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Veteran trees in an historic landscape: The Bidnija olive grove, Malta

Jonathan G.A. Lageard [a,*], Daniel Sultana [b,c], Francis Q. Brearley [a]

[a] Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK
[b] Junior College, University of Malta, Msida MSD 2080, Malta
[c] Environment and Resource Authority, Hexagon House, Marsa MRS 1441, Malta

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ABSTRACT

The ages of veteran olive trees forming a grove located in the north of the island of Malta were investigated using radiocarbon dating. This approach revealed that trees from the Bidnija grove were established during the mid-late Medieval period, before CE 1450–1669, rather than in considerably earlier Roman times when the surrounding agrarian landscape was thought to be an important production area for olives. This dating exercise highlights not only the potential for inter-disciplinary research, but also the need for caution when seeking to establish links between living veteran trees, archaeological evidence in the landscape and sedimentary records containing vegetation history

1. Introduction

Olive trees (*Olea europaea*) are closely-identified with the Mediterranean region historically, culturally and economically, dominating much of contemporary rural landscapes with over 10 million hectares under cultivation (Loumou and Giourga, 2003; Kaniewski et al., 2012; Newton et al., 2014; Gambin et al., 2016). They have a natural Mediterranean biogeographical distribution and have been present for much of the Pleistocene with pollen records from the early Holocene indicating that the Mediterranean was likely to have offered long-term refugia for the species (Langgut et al., 2019). Their distribution has been expanded by domestication (Polunin and Walters, 1985; Guerrero Maldonado et al., 2016; Langgut et al., 2019), and the significance of olive trees in Mediterranean cultural landscapes is evident at least as far back as circa 400 BCE when tenants in the Greek colony of Heraklea (present day North Macedonia) were 'required to build houses and barns, and to plant vineyards with olives amongst them', and as Spanish place names including *jara* and *xara* denoting 'wild olive' reference Moorish conquest from the eighth century onwards (Grove and Rackham 2001: 173, 175). Although palynological studies cannot differentiate pollen emanating from wild or domesticated trees, it has recently been possible to utilise increases in subfossil olive pollen, independent of other taxa, together with archaeological and archaeobotanical evidence, to definitively trace the westward spread of olive agriculture across the Mediterranean (Langgut et al., 2019). These conclusions support previous studies that identified the origins of domestication in the Near East (Liphschitz et al., 1991; Kaniewski et al., 2012; Besnard et al., 2018). Molecular analyses have provided further compelling evidence on the origin of veteran trees in the Mediterranean. Studies on old *Castanea sativa* in Italy and the Iberian peninsula have provided evidence of domestication by grafting in the fifteenth century (Pereira-Lorenzo et al., 2019), and of two main genepools possibly relating to glacial refugia (Mattioni et al., 2020). Similar research on cultivated and wild olives also identified separate genepools, in the eastern, central and western Mediterranean, but although these may represent local domestication events, the genetic evidence points to a major initial eastern Mediterranean event (Diez et al., 2015). These findings support the conclusions of Besnard et al. (2013) and others, and help to unravel the complexities revealed in the olive genome (Barghini et al., 2014).

Cultivation of olives is thought to have taken place on more marginal land following the initial domestication of grain crops such as wheat, permitting the development of sedentary agricultural communities and creating the Mediterranean 'village economy' (Cañellas-Boltà et al., 2018; Langgut et al., 2019). Archaeological investigations have also utilised the remains of olive production and consumption, for instance the morphology of olive stones, to demonstrate the use of both wild and domesticated plants and selection for improved varieties (Bourgeon et al., 2018). The use of irrigation in both wild and cultivated olives has also been revealed from charcoal evidence collected from Medieval sites in France and Spain (Terral and Durand, 2006), whilst processing residues are thought to have provided a dense, high-quality fuel source (Braadbaart et al., 2016). Olive wood was used in construction, as well

* Corresponding author.
E-mail address: j.a.lageard@mmu.ac.uk (J.G.A. Lageard).

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as for domestic and agrarian objects (Liphschitz et al., 1991). The physical remains of processing sites, such as olive presses made of stone and their associated infrastructure, are used as primary evidence of past olive oil production, but their dating can be problematic, not least as presses could have remained in use for centuries (Langgut et al., 2019). Evidence for processing sites have been identified throughout the Mediterranean, as far back as 7600–7000 years BP in the eastern Levant (Galili et al., 2018).

Veteran olive trees are often seen as tangible links with past agrarian landscapes, but their dating has proved problematic. Ideally, dating would be achieved using standard dendrochronological techniques as applied to species such as oak (*Quercus* spp.) that demonstrate more consistent or regular growth patterns (Haneca et al., 2009). However, due to the small cells in the anatomical structure of olive wood, at times indistinct growth rings, contorted growth patterns and the propensity of olive trees to develop hollow trunks (Schweingruber, 1990; Bernabei, 2015; Ehrlich et al., 2017), this technique is often both controversial and infrequently applied to *Olea europaea* (Cherubini et al., 2013, 2014; Friedrich et al., 2006, 2014). These issues were graphically illustrated by Arnan et al. (2012) who investigated 'monumental' or veteran olive trees from north-eastern Spain. They utilised tree girth and ring-width measurements from younger trees with complete ring series records (pith to bark) to estimate the age of older trees with hollow centres. Applying methodologies developed by Clark and Hallgren (2004), they were able to develop a relationship between olive tree diameter and age, estimating that the oldest tree of the 14 trees analysed had lived for 627 + 110 years (Arnan et al., 2012). Although this is one of the oldest olive trees reported, it fails to live up to often held expectations that veteran olives must have lived for millennia. Similar debates have occurred with other species such as yew (*Taxus baccata*) that develop hollow centres in senescence and that exhibit irregular growth patterns leading to sometimes contentious estimates of age (Chetan and Brueton, 1994; Hindson et al., 2019).

Alternative dating for olive and other veteran trees has been provided by radiocarbon (^{14}C) analysis (cf Chen et al., 2019; Patrut et al., 2020). There are, however, considerable difficulties in applying the technique to samples of 'recent' age (circa last 400 years) due to potential errors (sampling or contamination), the non-linear relationship between ^{14}C concentrations and age over the last c. 400 years (Bronk Ramsey et al., 2001) and issues due to atomic weapons testing from the mid-twentieth century (Ehrlich et al., 2017). Radiocarbon dating has, however, been carefully applied to large veteran olive trees of *'impressive size and appearance'* in the Garden of Gethsemane (Israel), with samples from central wood and younger trunk wood combined with estimated growth rates to date three trees to the 12th century (Bernabei, 2015). Bernabei did however, highlight the often considerable issues associated with sampling within the centre of old trees due to their irregular trunk shapes, hollow centres and venerated status. Despite the issues associated with radiocarbon dating, consistency has been demonstrated between tree–ring and ^{14}C approaches providing some confidence that the maximum ages of 'monumental' living olive trees normally range between 300 and 500 years (Camarero et al., 2021).

In this study, we sought to estimate the age of veteran olive trees from the Bidnija olive grove in central northern Malta and to consider their significance within the wider cultural landscape. The latter is evidenced by a local concentration of archaeological finds indicating the presence of a significant olive production area dating back to Roman times (Bonanno, 2005; Gambin et al., 2016). The nutrient status of the trees, the soil in the olive grove and in the surrounding agricultural environment, were also investigated and will be reported elsewhere.

2. Methods

2.1. Site

The Bidnija olive grove (Iż-Żebbuġ tal-Bidnija - *Bidni* means olive in Maltese) comprises 20 veteran trees (Fig. 1A) located close to the village of Bidnija, 3 km north-west of the town of Mosta in northern Malta. DNA analyses have demonstrated that grafts from the Bidnija trees were clones (Mazzitelli et al., 2015), and were thought to be of the old indigenous Bidni variety (Farrugia – Malta Independent, 2011; Mazzitelli et al., 2015). All the trees in the grove have been pollarded at a height of around 2 m, but several are now in more recumbent or collapsed growth forms due to their advanced age and largely hollow centres (see images in Additional Information). Although the precise timing of pollarding is unknown, well-established 'poles' and some sizable branches (Fig. 1A), support an extensive, productive and almost complete single canopy covering the entire grove site (Farrugia – Malta Independent 2011; see Additional Information).

The site is surrounded by small fields, typical of the island's agricultural cultivation and is adjacent to a small limestone promontory on which the remains of a Roman-age villa, Tal-Bidni, were discovered in 1912 (Superintendence of Cultural Heritage, 2011). The grove is one of the few places where veteran trees still grow on the Maltese islands and is protected by law (Government of Malta, 1933). Other similar localities include old individual carob (*Ceratonia siliqua*) trees and remnants of medieval holm oak (*Quercus ilex*) hunting forests (ERA No date).

3. Field sampling

The Bidnija olive grove was visited in January 2016 to map and sample the olive trees. The grove comprised 20 veteran trees, all apparently subject to central rot / decay and hence with hollow trunks (Fig. 1B). Access to the hollow centres of some of the trees was possible, and six trees (T1, T5, T8, T17, T18, T20 – see Fig. 2D) appeared to contain intact central wood 5–20 cm from the base of the trunk (see Fig. 3). Small samples of wood were removed from these trunk localities using a pruning saw to provide material for ^{14}C dating. Sampling took place under special licence (Removal of Biological Material - Malta Environmental Protection Act 2001) and was overseen by the Malta Environment and Planning Authority (now the Environment Resources Authority).

4. Radiocarbon dating

Wood samples were taken from each tree where heartwood remained very close to the geographical centre of the largely hollow trunk. The precise number of tree rings sampled for these analyses from each tree was impossible to calculate given the generally poor visibility of ring boundaries (see Fig. 3), but was likely to cover a period of less than one decade in each instance.

It should also be emphasised that whilst the wood samples emanated from very close to the centres of the trees, for example T8 and T18 were demonstrably close to a central pith (Fig. 3A and B), the possibility of the presence of multiple piths, potentially of differing ages, cannot be ruled out. Ehrlich et al. (2017) demonstrated the presence of multiple central piths on a transverse trunk section sawn from a dead olive tree, that were likely to have developed due to branching at an early age or from a cut stump or stool created by coppice type regeneration (coppicing is recommended in sustainable olive oil production, including the potential to 'renew' old trees - Cantini et al., 1998). Ehrlich et al., (2017) calculated pith ages varying between 1840 and 1920 CE for this relatively young tree and suggested that this date range represented a *terminus ante quem*, also observing that the main branching in olive trees is thought to occur during the first years of the trees growth (Ben Sadok et al., 2013 cited by Ehrlich et al., 2017).

Whilst the Bidnija olive trees also demonstrated prior management, this took the form of pollarding around 2 m above the ground producing relatively tall pollards rather than coppices (see Additional Information). Tall pollards may develop branches at lower heights, towards the base of the trunk (cf Ben Sadok et al., 2013), but these are likely to have been starved of light (or have been pruned) and to have died at a

Fig. 1. A: Veteran *Olea europaea* trees in the Bidnija grove, Malta. B: A hollow olive tree trunk demonstrating a lack of heartwood in the centre of the tree at about 1.3 m height.

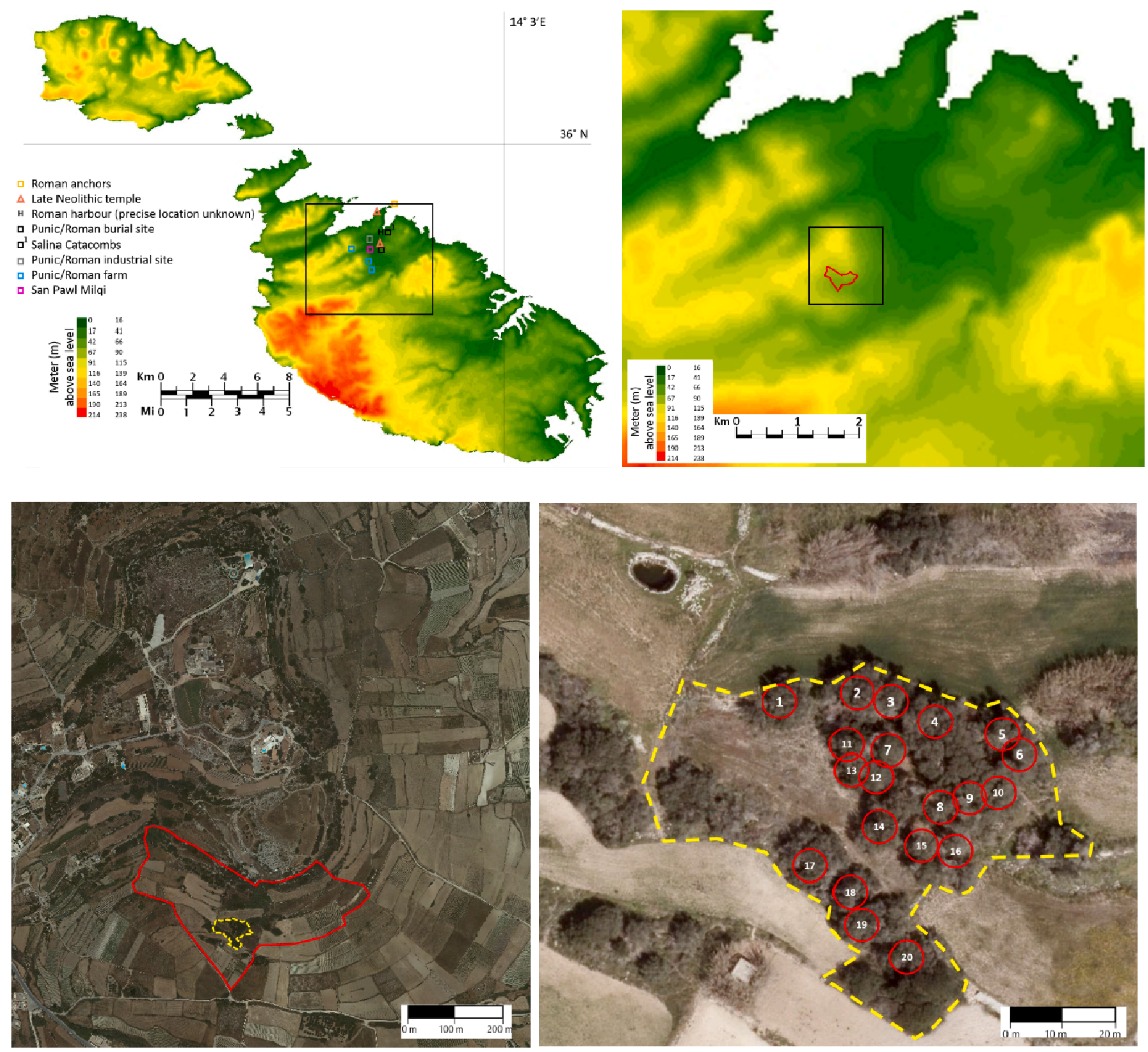

Fig. 2. Study area highlighted in the north of the island of Malta (A), including the locations of key archaeological sites mentioned in the text (based on Bonanno, 2005; Marriner et al., 2012). The Burmarrad catchment (B) and location of the Bidnija olive grove tree protection area (red boundary). Orthophoto showing the location of the Bidnija olive grove within the tree protection area (C) and position relative to adjacent fields, limestone promontory - site of the Tal-Bidni Roman villa. Locations of the 20 veteran olive trees comprising the Bidnija grove (D). Sources: (A-B) Digital terrain model generated from the European DEM (EU-DEM) version 1.1 (E40 N10); (C-D) Orthophoto: Malta Environment and Planning Authority (2012), Development of Environmental Monitoring Strategy and Environmental Monitoring Baseline Surveys (Lot 2).

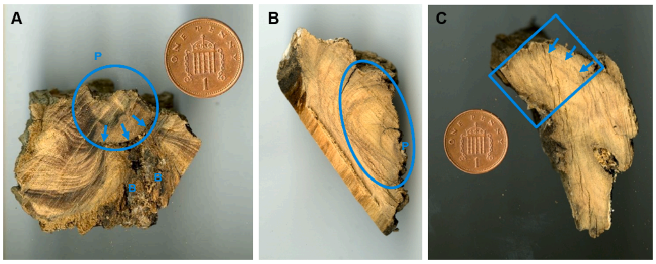

Fig. 3. Samples retrieved from heartwood at the geographical centres of olive trunks T8 (A), T18 (B) and T17 (C) in the Bidnija grove, Malta. Blue boundaries highlight areas sub-sampled for ^{14}C dating. Note the tight curvature of the tree-ring/s visible in T8 (a clearly curved ring boundary is visible, made prominent by a scarring injury inflicted on the tree at an early age: see arrows, B - bark inclusions; P – putative pith location) and T18 indicating likely proximity to the pith, contrasting with the more elongated ring boundaries (see arrows) in T17 [coin scale: 2 cm diameter].

relatively early age leaving small areas of multiple piths close to the centre of the tree. These would contrast with the larger pith areas illustrated in Ehrich et al's coppiced sample (Ehrlich et al., 2017: 4), and pollards are therefore expected to have fewer central piths than a coppiced tree (Peter Thomas pers. comm.). There was no evidence of multiple shoots or the development of stools in any of the Bidnija trees (see Additional Information) and the wood samples taken for this research are therefore thought to originate from close to the central stems of the chosen trees. Radiocarbon age estimates in this research should however be considered *termini ante quem* for the reasons mentioned previously, and also due to the potential presence of modern carbon from fungal hyphae associated with rot within the tree trunks. No rot or hyphae were visible on any of the wood samples sent for dating, but exposed outer surfaces were carefully removed as a precaution.

All samples were cleaned and sub-sampled, carefully avoiding contamination at every stage (between samples and with external environments: field and laboratory), to provide sufficient material for ^{14}C dating. Samples from six separate trees weighing between 2 and 6 g each were sent to Beta Analytic, Miami, USA for acid/alkali/acid pre-treatment and standard AMS ^{14}C analysis. Radiocarbon age estimates were calibrated using OxCal v 4.4.2 (Bronk Ramsey et al., 2001) and IntCal20 (Reimer et al., 2020).

5. Results

The results of the ^{14}C dating are presented in Table 1 and demonstrate a certain degree of uniformity. Dates for trees T8, T18 and T20, from wood samples thought to have come from close to a central pith (see Fig. 3), fall for the most part within the 2 sigma calibrated age range of CE 1450–1669. Although multiple samples were not taken from individual trees, the similarity in their general appearance, size and management history (tall pollards), provide reasonable assurance that the ^{14}C age estimates date the Bidnija grove to the mid- to late-Medieval period. Growth rates (cf Arnan et al., 2012; Bernabei, 2015) were not estimated due to the lack of trunk wood, as well as limitations placed on the amount of wood sampled.

6. Discussion

The Bidnija olive grove lies close to the headwaters of the second largest catchment (Burmarrad) on the island of Malta, and its topography has led to the development of a considerable tract of fertile agricultural land. The catchment's confluence with the north-eastern coast (Salina Bay) has also provided the area with good transport and communications since the Roman period in Malta (BCE 218 – CE 535: Bonanno, 2005) and probably further back in time (Marriner et al., 2012).

A second Roman invasion in 218 BCE marked Malta's inclusion in the Roman 'Commonwealth' and archaeological discoveries throughout the islands have shown that villas were built, often performing both residential and agrarian industrial functions (Bonanno, 2005). Excavations in the 1960s found that one of the larger of these sites, San Pawl Milqi, contained considerable infrastructure associated with the production of olive oil (two olive presses, *prela* and several olive crushers, *trapeta:* Bonanno, 2005; Cefai et al., 2005). San Pawl Milqi and two smaller Roman-age villas also containing evidence of olive processing (including Tal-Bidni: Docter et al., 2012), are located on the lower slopes of the Burmarrad catchment. Together these are thought to represent important components in an historic agrarian landscape that was geared to olive oil production for export, rather than solely for local needs (Gambin, 2005, cited by Marriner et al., 2012). This contention is further supported by evidence of Roman usage of the sheltered natural harbour provided by the ria of Salina Bay, including Roman anchor stocks found off Qwara Point, and a *hypogea* or burial site immediately to the south east indicating a sizable late-Roman community (Buhagiar, 1984; Bonanno, 2005; Marriner et al., 2012).

Bonanno (2005: 180) has observed that for Malta as a whole, despite '*olive oil production implying extensive olive groves surrounding these country villas, no trace of which* [sic has] *survived in the twentieth century*.' This is an understandable assertion given that the islands are largely devoid of trees of any significant age in the present day. Others, however, have implied a connection between old living trees and the historic landscape. In their discussion of the island's vegetation history, reconstructed from sediment cores and their palynological records taken in the Burmarrad catchment, Gambin et al. (2016: 287) state that olive production in the Burmarrad area during the Roman period is supported by '…*the nearby presence of an ancient grove* [the Bidnija trees] *that is situated next to a surveyed, but unexcavated Roman villa* [Tal-Bidni]…'. Such observations have led to the widely held assumption that due to their appearance and

Table 1
Conventional AMS radiocarbon age and calibrated age ranges (Bronk Ramsey et al., 2001; Reimer et al., 2020) for wood samples taken from central trunk localities within hollow veteran olive trees at the Bidnija grove.

Tree	Sample adjacent to pith	Lab. code	Lab ID.	Radiocarbon date [error] (^{14}C years BP)	Cal CE range, 1σ (probability)	Cal CE range, 2σ (probability)
T1	x	BIDNIJA 01	Beta-446579	60 [± 30]	1698 - 1722 (23.2%), 1814 - 1834 (21.1%), 1886 - 1909 (24.0%)	1694 - 1726 (26.8%), 1810 - 1918 (68.6%)
T5	x	BIDNIJA 05	Beta-446580	180 [± 30]	1666 - 1686 (13.3%), 1732 - 1784 (34.4.%), 1795 - 1806 (6.2), 1926 - modern (14.4%)	1655 - 1698 (19.3%), 1722 - 1814 (50.1%), 1836 - 1883 (7.5%), 1910 - modern (18.6%)
T8	✓	BIDNIJA 08	Beta-446581	370 [± 30]	1459 - 1515 (44.5%), 1590 - 1620 (23.8%)	1450 - 1528 (52.3%), 1551 - 1634 (43.1%)
T17	x	BIDNIJA 17	Beta-446582	110 [± 30]	1694 - 1725 (17.2%), 1812 - 1916 (51.0%)	1682 - 1738 (25.7%), 1754 - 1762 (1.1%), 1801 - 1938 (68.6%)
T18	✓	BIDNIJA 18	Beta-446583	270 [± 30]	1526 - 1556 (26.9%), 1632 - 1662 (39.7%), 1788 - 1791 (1.6%)	1510 - 1593 (43.0%), 1618 - 1669 (45.7%), 1780 - 1798 (6.7%)
T20	✓	BIDNIJA 20	Beta-446584	340 [± 30]	1494 - 1525 (21.9%), 1557 - 1602 (31.3%), 1609 - 1631 (15.1%)	1474 - 1638 (95.4%)

undoubted age, the Bidnija trees must be relics contemporary with the Roman historic landscape (Farrugia – Malta Independent, 2011; Heritage Malta, No Date).

Estimating the age of hollow olive trees depends not only on gaining access to trunk cavities, but also on obtaining wood that is close to a central pith or tree stem, if any remain/s, for ^{14}C analysis. Ehrlich et al. (2017) demonstrated that olive trees may have multiple central piths dating from when trees start to branch at an early age or when they regenerate from a previously cut stump or coppiced stool. Dating these 'false' centres therefore provide underestimates of tree age. In the case of the Bidnija olives we have demonstrated that these tall pollards (2 m +) provided samples close to the geographical centres of largely hollow trunk cavities, that were close to ground level. These samples are likely to have been adjacent to the original central tree stems, and therefore their associated ^{14}C dates provide realistic estimates of tree age, albeit *termini ante quem*. Three of the six wood samples ^{14}C dated in this study (T8, T18, T20), although appearing not to contain any actual pith material, originated very close to the centre of the tree (see Fig. 3A & 3B) and their calibrated age ranges provided appropriate replication (falling between CE 1450 – 1669: Table 1). Whilst this dating outcome demonstrates that these ^{14}C analyses only represent age estimates and not precise dates, the age of the Bidnija trees can be narrowed down to the mid- to late-Middle Ages, i.e. 15-17th centuries or slightly earlier. Reflecting on the physical attributes of these trees, they are certainly not as 'monumental' in their appearance as the 12th century trees from Gethsemane (Bernabei, 2015: 44), and although environmental conditions are certainly important considerations in determining growth rates (e.g. Pigot, 1989, cited by Bernabei, 2015), this estimate of age for the Bidnija grove seems reasonable, and also conforms to recent estimated ages for living veteran olive trees (Camarero et al., 2021).

Olive trees dated from Gethsemane (Bernabei, 2015), Bidnija (this study) and other locations (Parker and Lewington, 2012) were anecdotally reported to have lived for millennia, but in actuality there is a considerable mismatch between their scientifically-established ages and more romantic notions of age associated with historic circumstances and associated archaeological landscapes. This highlights issues relating to boundaries between academic disciplines, and to the correlation of insecurely-dated proxy records.

Veteran trees are recognised for their ecological values and landscape/historic importance where they have survived to the present-day (Rackham, 2003; Lonsdale, 2013), and their persistence in the landscape can be confirmed using ecological, pedological, historical and archaeological evidence (Spencer and Kirby, 1992; Rotherham, 2011). Archaeology in such landscapes can be related to past woodland exploitation such as the production of charcoal and evidence of 'worked' trees (Petit and Watkins, 2003; Rotherham and Ardron, 2006), but there may also be evidence of interruptions in tree cover or treeless phases in these environments (Day, 1993; Schöne and Schweingruber, 2001; Hazell et al., 2017). Despite old trees and ancient woodland being '*a living record of past woodland management practices and the organization of the landscape*' (Rotherham, 2011: 161), wooded landscapes rarely feature in archaeological investigations, which can ignore trees and be preoccupied with the site-specific rather than broader spatial interpretations (Rotherham and Ardron, 2006). A recent exception has been a study linking old trees in northeast Greece to sacred sites, demonstrating their cultural importance and their use in demarcating and possibly guarding communities from external environments (Stora et al., 2015). This work based its assessment of old trees on their diameter, and whilst this may provide some indication of actual age, there are pitfalls in this approach (Lennon, 2009). In environments such as those of the Mediterranean, there is certainly considerable scope for future ageing of remnant veteran trees and an assessment of their significance and relevance to wider archaeological landscapes.

It is also interesting to consider the Bidnija trees in relation to vegetational history. The 10 m deep core from the Burmarrad catchment (Gambin et al., 2016), contained hiatuses in sedimentation and phases of sparse pollen, but also sufficient subfossil *Olea* pollen to be able to trace the local history of this taxon during significant parts of the Holocene. There was an expansion of *Olea* during the Neolithic 'Temple' period (6050–4450 cal BP) mirroring similar increases elsewhere in the Mediterranean, thought to be related to the expansion of agrarian technology. A later increase in *Olea* pollen (c. 1800 cal BP) is linked to the increase in olive production in the catchment during the Roman period (see previous discussion of the local archaeology and the implied age of the Bidnija trees). If the Bidnija trees had been dated to the Roman period, comparison would have been possible with the results of pollen analysis on contemporaneous sediment from the Burmarrad core between 2000 and 1700 cal BP. This is now precluded by the mid-late Medieval date for the Bidnija grove, as analyses were not reported above 200 cm core depth (Gambin et al., 2016). Caution therefore needs to be exercised not only when dating old trees, but also when identifying comparable pollen depositional records of appropriate age and resolution.

7. Conclusion

The olive trees that comprise the Bidnija grove in Malta are clearly old, with gnarled and hollow trunks, and they can certainly be termed 'veteran' (Lonsdale, 2013). Their likely mid- to late-Medieval age, as established by this research, has however highlighted erroneous links previously drawn between these remnant olive trees and the surrounding rich cultural landscape (previous archaeological investigations have revealed significant olive oil production during the period of Roman influence in the Maltese islands, BCE 218 – CE 535). The Bidnija pollards could of course indicate a similar land use in this locality as far back as the Roman period and possibly beyond, and the present-day living trees would therefore represent a relatively recent phase in a continuum of replanting and management – pollarding has a longer more continuous history in the Mediterranean compared to elsewhere in Europe (Petit and Watkins, 2003). There are clearly opportunities for future research that assesses the age and significance of veteran trees in historic / archaeological landscapes (cf Kirby and Watkins, 1998; Stora et al., 2015), particularly in the Mediterranean, but the Bidnija grove also highlights that interdisciplinary synergies between accurate dating of trees, archaeological contexts and sedimentary records remain crucial.

Declaration of Competing Interest

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

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Appendix A. Supplementary data

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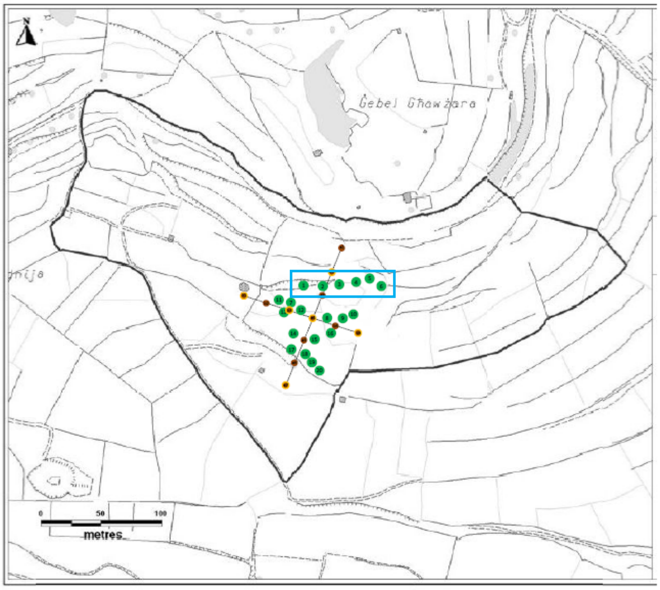
Additional Information:

Lageard et al **Veteran trees in an historic landscape: the Bidnija olive grove, Malta**



(Map: D Saltana)

T1 **Pollard 2m+**

T2 **Pollard 2m+**

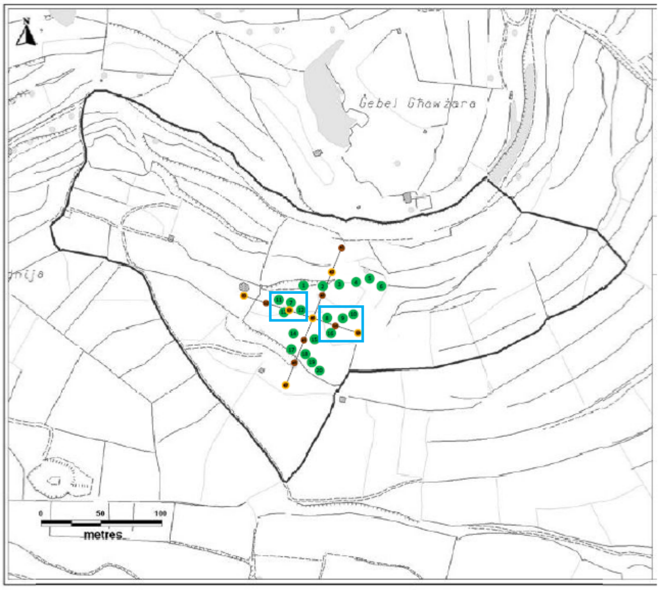
T3 **Pollard 2m+**

T4 **Pollard 2m+**

T5 **Pollard 2m+**

T6 **Collapsed pollard**

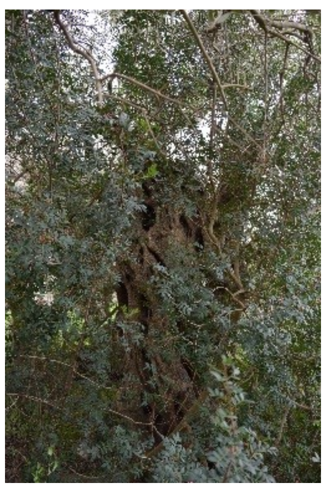
(All images: JGA Lageard)



(All images: JGA Lageard)

T11 **Collapsed pollard**

T7 **Pollard 2m+**

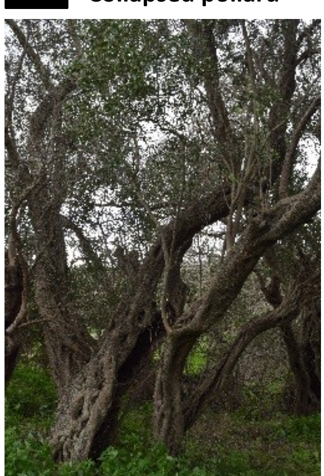


T13 **Collapsed pollard**

T12 **Pollard 2m+**

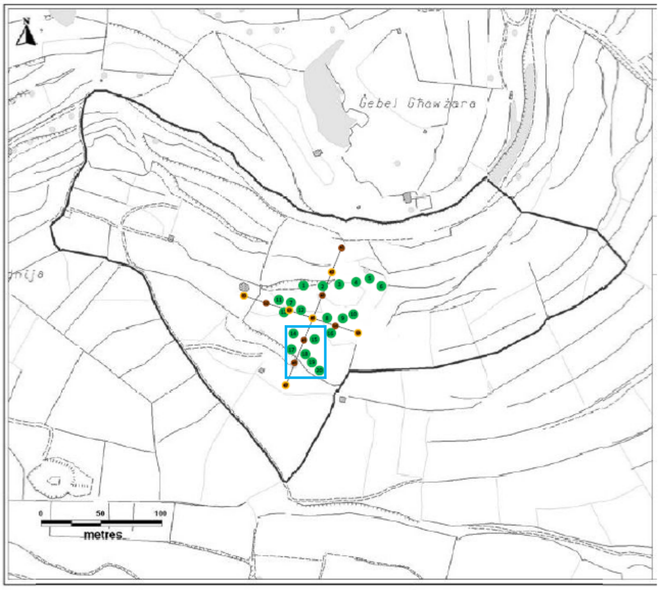
T8 **Pollard 2m+**

T9 **Collapsed pollard**



T10 **Collapsed pollard**

T16 **Pollard 2m+**



Sapwood collection (T17) for dendrochemical assay (results not reported in this paper). NB height of person conducting the sampling on 13.1.16 was 191 cm.

T14 **Pollard 2m+**

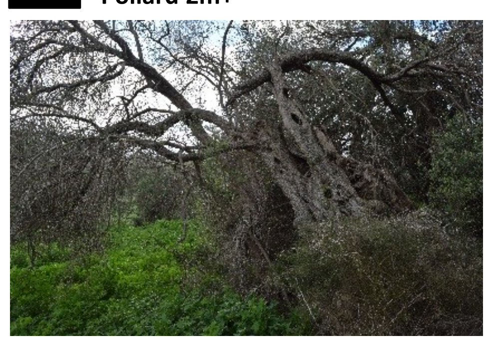
T15 **Pollard 2m+**

T17 **Pollard 2m+**

T18 **Pollard 2m+**

T19 **Collapsed pollard**

T20 **Pollard 2m+**



(All images: JGA Lageard)

Bidnija Olive Grove 10.1.15

Bidnija Grove viewed from the southwest demonstrating the almost complete canopy cover (Image: JGA Lageard)

Panorama from within the Bidnija Grove facing northeast to southeast (Image: JGA Lageard)