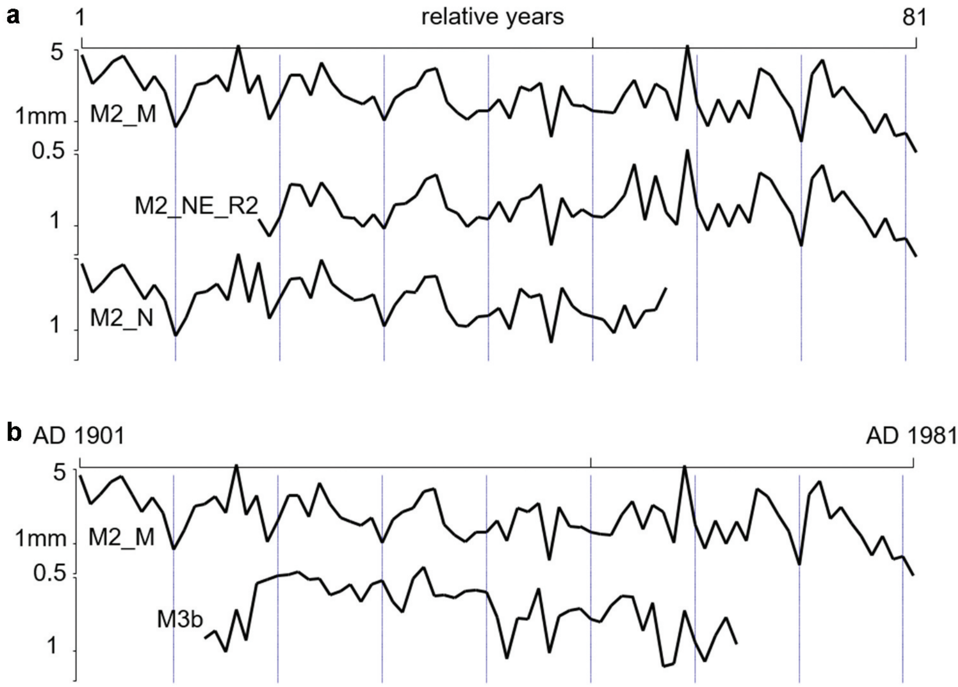

Figure 8. **A** – Creating a mean growth record for Mulberry M2 (M2_M) using ring-width measurements from two cores from the tree's lower trunk, M_NE_R2 and M2_N. **B –** Dating M2 (M2_M) with reference to the ring-width record M3b (component of chronology CH_Mulberry).

Mulberry trees M1 and M2 from Preacher's Court were initially thought to be the oldest based on their larger forms. Whilst samples taken from M1 were insufficient to establish any convincing estimate of age other than that the tree exceeded 80 years, it was possible to date the earliest ring sampled from M2 to AD 1901 (Figure 8; Table 1). As this ring (from core M2_N) was estimated to be located < 5 years from the pith, a minimum age of AD 1897 was assigned to mulberry M2 using dendrochronology, with actual germination probably 10 or more years before (as discussed previously).

During this research historic images of Preacher's Court were discovered, including an illustration of Mulberry M1 as viewed by the artist and illustrator Edward Ardizzone in AD 1964 (Figure 2(b)). Leathart noted that White Mulberry (*M. alba*) has never really succeeded as an ornamental and fruit-producing tree in Britain referring to it as a small "often tortuous" tree rarely exceeding 12 m (Leathart, 1991, pp. 184–185), a description that can also be applied to *M. nigra*. This is borne out by Ardizzone's illustration of M1, and also by observations of living trees. A specimen from the southeast of England and known to have been planted in the 1970s *"has the appearance* [in AD 2021] *of an old tree with some of the branches splitting away from the trunk."* (Arbury pers. comm.). The present-day growth and vitality of M1 in comparison to its form in AD 1964 is also worthy of note [also M2] and may be of surprise to some (Figure 2).

Additionally, images of a postcard were forthcoming depicting "The Charterhouse, Outer Quadrangle". The postcard is identified as "London. The Wrench Series 7997" (Figure 9; Isherwood pers. comm.), which can be traced to a range of postcards

Table 1. Summary of samples retrieved from mulberry trees M1-M4, their subsequent analyses and in a number of cases dating.

Tree	Lab code	Sample type	Indistinct rings not measured	Rot	Visible sapwood rings	N° Rings measured	Pith	Bark	Dating
M1	M1_N	core		✓	x	40	x	✓	
	M1_NW	core – lower trunk	✓		x	80	10>	✓	
M2	M2_N	core – lower trunk	✓		x	57	5>	✓	AD 1901–1957
	M2_NE_R2	core – lower trunk	✓		x	64	10>	✓	AD 1917–1981
	M2_M	mean	n/a	n/a	n/a	n/a	n/a	n/a	AD 1901–1981
	M2_BR_A	image – branch			✓	19	✓	✓	AD 2001–2019
	M2_BR_B	image – branch			✓	45	✓	✓	AD 1975–2019
	M2_BR_C	image – branch			✓	18	✓	✓	AD 2002–2019
	M2_BR_D	image – branch			✓	69	5>	✓	AD 1951–2019
M3	M3a	core – lower trunk	✓		x	53	x	x	
	M3b				x	52	5>	x	AD 1913–1964
M4	M4	core – lower trunk	✓		x	80	5>	✓	AD 1927–2007

produced by (John) Evelyn Leslie Wrench (Wrench Postcards Ltd.) between AD 1900–1904 and AD 1904–06 (British Museum, No Date). The postcard image is clearly of Preacher's Court and includes three juvenile fruit trees (most probably M1, M2 and a third tree in the centre with a smaller canopy that is no longer extant). The postcard's franking records a date of 30 September 1905.

Mr Jim Arbury (Curatorial & Horticultural Specialist, Royal Horticultural Society) kindly viewed the postcard image and based on knowledge of present-day mulberry trees growing at RHS Wisley (near Woking circa 25 kms southwest of The Charterhouse) he considered that due to the narrow, smooth trunk with no thick or cracked bark and its general stature, the right hand tree (probably M2) captured on the postcard (Figure 9) was likely to have been 25–30 years old at the time of the image (Arbury pers. comm.). As the photograph was probably taken especially for the postcard series, it is likely to date from circa AD 1900 and a germination date for mulberry M2 of circa AD 1870–1880 therefore does not seem unreasonable. This estimate coincides well with that previously obtained using dendrochronology, AD 1887 or earlier.

Although neither dendrochronological nor the photographic evidence can pin-point the exact germination date for Charterhouse mulberry M2, the previous discussion suggests that the tree could well have been planted as a nursery-grown sapling in the 1880s or 1890s, and that the Preacher's Court plantings might well have commemorated Queen Victoria's Golden or Diamond Jubilees (in AD 1887 and AD 1897).

As with other types of fruit tree, mulberries present a number of challenges to a dendrochronologist. Central rot leading to loss of growth rings can be a common

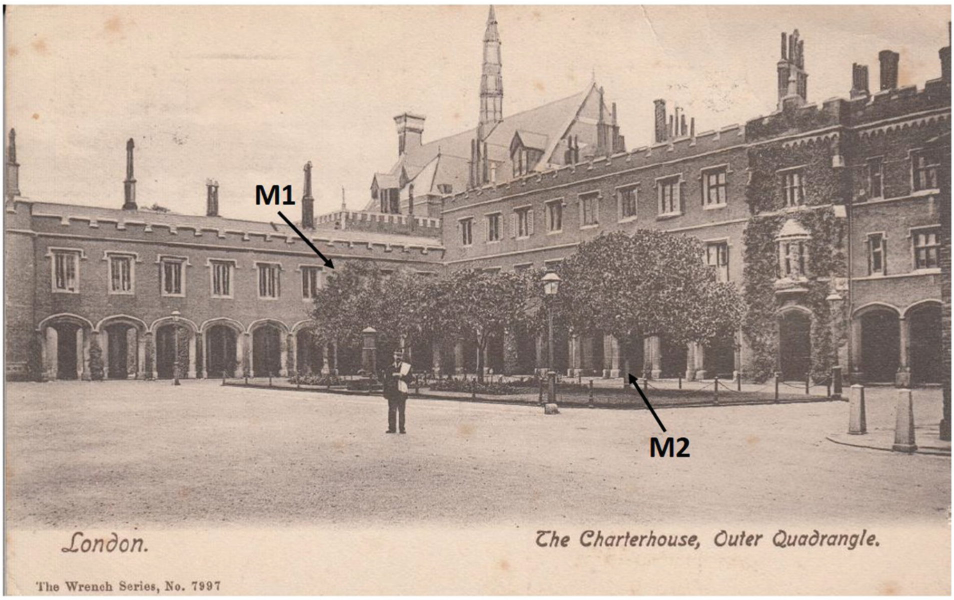

Figure 9. An early postcard of The Charterhouse's Preacher's Court ("Outer Quadrangle") viewed from the south-west and showing youthful Mulberries M1 and M2. Postcard franking dated "30 September 1905".

issue, particularly where trunks and branches have been trained or have begun to lean (Lageard & Billington, 2008). However, whilst the distinct heartwood of living mulberry trees (*M. alba* & *M. nigra* cannot be differentiated based on wood anatomy) reveals a greeny-yellow ring porous structure (Figure 6: Schweingruber, 1990, p. 553) permitting generally easy definition of growth rings, the pale-yellow sapwood is a significant barrier to both tree-ring differentiation and measurement (M2 Branch D sapwood visibility – see Figure 4 caption). This issue can prevent dating living trees to calendar years, but was overcome in this research by measuring the ring-widths of a long-lived pruned branch (M2 Branch D), which was then correlated or cross-matched with heartwood rings to date chronology CH_Mulberry and subsequently mulberry M2 (also helping to establish that mulberry M4 contained 12 sapwood rings – see Figures 6 and 7).

Trees grow by adding a layer of wood over the whole tree including any branches. All branches can be traced back to the middle of the trunk from which they are growing, and although tree rings are generally thicker in a tree trunk, rings forming in branches are directly related to those of the trunk and their ring-widths are governed by the similar growth factors (Grace, Blundell, & Pont, 1998; Thomas, 2000, p. 66). Branch rings, as well as appearing smaller can also however be distorted or eccentric due to their normally inclined rather than vertical development (Thomas, 2000). The use of Branch D (M2) in dating mulberry trees at The Charterhouse should therefore reflect standard dedrochronological practice. However, what is surprising is the limited use of branch rings and their measurements previously reported in the literature. Whilst research has investigated branch wood properties in a range of fruit trees (Passialis & Grigoriou, 1999), tension wood in *Populus nigra* (Lautner, Zollfrank, & Fromm, 2012), branch diameters using laser scanning (*Quercus petraea* – Dassot, Fournier, & Deleuze, 2019) and rates of branch growth in tropical trees (Nicolini et al., 2012), comparatively few studies have featured ring-width measurements and dendrochronological analyses. Exceptions have revealed the effects of pruning on *Prosopis flexuosa* semi-arid woodlands in South America (Giantomasi, Alvarez, Villagra, Debandi, & Roig-Juñent, 2015) and a small number of studies focussing on branch wood in archaeological contexts (Billamboz, 2008; Pichler et al., 2013; Rybníček et al., 2018).

Conclusion

This investigation of old Mulberry trees (*M. nigra*) that have survived at The Charterhouse since their planting in the late nineteenth and early twentieth centuries contributes to the limited body of existing research that has applied dendrochronology to the aging of fruit trees. It has demonstrated that issues associated with the visibility of sapwood rings can be overcome using measurements of branch wood growth to facilitate dendrochronological dating. Further it also highlights that such dating often provides under-estimates of actual tree age and that aging trees in such circumstances is best undertaken when combined with other information such as from historic images and from horticultural experience.

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Disclosure statement

No potential conflict of interest was reported by the author.

Data

Ring-width data files for series M3b, M4, M2_M, M2_BR_D and chronology CH_Mulberry are available in Supplementary Information.

Notes on contributor

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