



University of
Sheffield

**From Grove to Goods: A Diachronic Study of Tree Fruits and Their Value-Added Products
in the Eastern Mediterranean and Armenia from 10,000 to 700 BCE**

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Abstract

This dissertation examines the diachronic development of tree fruit processing and its role in ancient economies across the Eastern Mediterranean and Armenia (10,000–700 BCE). By integrating archaeobotanical data, processing equipment analysis and comparative ethnographic studies, it traces the transition of grapes, olives, figs, pomegranates and dates from local consumption to large-scale production of value-added commodities such as raisins, wine, vinegar and oil. The study addresses key questions on the extent of tree fruit exploitation, technological advancements, regional variations and the economic significance of these commodities.

A major contribution is the interdisciplinary methodology that combines archaeobotanical evidence, material culture and ethnographic analogies. Employing GIS to map botanical remains allows for spatial and temporal analyses of fruit exploitation, while evaluations of historical processing techniques and the mechanical efficiency of pressing equipment shed light on labour organisation, production scales and technological choices in ancient communities. A case study of the Uartian region introduces a novel framework for detecting absent or underrepresented production technologies, demonstrating that a lack of physical remains does not necessarily indicate a lack of industrial activity.

Findings indicate a gradual, regionally diverse transition influenced by ecological conditions, processing innovations and socio-economic factors. Early societies consumed fruits, with scant evidence of processing but by the Chalcolithic and Bronze Ages, increased archaeobotanical remains and simple installations point to early surplus production. In the Late Bronze and Iron Ages, the emergence of large-scale pressing equipment, including lever and weight presses, marked a shift toward organised, trade-oriented production. Regional disparities reveal different trajectories in fruit processing, with advanced installations yielding greater efficiency and standardisation, supporting extensive trade networks, while small-scale methods persisted in balancing subsistence needs and surplus trade. This research deepens our understanding of ancient horticultural economies, technological evolution and the socio-economic impacts of fruit processing.

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Declaration

I, the author, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means. This work has not previously been presented for an award at this or any other university.

Chapter 1 - Fruit for Thought: An Introduction

1.1 Topic in Context

Fruit tree crops, most notably but not exclusively, olives and grapes and their value-added products like fermented beverages (e.g., wine and vinegar and oil), feature prominently in a number of arguments (e.g. Renfrew, 1972; Heath, 1987; Dietler, 1990, 2006; Sherratt and Sherratt, 1991, 1993; Hamilakis, 1996; Joffe, 1998; Sherratt, 1999; Fall et al., 2002; Foxhall, 2007; Chaniotis and Hadjisavvas, 2012; White et al., 2014; Liu et al., 2018; Batiuk et al., 2021). They concern the development of urbanisation, long-distance trade, social stratification, social stability and economic growth and diacritical cultures of consumption in the Neolithic, Chalcolithic, Bronze and Iron Ages of the eastern Mediterranean over the past fifty years. Additionally, the majority of scholarship on alcohol in ancient societies has predominantly examined its influence on health and diet, its ceremonial importance and the ways it helped shape and reinforce group identity (Joffe 1998). However, comparatively little attention has been given to the economic dimensions of alcohol, particularly its variability within ancient markets processing equipment and organisation of labour (Dietler 1990, p. 297).

Fruit tree crops present a paradox within ancient agricultural economies. While they offer valuable products for trade and consumption (i.e. wine and olive oil) they are inherently unreliable as subsistence crops due to their long maturation periods and vulnerability to environmental hazards (e.g., they involve economic risks) (Miller and Gross, 2011). Unlike annual grains which provide a more immediate and stable food source, tree crops such as olives, grapes, pomegranates, figs and dates require several years to reach full productivity (Zohary and Spiegel-Roy, 1975; Weiss, 2015). Furthermore, they are highly susceptible to climatic fluctuations, pests and disease outbreaks, making them a relatively risky, longer-term investment for subsistence farming communities. If an orchard were damaged by drought, frost or infestation, it could take years, if not decades, for it to recover, posing a significant economic challenge for communities reliant on these crops (Abbot et al., 2015). However, despite these risks, fruit tree crops were highly valued for their ability to produce long-lasting, transportable and high-value goods, such as olive oil, wine, vinegar and dried fruits. These value-added products had a longer shelf life compared to fresh produce, making them ideal commodities for

inter and intra regional trade and exchange (Pratt, 2021, 2025; Bevan, 2016). Their high economic value often justified the risk related to initial investments and long wait times required for tree cultivation.

However, there is significant dispute that revolves around the scale at which these crops were exploited and their products processed for trade (e.g., Chaniotis and Hadjisavvas, 2012; Pratt, 2014; Genz, 2013; Hamilakis, 1999; Renfrew, 2002; Amouretti et al., 1991). The extent of surplus production and commercialisation of these goods remains a contested issue, particularly in regions where evidence of large-scale processing facilities, trade routes or state-controlled production is sparse. Another aspect of this debate involves regional variations in exploitation and processing strategies. The extent to which tree crop economies operated similarly across different areas, such as the Aegean, Anatolia and the Levant, is still unclear. While some regions, such as the Levant, provide clear archaeological evidence of extensive olive and grape cultivation and processing alongside specialised storage, other areas present a more complex and less well-documented picture (see Chapter 2 concerning bias in the data). There is also some risk that arguments for their importance rely more on modern arboricultural realities than actual ancient evidence.

Set within this context, it is striking that the archaeobotanical record for key tree crops, grapes, olives, pomegranates, figs and dates, as well as their associated processing equipment, remains relatively understudied across vast chronological periods and geographic regions. This gap is even more pronounced for prehistoric and earlier periods, as discussed below. Despite the economic and cultural significance of these crops, comprehensive datasets tracking their presence and absence are notably absent. To this author's knowledge, there is currently no centralised database for tree fruit remains, specifically the ones under study, in Europe and the Near East. Instead, relevant data are scattered across multiple smaller databases (e.g., Fuller and Stevens, 2019; Fuller, 2018; ADEMNES; Integrated Archaeobotanical Research Project) and reports, making it challenging to conduct large-scale comparative studies.

Research on wine and oil processing equipment has primarily concentrated on the later periods, particularly from the Hellenistic to the Byzantine era, due to the relative abundance of archaeological evidence. These studies have largely approached the topic diachronically,

focusing on changes in processing technologies over time (e.g., Ayalon et al., 2009; Tuna, 2020; Dodd, 2022; Hadjisavvas, 1987, 1988; Foxhall, 2007). However, investigations that systematically examine earlier periods or attempt broader chronological syntheses remain rare. Only a few studies (notably Hadjisavvas, 1992 and Frankel, 1999) have undertaken long-term temporal analyses, examining wine and oil production from the Bronze Age to the Byzantine period in Cyprus and from the Neolithic through to the modern period in Palestine. While these works provide valuable insights, they are limited in scope as they focus on single geographic regions rather than adopting a broader comparative perspective across multiple areas, with the majority of attention placed on later periods. Additionally, these studies primarily concentrate on creating typologies and identifying differences in processing technologies, without explaining and/or examining the practical implications of those differences (e.g., ease of use and efficiency in producing larger quantities and varying qualities of wine and oil). More importantly, no systematic attempt has been made to conduct a diachronic analysis that integrates archaeobotanical and artefactual (notably processing equipment supported by iconographic, textual and ethnographic evidence) to comprehensively study fruit tree crop exploitation and processing across multiple time periods and regions. This study seeks to address this gap by developing a novel and interdisciplinary approach that combines these diverse sources of evidence. By doing so, this research not only fills a critical gap in our understanding of fruit tree crop economies but also establishes an innovative proxy for assessing market variability in the eastern Mediterranean and Armenia while offering new insights into long-standing debates on agricultural economies in the ancient world.

Given the complexities surrounding the exploitation and processing of tree fruits, a broader analytical framework is needed to systematically examine their economic role in ancient societies. Economic archaeology provides such a framework by investigating the long-term interactions between societies and their natural and cultural resources, with a particular focus on patterns of production, distribution and consumption (Outram and Bogaard, 2019). By applying this approach, this study seeks to contextualise the market variability (the term is explained in detail in Section 1.3.7), specifically examining how tree fruits were used and the quantity, quality and types of value-added products, particularly olive oil and wine. It also aims to assess how factors such as climate, geography, technological advancements and labour organisation

influenced their exploitation and market integration over time (Feinman, 2008, p.1115; Sheridan and Bailey, 1981).

1.2 Focus and Scope

This study investigates the consumption and processing of tree fruits, including grapes, olives, pomegranates, figs and dates, by examining the technological and economic implications of producing value-added products such as olive oil, wine and other liquid derivatives. The core focus of this research is the exploitation of these fruits in both the recent past and prehistoric and ancient times, the evolution of processing technologies across different regions for transforming these fruits into value-added products, the economic implications of these processes and the role of archaeobotanical data in understanding the spread and consumption of tree fruits.

Additionally, the study explores the ethnographic analysis of traditional winemaking equipment and its use as a heuristic tool for understanding historical fruit processing. A key aspect of this research is examining how this knowledge can be practically applied in historical and modern contexts, using a case study of missing Urartian wine presses.

This focus is achieved by integrating multiple sources of evidence, including ethnographic studies, encompassing botany, ecology, processing equipment and labour investment, alongside archaeobotanical data, particularly macro-remains and archaeological findings. Additionally, textual and iconographic sources are employed to provide further insight into the evolution of processing techniques and economic transitions associated with these tree fruits. This research adopts an interdisciplinary approach by incorporating methodologies from botany, biochemistry and mechanical engineering to enhance the analysis of ancient and traditional production methods. By synthesising these diverse data sets and perspectives, the study aims to provide a comprehensive understanding of the development and impact of tree fruit and processing technologies over time.

To provide meaningful contrasts and comparisons in the scale, nature and evolution of tree fruit exploitation and associated technologies across different environmental and cultural contexts a broad temporal scope, ranging from the Pre-Pottery Neolithic to the Iron Age (c. 10,000–700 BCE) and a wide geographical frame that includes Greece, Crete, western Turkey, Cyprus, Lebanon, Syria, Palestine and Armenia. For further details on these decisions, see Section 1.3.

Despite substantial scholarly attention to the domestication and symbolic significance of tree fruits in antiquity, there remains a critical gap in understanding how the technological trajectories of fruit processing, especially the production of value-added liquid derivatives like wine and oil, developed across time and space and how these innovations influenced and reflected wider economic and social changes. Furthermore, the methodological potential of synthesising ethnographic analogues with archaeobotanical, textual and iconographic data for reconstructing ancient production systems remains underutilised. Specifically, no comprehensive, interdisciplinary synthesis currently exists that systematically examines: (1) the regional variability and technological trajectories of tree fruit exploitation; (2) the economic implications of processing innovations; and (3) the applicability of ethnographic analogues, such as traditional winemaking equipment, for interpreting archaeological absences, such as the missing Urartian wine presses. This study seeks to fill that gap by offering an integrated, diachronic and regionally comparative analysis of tree fruit exploitation and processing.

1.3 Explanation of Focus, Scope, Terms and Definitions

1.3.1 Time Periods and Geography Under Study

The selection of the Pre-Pottery Neolithic (10,000 BCE) to the Iron Age (700 BCE) for this research is based on several key factors. This timeframe encompasses the earliest evidence of some of the tree fruits under study, the origins of agriculture and early cultivation and domestication. It also includes the rise of urbanisation and the emergence of civilizations, the development of processing techniques and technologies, the expansion of interregional connections and trade networks and the increasing diversification and regional variability in fruit use and processing (e.g., Gimbutas, 1963; Renfrew, 2017; Wiersma and Voutsaki, 2016; Colledge et al., 2004; Weiberg et al., 2019; Zeder, 2008).

As indicated, much of the existing research on wine and oil production, from the eastern Mediterranean and Armenia, has focused on later periods, particularly from the Hellenistic to the Byzantine era, due to the abundance of available evidence (e.g., Ayalon et al., 2009; Tuna, 2020; Dodd, 2022; Senol and Aydinoglu, 2010; Hamilakis, 1996; Hadjisavvas and Chaniotis, 2012).

However, earlier periods, such as the Chalcolithic or the Middle Bronze Age, are often examined in isolation rather than within a broader chronological framework. By covering nearly 11,000 years, this study enables a comprehensive diachronic analysis, allowing for a more nuanced understanding of long-term trends in tree fruit cultivation and processing across multiple civilizations and regions.

These geographical regions, Greece, Crete, western Turkey, Cyprus, Lebanon, Syria and Palestine, were selected for their historical, cultural and economic importance in the development of tree fruit processing (particularly olive oil and wine production) and trade in the eastern Mediterranean (e.g., Renfrew, 1972; Sherratt and Sherratt, 1991; Hamilakis, 1996; Foxhall, 2007, Chaniotis and Hadjisavvas, 2012). Selection criteria for these regions included the availability of sufficient archaeobotanical, ethnographic and archaeological data (e.g., ADEMNES; Callot, 1987; Frankel, 1999), the presence of well-documented trade and cultural interactions (both maritime and overland) (e.g., Sauvage, 2017; Bakker et al., 2021; Gilboa and Yasur-Landau, 2020) and the environmental and climatic suitability for cultivating grapes, olives, figs, pomegranates and dates (e.g., Abbot et al., 2015; Zohary et al., 2012; Spiegel-Roy, 1986).

Clarification on geographical classification is necessary. The Cyclades, even though they are distinct insular regions with unique maritime trade connections, are still considered part of Greece. Crete is categorised separately due to its distinct archaeological record, particularly the Minoan civilization. Western Turkey (Anatolia), is included since it serves as a bridge between the eastern Mediterranean, Armenia and Mesopotamia and was historically one of the most densely populated areas compared to the rest of modern-day Turkey. Regarding the Levant: the Southern Levant refers to present-day Palestine and Jordan, while Northern Levant includes Syria and Lebanon. The term Levant, when used generally, encompasses all four modern countries. The term Palestine, refers to modern day Gaza, West Bank and Israel.

Armenia was included in this research for several key reasons. Funding opportunities and professional development made it a viable research location. While the dissertation primarily focuses on Greece, Crete, Cyprus, western Turkey and the Levant, Armenia remains relatively under-explored archaeologically, particularly in relation to wine processing. This makes it a valuable addition. Its climate and agricultural practices closely resemble those of the eastern

Mediterranean, providing a relevant context for studying diachronic trends in fruit processing. Additionally, Armenia serves as an ideal case study for testing hypotheses and refining methodologies for interpreting absent, scarce or fragmented archaeological data. By broadening the study's scope, this research contributes new insights into wine processing, trade and agriculture in an under-examined region.

1.3.2 Tree Fruits Under Study

The tree fruits selected for this study are based on five major taxa identified in the classic study of tree fruit domestication by Zohary and Spiegel-Roy (1975): grape, olive, fig, pomegranate and date. These fruits were also highlighted by Stager (1985, pp. 172-173) in his discussion of tree crops domesticated during the second agricultural revolution, as well as by Fuller and Stevens (2019, pp. 266-273) in their analysis of the earliest occurrences of tree fruit crops, their domestication and their role in urbanisation. It should be noted that grapes are not actually tree fruits but are grown on vines. However, they have been categorised alongside tree fruits to maintain consistency and ease.

These five tree fruits are ideal for study in the eastern Mediterranean and Armenia due to their historical, cultural and agricultural significance in the region. First, they are prevalent in the archaeobotanical record compared to other fruits and vegetables (e.g., ADEMNES; Fuks et al., 2023; Abbo et al., 2015; Fuller, 2018; Orendi and Deckers, 2018). Second, their origins or at least one of their cultivation or domestication events, occurred in the eastern Mediterranean or Armenia, which are the main study areas (e.g., Zhou et al., 2019; Klinge and Fall, 2010; Meyer et al., 2012). Third, these species are well suited to the Mediterranean climate and their resilience has contributed to their widespread cultivation (e.g., Holland and Smit, 2010; Chaudhary et al., 2022). Fourth, they hold significant economic value, both historically and in the present, playing an important role in agricultural and broader economic systems (e.g., Sherratt and Sherratt, 1993; Renfrew, 1972; Hamilakis, 1996; Hansen, 1988; Pratt, 2021; Weiss and Kislev, 2007). Fifth, their diverse uses and processing potential, whether consumed fresh, dried or processed, highlight their role (or at least emerging role) as evidence of complexity in ancient market dynamics and systems (e.g., Fuller and Stevens, 2019; Harutyunyan and Malfeito-Ferreira, 2022). Finally, they have deep cultural and historical significance in the areas under study: they have been cultivated

for centuries and are embedded in the region's agricultural traditions (Walsh, 2018; Essid, 2012; Arnoni and Berry, 2015; Berry et al., 2011, pp. 2288-2295).

Tree fruits were likely not originally domesticated as staple food sources, unlike grains such as wheat and barley. An exception may be the date palm, which provides a significant source of carbohydrates in desert environments and certain cultures (Abbo et al., 2015, p. 328). Similarly, in the Southern Levant, figs appear to have been important, as evidenced by nearly 700 fig fruits deliberately laid out to dry in the Pre-Pottery Neolithic, likely to produce dried figs valued for their high calorific content and sugar (Whitlam et al., 2023). These selected tree fruits are long-lived perennials, requiring years to mature and often reproducing both sexually and asexually (Vallejo-Marín, 2019; Smith & Donoghue, 2008). As investment crops, perennials demand significant time, resources and risk before yielding returns. They undergo a long gestation period before reaching peak productivity, followed by a gradual decline (Devadoss & Luckstead, 2010; Chapman et al., 2022; Kreitzman et al., 2020; French & Matthews, 1971). Their processed products, such as oil and wine, are particularly valuable for study as they enhance usability, enable long-term storage and facilitate trade. These durable commodities supported economic specialisation, long-distance exchange and taxation, serving as key items in ancient markets (Foxhall, 2007; Brun, 2003).

1.3.3 'Value-Added Product' as a Term

The term *value-added product* is used to describe the process of adding value to raw tree fruit materials by altering their state to create entirely new products, such as oil, wine, vinegar and spirits. This transformation involves various processes and time, which inherently increase the product's value by making it less perishable, more tradeable and usable over a longer period, along with the development of other industry and revenue streams. This current definition is primarily adapted from Sherratt's (1981, 1999, pp. 14–15) concept of a *secondary product*, which he defines as a product that can be extracted continuously without killing the organism and can be converted into more valuable forms through work or processing, thus yielding commodities. Sherratt highlights olive oil as a prime example, as it is derived from perennial crops and enhanced through processing techniques. Additionally, this definition draws from the flowchart developed by Lu and Dudensing (2015, pp. 3–4, fig. 1), which itself is based on Ernst

and Wood (2011). The flowchart emphasises that value-added agriculture generates additional revenue by extending beyond the mere production and sale of raw commodities. This includes transforming products into specialty goods, among other strategies. This perspective contrasts with more contemporary interpretations linked to marketing and modern economics, which focus more on aspects such as supply chains, packaging, branding and advertising (Sharif et al., 2018; Kilkenny & Schluter, 2001, p.12; Clark et al., 2021; Dudensing, 2023).

1.3.4 Types of Value-Added Products

It should be noted that when referring to *wine* within this study, the term may encompass different stages of processing in the creation of a value-added product, not necessarily the first fermentation. This includes the initial transformation process, such as the crushing of solid grapes into liquid form (juice), the actual first fermented liquid commonly recognised as wine and any additional processing techniques, such as double fermentation to produce vinegar, unless explicitly specified otherwise. This broad definition is necessary because, even with the support of chemical analysis or written records, the archaeological record often does not allow for the precise identification of a specific value-added product (Rosen and Ayalon, 2021). The most that can be determined based on the archaeological equipment (and some archaeobotanical data) is that the tree fruit underwent a transformation in its state of matter, changing from solid to liquid (Langford, 2015). While chemical analysis can confirm this physical transition and, in some cases, suggest the type of fruit involved, it does not always provide definitive evidence of whether the resulting liquid was intended as wine, vinegar or another derivative product (Barard et al., 2011; Drieu et al., 2020; Whelton et al., 2021).

Traditional studies on ancient fermented beverages often examine and classify them within a binary framework, focusing either exclusively on grape wine or on the beer-versus-wine dichotomy (Batiuk, 2021, pp. 103–104). This narrow perspective overlooks the diverse range of fermented drinks made from alternative ingredients, such as other tree fruits as well as natural sources like honey (McGovern, 2003, pp. 263–266). It also fails to account for the full spectrum of historical brewing practices and ingredient diversity, as similar techniques could be used to produce both beer and fermented beverages from dates and figs (see Chapter 7). Additionally, these studies often neglect the role of secondary fermentation, which was essential for producing

vinegar, a key component in ancient culinary traditions and food preservation (Rosen and Ayalon, 2021; Khalifa et al., 2024).

To address these gaps, this study focuses on the often-overlooked fermented beverages derived from other tree fruits, specifically pomegranates, figs and dates and clarifies the terminology used to distinguish them. The term *wine* refers specifically to a grape-based product unless otherwise stated. When referring to a fermented beverage made from another type of tree fruit, it will be explicitly labeled with the fruit's name (e.g., *date wine* or *fig wine*) or discussed within the section dedicated to that particular fruit. This distinction ensures clarity when examining various fermented fruit-based beverages and their respective processing methods.

It should also be noted that when referring to any type of tree-fruit-based liquid, it is unlikely that ancient people consumed the value-added product in its "pure" fermented form without modification, unlike most modern wine. These beverages were often combined with other ingredients, enhanced with spices, diluted with water or subjected to additional processing to alter their flavour, potency or preservation (Batiuk, 2021, p. 114; McGovern, 2009, p. 8; McGovern, 2003, pp. 171-173).

1.3.5 Explanation of Equipment Terminology

In this work, the terms *processing equipment*, *production equipment*, *installations* and *tools* are used interchangeably to refer to any type of instrument employed in the extraction of juice, the fermentation of liquids or the production of oils from the tree fruits under study. Therefore, storage containers for wine and oil would not qualify. In an ancient context, the terms *winery* or *oilery*, as used in this study, denote any facility that houses such equipment within the same location as a storage area (Laurent et al., 2025; Dodd, 2022). In some cases, these terms may also refer to a site dedicated solely to the storage of oil or wine, such as a wine cellar or an oil cellar, without necessarily including production equipment (Yasur-Landau et al., 2018; Rosen and Ayalon, 2021). Additionally, the terms *pressing* or *crushing* are often used interchangeably to describe the physical process of applying weight to tree fruit that breaks down the fruit into fragments and/or extracts the liquid.

1.3.6 Market Variability

In this study, *market variability* describes the degree of differentiation in the use, quantity, quality and types of tree fruits and their value-added products, such as wine and olive oil, across various regions within the eastern Mediterranean and Armenia. It is based on economic archaeology, which examines the long-term interactions between ancient societies and their accessible natural and cultural resources, focusing on their utilisation, production, distribution and consumption over time (Outram and Bogaard, 2019; Feinman, 2008, p.1115; Sheridan and Bailey, 1981). This concept encompasses several key aspects: fruit use (e.g., differences in how tree fruits were present, consumed and processed); quantity (e.g., variability in production ease, efficiency, methods and equipment); quality (e.g., differences in fruit standards, suitability for fresh consumption or processing and production ease and techniques); and type by region (e.g., regional disparities in the species or varieties of tree fruits cultivated and utilised, influenced by climate, resource availability and economic demand). Additionally, market variability extends to the types and distribution of processing equipment, highlighting disparities in value-added product processing. These differences include variations in processing methods, techniques, equipment, technological advancements and the effectiveness of the equipment used. Understanding these variations provides insight into how different regions of the eastern Mediterranean and Armenia adapted to climate conditions, resource availability, the technology of processing equipment and consumer demands.

1.3.7 Urartu as a Case Study

Urartu presents a compelling case for investigation due to its geographic, historical and economic significance in ancient wine production. Located in the Armenian Highlands, the Urartian kingdom was a major center of viticulture, yet a striking phenomenon exists: despite extensive evidence of a thriving wine industry (including written sources, iconographic depictions and large-scale storage facilities), there is a notable absence of processing equipment beyond storage ceramics (see Chapter 8). A similar phenomenon has been observed in the case of the Phoenicians in Lebanon. Despite their well-documented role in the ancient wine trade, no clear evidence of wine presses was found until 2019, when the first known Phoenician wine press was discovered at the site of Tel el-Burak (Orendi and Deckers, 2018; Orsingher et al.,

2020). Furthermore, Urartu falls at the later end of the chronological periods under investigation, making it a crucial point of comparison for understanding broader developments in ancient winemaking. By examining Urartu's role in viticulture, this study aims to bridge gaps in knowledge about the continuity and transformation of wine production techniques from earlier periods into the first millennium BCE. Additionally, this research aligns well with ongoing fieldwork in Armenia, specifically within the Urartian region. As part of this study, the author was part of a team that conducted an ethnographic investigation of traditional wine production methods, equipment and labour. By analysing contemporary practices, this research seeks to provide insights into possible ancient winemaking techniques, particularly in light of the unexplained absence of processing facilities in the archaeological record, along with other methodologies (see section 1.5). Given these combined factors, the historical significance of Urartu, the unexplained absence of wine processing equipment, the parallels with the Phoenician case, its position within the broader chronological framework of this study and its connection to ongoing fieldwork, Urartu emerges as a highly relevant and valuable focus for this study.

1.4 Research Questions and Objectives

This work seeks to address four overarching research questions:

- **Research Question 1 (RQ1):** To what extent can a trend, ranging from the local consumption of raw tree fruits to their systematic processing into storable and tradable value-added products such as olive oil and wine, be identified between the Pre-Pottery Neolithic (10,000 BCE) and the Iron Age (700 BCE) in the eastern Mediterranean and Armenia, based on archaeobotanical and processing equipment data?
- **Research Question 2 (RQ2):** To what extent does the transition from fresh fruit consumption to processed products vary across different regions of the eastern Mediterranean and Armenia, as evidenced by differences in fruit use and variations in processing equipment types and distribution?
- **Research Question 3 (RQ3):** To what extent do these trends indicate how tree fruits were used and the quantity, quality and types of value-added products by region in the

eastern Mediterranean and Armenia, as evidenced by archaeobotanical and processing equipment data?

- **Research Question 4 (RQ4):** Given the abundance of textual and storage evidence pointing to a significant Urartian wine industry but the absence of archaeological processing equipment, how can comparative methods, in particular, blending ethnographic analogy archaeobotanical analysis and knowledge of other archaeological equipment, help pinpoint where and how Urartian wine presses likely existed and what implications does this case study hold for broader applications of interdisciplinary methods when direct physical remains of specialised equipment are absent, scarce or destroyed (a frequent occurrence)?

These four research questions function together to build a comprehensive, diachronic analysis of tree fruit consumption, processing and links across the Mediterranean and Armenia from the Pre-Pottery Neolithic (10,000 BCE) to the Iron Age (700 BCE). RQ1 provides the overarching framework for understanding the transformation of fruit use over millennia by establishing a broad diachronic trend. RQ2 and RQ3 refine this framework by introducing spatial variability, ensuring that the model accounts for regional and sub-regional differences. RQ4 acts as a methodological pivot, demonstrating how to handle cases where direct archaeological evidence is absent and applying comparative methods, making the study's findings applicable to other historical and archaeological contexts.

The most effective approach to answering these crucial questions is a diachronic study of archaeobotanical and artefactual evidence, with a primary focus on processing equipment, as physical installations provide the strongest evidence for olive oil and wine production (Pratt, 2021, p. 47). This study is supplemented by analyses of specific ceramics and iconography, while ecological and ethnographic studies serve as heuristic tools when needed.

1.5 Overview of the Thesis Structure

The thesis is divided into nine chapters, including this one and a conclusion chapter (Chapter 9). Chapter 2 discusses the methodology and materials used to analyse various types of data across different time periods, including ethnographic, archaeobotanical and archaeological data. It

discusses the creation of a new chronological framework, the application of the GIS and the research approach (i.e., how the datasets were integrated). It outlines how data were collected and analysed, as well as the rationale behind the chosen methods, including the use of databases, R and spreadsheets.

Chapter 3 examines the ecology and ethnography of tree fruits in the regions and periods under study, focusing on where the species grew (whether wild or domesticated), their growth requirements, life cycle, fruiting behavior, domestication history and ethnographic consumption and uses of key fruit species. It explores traditional cultivation methods such as grafting, tillage and pruning, as well as how these fruits were consumed, whether fresh, dried or as extracted juice, along with their associated benefits. The chapter analyses the morphological, chemical and phenolic differences between wild, cultivated and domesticated tree fruits and their implications for quantity, quality (including taste) and fruit types. By critically assessing this information in conjunction with ecological data, which is generally more applicable to the distant past than ethnographic data, the chapter clarifies the potential and constraints of ancient tree fruit production, processing and consumption in relation to wild cultivation and domestication, labour, resources, climate and geography and how human intervention shaped fruit availability and use. It sets the stage for whether production could escalate from small household needs to a surplus intended for broader exchange.

Chapter 4 explores the ‘traditional’ (pre-industrial) techniques, tools and facilities used in tree fruit processing in the Mediterranean, Black Sea and Caucasus regions in the recent past. This analysis serves as a heuristic framework for interpreting and analysing surviving archaeological equipment, both for this study and for future research. By examining alternative *chaînes opératoires* (Porqueddu et al., 2023; Coupaye, 2022) and the types of equipment that may have been used in earlier periods, this chapter provides critical insights into historical processing methods, from fruit harvesting and raw consumption to multiple stages of liquid-food production. It bridges the gap between ethnographic observations and archaeological interpretation (Chapters 7 and 8), offering a tangible perspective and tool on how past societies may have processed and utilised tree fruits (Hamilakis and Anagnostopoulos, 2009).

Chapter 5 builds on the aims and objectives of Chapter 4 by focusing on a new ethnographic study conducted in Armenia from January 2020 to September 2023 that aimed to document and analyse the equipment, techniques and practices used in wine production through interviews and surveys of available processing equipment. The chapter examines modern period wineries to assess how different layouts, equipment types, variables and materials and labour arrangements vary and how it influences operational scale and the labour force. This analysis is intended to enhance the interpretation of archaeological equipment discussed in Chapters 7 and 8, serving as a heuristic tool to investigate the causes and contexts of variability in production methods and equipment and how these insights echo in traditional and modern equipment, whose core features, presses, treading floors and storage installations, strongly resemble those found in the archaeological record.

Chapter 6 provides a comprehensive survey of the available archaeobotanical data to determine which tree fruits were present across different regions and time periods under study and, whenever possible, how these fruits were consumed or utilised in each context. For instance, a cache of grape pips imply that grapes were being processed *en masse*, potentially for winemaking, drying into raisins or other forms of preservation. By systematically analysing these archaeobotanical remains, the chapter aims to reconstruct patterns of fruit presence, usage and broader socio-economic or cultural trends related to fruit presence and consumption in each region and period under study, using the information gathered in Chapter 3.

Chapter 7 examines archaeological evidence of oil and wine production equipment from the Pre-Pottery Neolithic to the Iron Age in the eastern Mediterranean, incorporating ethnographic (Chapters 4 and 5) and archaeobotanical data (Chapter 6) to interpret material culture. The primary objectives are to determine whether such equipment became larger and more specialised over time, whether the rate of development varied across regions and micro-regions and whether simpler, less specialised tools and facilities continued to be used alongside more advanced equipment and in what economic contexts. It is important to note that the focus was not placed on conglomerations of processing equipment, as a form of analysis, to avoid significant bias arising from the bibliographic availability, which predominantly centers on Palestine during the periods under study. By analysing when and where processing equipment first appeared, the types and distribution of semi-specialised or specialised equipment, changes in technology (e.g.,

markers of a transition to higher-volume or tradable products and their effectiveness and impact on quantity, quality and product type), the geographical spread of these technologies, their role in the broader economy and the effectiveness of each processing method for different tree fruits, crucial, though limited, insights can be gained into the variability of ancient olive oil and wine markets across different regions and time periods.

Chapter 8 synthesises key findings from previous chapters, including ecological insights on grape cultivation and domestication (Chapter 3), ethnographic data (Chapters 4 and 5), archaeobotanical evidence (Chapter 6) and archaeological insights (Chapter 7) and integrates two new survey projects in Armenia. Serving as a "put it into practice" section, this chapter applies the study's main conclusions to identify where Urartian wine processing equipment would likely be found, how it functioned and what materials it was made from. It provides a roadmap for future excavations and explores the technological and economic capabilities of the Urartian state. Using a comparative, interdisciplinary approach, Chapter 8 reconstructs past viticulture and winemaking practices, even in the absence of direct archaeological evidence. By emphasising comparative analysis, ethnographic analogy and new survey work, it demonstrates how even limited or fragmentary data can yield meaningful and useful insights.

1.6 Relevance and Contributions

This study contributes to both the scholarship of discovery and the scholarship of summary, advancing knowledge through new investigations while critically reviewing and synthesising existing research across multiple disciplines. Each chapter plays a distinct role in shaping these contributions.

1.6.1 Scholarship of Summary

Chapter 4 reviews, synthesises and examines existing knowledge of pre-industrial processing techniques and equipment, offering the first comprehensive diachronic analysis of these technologies across the Mediterranean and Near East focusing on the recent past. To this author's knowledge, no such synthesis has been undertaken before.

Chapter 6 builds on previous archaeobotanical research by systematically compiling and analysing fruit remains across multiple regions and time periods, reconstructing patterns of tree

fruit exploitation. In doing so, it creates the most comprehensive database, known to this author, of its kind for the five tree fruits (grapes, olives, pomegranates, figs and dates).

Chapter 7 extends research on production equipment, offering a more nuanced interpretation of material culture and deepening our understanding of the technological and economic complexities of ancient tree fruit processing. It also plays a key role in the interdisciplinary approach of this study, applying engineering principles to assess the efficiency of different pressing technologies and investigating how they impacted market variability. Additionally, it reviews and synthesises archaeological evidence for oil and wine production equipment, examining how processing technologies evolved across different regions and time periods.

1.6.2 Scholarship of Discovery

Chapter 5 explores an under-researched geographic area, focusing on Armenia, a region that, while gaining archaeological attention in the past two decades, remains largely overlooked in studies of ancient viticulture and fruit processing (with the exception of Areni-1 Cave). This chapter presents a new, unpublished ethnographic study on traditional wine production methods and equipment in Armenia, offering valuable comparative data for archaeological interpretation.

Chapter 8 explores an under-researched area and it applies new methodological approaches to identify potential Urartian processing technologies and sites, demonstrating how a comparative, multi-proxy model can reconstruct production systems even in the absence of direct archaeological evidence. It integrates ethnographic, archaeobotanical and material culture studies. Additionally, this chapter provides a roadmap for future surveys and excavations, guiding future archaeological research in the region.

1.6.3 A Novel and Interdisciplinary Contribution

This is the first study to systematically analyse grapes, olives, pomegranates, figs and dates and their value-added products across multiple time periods and geographic regions. It bridges disciplinary boundaries by integrating insights from botany, biochemistry, mechanical engineering and economic archaeology to develop a comprehensive framework for understanding tree fruit exploitation and processing. This methodology establishes a new proxy for assessing market variability and contributes to a broader understanding of fruit tree

exploitation, technological adaptation and economic transformations in prehistoric and ancient societies of the eastern Mediterranean and Armenia from 10,000 to 700 BCE.

Chapter 2 - Getting to the Root: Methodology and Materials

The project is predominantly bibliographic, relying on existing synthetic studies and archaeological databases wherever possible. This approach enables a broad comparative perspective, ensuring that data from different geographical regions and chronological periods are considered systematically. Key sources include well-established works on processing equipment (e.g., Frankel, 1999; Hadjisavvas, 1992, 2020; Hamilakis, 1996; Foxhall 1993, 2007; Platon and Kopaka, 1993; Onozuka, 2012; Callot, 1987; Heltzer and Eitam, 1987), which provide a foundational understanding of technological and economic patterns. These studies are complemented by targeted analyses of primary excavation reports and secondary journal articles, particularly in cases where significant gaps exist in the available syntheses. This selective engagement with primary reports is essential for refining broader interpretative frameworks and addressing specific lacunae that might otherwise distort the overall conclusions. In addition to the bibliographic component, the project also includes primary sources and research in the form of ethnographic and survey work conducted in Armenia.

Given the diversity of topics addressed in each chapter, a flexible and multi-method approach is essential. Each chapter requires its own tailored methodological framework, carefully designed to align with the specific type of evidence under analysis, the unique aspects and complexities of each subject and the research questions posed. By using specialised approaches for each type of evidence, the study achieves both depth and accuracy, while also offering a nuanced understanding of the interconnected themes throughout the work. To reflect this methodological diversity, this chapter is organised into distinct sections, each dedicated to the methods employed for a specific chapter's focus. This structure not only clarifies the methodological choices made but also ensures transparency in how different datasets are approached, analysed and integrated into the broader study.

2.1 New Chronology

Given the diversity of chronologies and dates spanning various time periods and geographic locations, it was necessary to establish a standardised chronological system. This approach involved synthesising overlapping regional chronologies to create a unified timeline that improves both clarity and coherence (see [Appendix 1](#)), minimising the challenges posed by

regional variations and ensuring consistent understanding throughout the analysis. For example, the start of the Iron Age may vary depending on the regional context (such as Crete versus Palestine) and competing perspectives exist within the chronology of Crete (e.g., Evans vs. Warren and Hankey vs. Platon vs. Manning). To deal with these issues, this unified chronology establishes a clear point of reference that reflects the broader context of the eastern Mediterranean and Armenia (Table 2.1).

The importance and utility of this new chronology extends beyond simplification. It allows for a more precise, accessible and cohesive understanding of historical developments across the various regions. By aligning different periods across regions, this system allows for meaningful cross-regional comparisons without the distortions that would arise from relying on region-specific dates. The standardised chronology helps readers grasp how developments in one region may align with or differ from those in another, fostering a clearer picture of broader historical trends. With one integrated timeline, the study avoids the confusion that multiple, sometimes conflicting regional chronologies would introduce, particularly for readers less familiar with the subject. This model provides a foundation that researchers and scholars can build upon, creating a consistent reference point for future studies that span diverse geographic and cultural areas within the eastern Mediterranean. The new times periods and dates are as follows:

Time Periods	Dates
Pre-Pottery Neolithic (PPN)	10,000 - 7,000 BCE
Neolithic	7,000 - 4,500 BCE
Chalcolithic	4,500 -3300 BCE
Early Bronze Age (EBA)	3,300 - 2,200 BCE
Middle Bronze Age (MBA)	2,200 - 1,500 BCE
Late Bronze Age (LBA)	1,500 - 1,000 BCE
Iron Age (IA)	1,000 - 700 BCE

Table 2.1: The new chronology, time periods and dates.

2.1.2 Site-Phase(s)

The term *site-phase(s)* is based on the Harris Matrix conventions (Harris, 1979, 1989; Harris et al., 1993) and Carver sequencing (Carver, 2009). A *site-phase* refers to a distinct chronological division within an archaeological site, representing a specific period, based on a new chronology developed for this project (see Chapter 2, Section 2.1), determined through relative or absolute dating methods. It helps to organise stratigraphic layers and associated data systematically. For example, at the site of Tuleilat Ghassul in modern-day Jordan, evidence of domesticated *P. dactylifera* is divided into two site-phases in [Appendix 8](#) based on radiocarbon (C14) dating. The presence of *P. dactylifera* is recorded in both the Neolithic period (5600–4800 BCE) and the Chalcolithic period (4800–4250 BCE). Because these phases correspond to different chronological contexts, they are listed in separate rows within the dataset. By organising data into clearly defined site-phases, it becomes easier to identify the presence or absence of specific features and to track the development of data points over time, especially using Geographical Information System (GIS). This method allows for a more systematic comparison of archaeological contexts, facilitating the recognition of broader economic and chronological trends.

2.2 Geographic Information System (GIS)

Data visualisation and digital mapping were performed using QGIS (Esri), a Geographic Information System (GIS). The datasets, provided as a CSV spreadsheet, were imported and georeferenced using longitude and latitude coordinates within the GCS WGS 1984 (Geographic Coordinate System, World Geodetic System 1984), ensuring precise spatial alignment of archaeological site locations. Various spatial data layers were integrated, including point data (e.g., olive site-phases and wine installations), a base map sourced from OpenStreetMap, TomTom, Garmin, FAO, NOAA and USGS and an inset map highlighting dense site clusters. Through GIS processing, the archaeological sites were organised within an attribute table, classifying them by time period. Symbolisation and classification were applied using a categorical symbology method, with each site colour-coded according to its historical period and a legend providing interpretive clarity. Ultimately, the GIS system integrates coordinate reference frameworks, spatial layers, metadata management and geospatial tools to effectively visualise

data distribution while ensuring both accuracy and interpretability (Menéndez-Marsh, et al., 2023; Kempf and Günther, 2023).

2.3 Ethnographic Studies (Chapters 4 and 5)

2.3.1 Ethnography of Processing Equipment (Chapter 4)

Processing equipment data were collected, contextualised and structured through an ongoing critical discussion up to January 2020. This process drew on synthesised databases of ethnographic evidence (Hadjisavvas, 2020; Frankel, 1999) and peer-reviewed journal articles covering a range of historical periods and regions across the Mediterranean and Caucasus. Given the vast amount of available ethnographic data, the material was not catalogued systematically. Instead, it was critically assessed in a flexible, comparative manner, an approach that proved especially useful in accounting for the diversity of equipment used in different cultural and environmental contexts (Hamilakis and Anagnostopoulos, 2009). Criteria for inclusion involved: archaeological relevance, comparability, geographical scope, temporal breadth, regional diversity, functional classification and material and technological factors.

The selection of ethnographic processing equipment was guided by its archaeological relevance and comparability to previously catalogued artefacts (e.g., Callot, 1987; Frankel, 1999; Hadjisavvas, 1996; Eitam, 1986, 1996). By choosing ethnographic parallels that closely resemble archaeological finds, this study aimed to establish a clearer understanding of how these tools were used, why they were designed in particular ways and what implications these designs had for productivity, labour requirements and technological constraints and to ensure meaningful comparisons (Mód and Simon, 2023; Ana, 2022; Viecegli, 2022; Mazzotti 2004). The use of functional analogies helped to bridge the gap between archaeological evidence and experimental reconstructions, providing insight into the operational sequences involved in ancient processing techniques. Including multiple time periods and regions was essential to capture the diversity of winemaking and oil production practices and as much variation as possible. This wide geographical scope ensured that regional traditions, technological adaptations and environmental influences were taken into account (Bonnett, 2003). It also allowed for cross-cultural comparisons, highlighting potential shared practices and innovations across different communities. The decision to include such diverse examples reflects the need to acknowledge

both regional specificity and overarching patterns in processing technology (Murphy, 2013). Additionally, processing equipment was categorised based on processing ability (e.g., capacity and throughput) and production stage (e.g., crushing, pressing and storage) to facilitate structured comparisons. This classification system allowed for a more detailed analysis of workflow, efficiency and scalability, enabling the study to examine whether certain tools were better suited for large-scale production or small-scale domestic processing. Material and technological factors such as durability, material composition, ease of use, technological constraint and regional variations were considered to determine the practical and economic feasibility of different types of equipment.

Based on all of these criteria and considerations, the selected ethnographic and archaeological processing equipment was systematically analysed with a focus on identifying recurring features and patterns that transcended regional and temporal boundaries. These shared characteristics, whether related to form, function, material choice or manufacturing technique, were instrumental in isolating core design principles that appeared to have been effective across a variety of contexts. By examining these commonalities, the study aimed to distinguish between innovations driven by local environmental or cultural factors and those that may represent broader technological solutions to similar processing challenges. To facilitate clarity and coherence in the analysis, these shared features were organised into distinct thematic sections corresponding to each major stage of the production process: crushing, pressing, storage and where relevant, secondary processing or by-product management. This process-based structure enabled a nuanced understanding of how different tools and equipment contributed to the overall production sequence, highlighting areas where innovation or standardisation may have occurred.

2.3.2 Armenian Ethnographic Study (Chapter 5)

An unnamed ethnographic project conducted between January 2020 and September 2023 in collaboration with the Armenian Ministry of Education, Science, Culture and Sport, aimed to document and analyse the equipment, techniques and practices used in the production of wine in Aragatsotn/Արագածոտն), Ararat/Արարատ and Vayots Dzor/Վայոց ձոր. This research was carried out through structured interviews and observations/surveys of available processing equipment (see Chapter 5 for more detail about the aims and objectives). However, due to official publication restriction currently in place by the Armenian government and in light of the ongoing genocide

in the region, it is not possible to disclose the name of the project, share interview transcripts or release any identifying information related to testimonies, images of the land, wineries or their locations until at least summer 2026 (subject to change). These restrictions also apply to the survey work undertaken at Argishtikhinili and Aghavnadzor as extensions of this project (see Section 2.6 and Chapter 8). As a result, the only data available for analysis in this thesis pertain to the processing equipment and observations related to labour distribution. Therefore, this chapter focuses solely on those aspects and excludes discussion of other data collection methods, such as structure interviews and participant observation.

2.3.2.1 Site Selection and Rationale

The selected regions of Aragatsotn, Ararat and Vayots Dzor were chosen for their historical and contemporary significance in grape cultivation and wine production during the Medieval and Modern periods. These areas are distinguished by their unique soil composition, the presence of indigenous grape varieties and their historical role as centres of winery development and consolidation (Hovhannisyan et al., 2015; Rytönen, 2024; Dallakyan et al., 2020; Margaryan et al., 2019). Additionally, they were among the most prominent wine-producing regions during the 18th and 19th centuries (Collection of Information on Viticulture and Winemaking in the Caucasus, Erivan Governorate, 1896). Sites were identified in collaboration with the Armenian Ministry of Education, Science, Culture and Sport, using demographic and land use data from the 2011 national census and prior consultations with government horticulturists and land surveyors. This strategic selection enabled a comprehensive examination of both the continuity and transformation of viticultural practices over time.

2.3.2.2 Participant Selection and Rationale

Participants were also selected in collaboration with the Armenian Ministry of Education, Science, Culture and Sport, drawing on demographic data from the 2011 national census (Հայաստանի Հանրապետություն/Armenian Census, 2011) and recommendations from government horticulturists and land surveyors. The primary selection criteria focused on individuals aged 70 and above with at least 40 years of professional experience in agriculture or horticulture, especially those with direct involvement in alcohol production or the trade of wine and brandy. This approach ensured access to intergenerational knowledge and firsthand accounts of

traditional viticultural techniques, as well as insights into the historical evolution of winemaking practices within the region.

2.3.2.3 Data Collection, Management and Methods of Analysis

All collected data on processing equipment were systematically recorded and entered into structured spreadsheets to ensure consistency and ease of analysis. The dataset, for this work, was then consolidated into a single spreadsheet ([Appendix 2](#)), which was subjected to a data-cleaning process using R. This cleaning stage involved the removal of duplicate or erroneous entries, standardisation of terminology and reformatting to enhance readability and analytical efficiency. The cleaned dataset was designed to be concise yet comprehensive, optimised for both comparative and thematic analysis, which were the primary analytical approaches employed in this study. The comparative analysis aimed to identify similarities and differences in equipment usage across different regions and chronological periods. This was achieved by systematically examining key variables, which included:

- Participant numbers – to be feasibly linked to interviews and observations
- Province location – to establish geographical patterns in technological adaptation.
- Dates (CE) – to trace diachronic changes in equipment use and production techniques.
- Location and Equipment layout – to assess spatial organisation and operational efficiency within production sites.
- Methods of production – to classify and compare technological processes.
- Pressing mechanisms – to distinguish variations in mechanical versus manual processing techniques.
- Materials used – to explore the availability and selection of resources, as well as their impact on durability and function.

Thematic analysis was employed to identify broader trends in production methods and to understand historical continuities and shifts in technological practices. By grouping data into recurring typologies and themes, such as mechanisation levels, material choices and regional specialisation, this approach facilitated the recognition of long-term patterns in production. [Appendix 3](#) was developed as a byproduct of this analysis, in which all the methods used were analysed for their effectiveness and benefits of processing in terms of force, mechanical

advantage, control over pressing, complexity, investment (cost not including labour), labour, time, quantity and quality of product and evidence within the record. Each factor was then ranked as part of the analysis.

2.3.2.4 Ethical Considerations and Publishing Limitations

All research activities adhered to strict ethical guidelines. The study was approved by the University of Sheffield ethics committee under application #030453, which outlines protocols for informed consent, participant anonymity and data protection. For further details regarding ethical considerations, including research summaries, participant data and data management, refer to the ethics application documentation.

2.4 Archaeobotanical Data (Chapter 6)

2.4.1 Dataset Creation and Structure

The dataset for this study was constructed to systematically document and analyse the presence of five key tree fruits, grape (*Vitis*), olive (*Olea*), fig (*Ficus*), pomegranate (*Punica*) and date palm (*Phoenix*), across the selected regions and time periods under investigation. Data collection was conducted systematically until March 2020, drawing from synthesised databases of archaeobotanical evidence and archaeobotanical literature (e.g., ADEMNES origins of Agriculture: Archaeobotanical Database, Old World Crops Archaeobotanical Database, ArchbotLit, ArboDa Archaeobotanical Reports from Sites in the Near East by Naomi Miller), primary archaeological reports and articles from targeted geographical areas and periods.

For specific site-phases for the archaeobotanical data, if they fell within vastly different time periods, they were counted again or if the site-phases had two different species, it was counted as two separate site-phases. For example, at Wadi Fidan in Jordan, there is presence of *Vitis vinifera* accounted for in two different site-phases due to the exact dates of the pips, 5200-5900 BCE and 4700-4600 BCE or at Makriyalos in Greece, two species of grapes were identified from the same time period, so both were counted as separate site-phases.

Given the ever-expanding nature of archaeological research, additional has and will emerge in the future, further enhancing and refining the dataset. The compiled data were structured into

newly created .XLSX datasets (**Appendices 4, 5, 6, 7 and 8**), with each entry representing a specific site-phase, defined as a particular site during a specific time period, where species were identified based on macrobotanical remains (e.g., seeds and stones) (Zohary, 1995). For archaeobotanical data, if a site-phase spanned different exact dates of a specific time period, it was counted separately for each period. Similarly, if a site-phase contained two different species, it was recorded as two separate site-phases. For example, at Wadi Fidan in Jordan, *Vitis vinifera* was recorded in two distinct site-phases due to the precise dating of pips: 5200–5900 BCE and 4700–4600 BCE. Likewise, at Makriyalos in Greece, two different grape species were identified within the same time period and each was counted as a separate site-phase.

It is crucial to acknowledge that the absence of a specific species in the dataset does not necessarily indicate its complete absence in the past environment. Rather, it reflects its absence in the current archaeobotanical record. The dataset thus serves as a compilation of all confirmed findings.

2.4.1.1 Data Processing and Analytical Methods

RStudio was used for data cleaning, standardisation and initial analysis. To examine spatial and temporal variations in the presence of these tree fruits, as well as their classification as wild or domesticated, GIS was employed to generate maps for visual analysis (see attached sheets within the spreadsheet).

The dataset includes the following variables:

- Site numbers
- Site name
- Modern country
- Geographical coordinates (for GIS analysis)
- Recovery methods
- Preservation type
- Dating method
- Data quality
- Broad cultural periods
- GIS periods
- Exact dates
- Presence vs. absence (# when possible)
- Species type
- Domesticated/Wild
- Plant part(s)
- Context
- Additional information
- Source

Each row in the dataset corresponds to a specific site-phase and plant part.

2.4.1.2 Rationale for Dataset Design

The dataset was designed with three key objectives: flexibility, scalability and comprehensiveness. It accommodates variations in sampling techniques, analysis levels and data recording methodologies across archaeobotanical publications while maintaining a high level of integrity and efficiency. The dataset can be expanded, modified and re-utilised for future research projects or comparative studies. It is, to the best of the author's knowledge, the most extensive compilation of archaeobotanical macrobotanical remains for grapevine, olive, fig, pomegranate and date palm currently available. Since most other databases, focused on grains/cereals and weeds (see databases mentioned above).

2.4.1.3 Recovery Methods and Preservation

One of the primary challenges in synthesising such a large dataset was reconciling variations in recovery, dating and quantification methods. The dataset incorporates materials recovered through flotation (bucket, hand, water, froth, suspension, machine), hand-picking, judgemental sampling and sieving (both dry and wet) (Integrated Archaeobotanical Research Project, 2009). However, many datasets lacked information on recovery methods (e.g., flotation, hand-picking and judgemental sampling and sieving), introducing potential biases when comparing data since different recovery techniques vary in their ability to detect and preserve small, fragile or sparse remains. These inconsistencies can result in the underrepresentation of small or fragile fruits, overrepresentation of durable and visible remains (e.g., olive and date stones), inconsistent quantification across sites and potential under or overestimation of plant diversity of presence to name a few (Lodwick and Rowan, 2022). For instance, in both dry and wet sieving, mesh size plays a crucial role in what is retained. Coarser meshes may allow small seeds to pass through undetected, while finer meshes can capture a wider range of materials but are more labour-intensive and therefore applied less consistently (Steiner et al., 2015).

Preservation methods varied across samples and contexts, with plant remains preserved through carbonised, charring, waterlogging, mineralisation, desiccation or some combination (Colledge and Conolly, 2014). Each preservation type influences which plant materials survive, often favouring certain parts (e.g., seeds, pits) or species over others. This selective survival can skew

the apparent abundance or absence of particular fruits. Furthermore, site- and region-specific preservation conditions limit the comparability of data across different contexts. It can be difficult to distinguish between the true absence of a species and its loss due to taphonomic processes. As a result, various biases are introduced, including contextual bias, regional preservation bias, climatic bias and activity-related bias (Bates and Jiménez-Arteaga, 2024; Fuller and Lucas, 2020). In some cases, preservation methods were not specified in the excavation reports. These entries were marked as blank.

A broader reporting bias affects the transparency and comparability of the dataset, stemming from inconsistencies or omissions in how key contextual information is recorded in excavation and publication reports. Since archaeobotanical data often draw from studies conducted over decades with varying documentation standards, the detail and quality of reporting differ widely. This inconsistency leads to reduced transparency, limited comparability and difficulties in applying standardised criteria, ultimately obscuring genuine patterns and complicating regional or supra-regional synthesis.

2.4.1.4 Dating Methods and Data Quality

The majority of dating was based on chronological assignments to assemblages, with absolute dating methods including dendrochronology, radiocarbon (C14) dating and accelerator mass spectrometry (AMS) used where available (Lodwick, 2019; Leipe et al., 2023). Since many tree fruits were dated based on their associated assemblages, this reliance can result in misinterpretations, particularly when species are incorrectly associated with specific time periods or archaeological features (Colledge and Conolly, 2014). For example, the sites of Shulaveris Gora and Drangreuli Gora in Georgia were originally assigned to the Late Neolithic (5700–4700 BCE) based on assemblage context (Maghradze et al., 2019; Jalabadze, 2017). However, subsequent C14 dating, geometric morphometrics (GMM) and ancient DNA analysis determined that they actually date to the 17th/16th centuries CE (Bouby et al., 2020). In some cases, no dating method was specified, even basic relative dating, so that data were not included. The site-phases were categorised into broad cultural periods specific to their respective regions, followed by GIS periods to visualise the data and compile a catalogue of exact dates. To ensure consistency in period classification, site-phase dates that fell between two periods were assigned to the later period. If a site spanned multiple periods, it was assigned to the period that best

represented the majority of its duration. For example, if a site-phase covered 2350–2250 BCE - 150 years in the Early Bronze Age (EBA) and 50 years in the Middle Bronze Age (MBA) - it was assigned to the Early Bronze Age. For certain site-phases with cataloged specimen counts that fell at opposing ends of a specific time period, both were recorded. For example, evidence of date palm from Tannach is noted twice during the Iron Age because one sample dates to 1000 BCE and the other to 700 BCE. These samples originated from two different sites within that time frame, with specimen counts of 78 and 3, respectively.

Data confidence was assessed using a ranking system, where a score of 3 indicated high certainty and 0 indicated low certainty regarding both the correct identification of the tree fruits and the reliability of its associated dates. Broadly categorised fruits (e.g., *Vitis* sp.) were often assigned higher confidence scores due to the relative ease of identification at the genus level rather than species level. Higher scores were also given to entries dated using absolute methods, such as radiocarbon dating. The type of preservation (e.g., carbonisation, charring, waterlogging, mineralisation and desiccation) was not used as a criterion in the confidence scoring system, as preservation quality is influenced by a wide range of environmental and contextual factors. These include soil chemistry (such as pH and acidity), microclimatic conditions, the depositional environment (e.g., anaerobic or aerobic) and post-depositional disturbances. A major limitation in standardising the dataset is the reliance on the data quality classifications of previous authors, which were often provided without detailed justification (Warinner and d’Alpoim Guedes, 2014; see example in Chapter 6). To address this, the study prioritised entries with high-confidence scores supported by clearly defined preservation and dating methods. This ranking system was consistently applied to each dataset entry to ensure transparency and facilitate critical interpretation of the evidence.

2.4.1.5 Quantification System

Due to significant variation in sampling strategies, quantification methods and reporting styles, data were standardised to a presence/absence system for comparative purposes (Berihuete-Azorin et al., 2023). Where possible, specimen counts were recorded. If a publication presented values semi-qualitatively (e.g., <20, >20, 10–15), approximations were assigned to facilitate analysis (e.g., <10 = 5, <20 = 10, 10–15 = 15, >20 = 20). The highest reported quantity

was used as the Minimum Number of Individuals (MNI) (González Carretero et al., 2017; Jones, 1990; Bates and Jiménez-Arteaga, 2024).

2.4.1.6 Species and Plant Parts

The dataset includes wild and domesticated species of *Vitis*, *Olea*, *Ficus*, *Punica* and *Phoenix*, with morphological and growth pattern distinctions discussed in Chapter 3. Macrobotanical remains, like seeds and pips, are the most suitable dataset for determining fruit consumption and oil and wine production because they provide direct, tangible evidence of plant-based foodstuffs and processing by-products (Hamilakis, 1996; Pecci et al., 2020; Fairbairn et al., 2002). For oil production, the presence of olive pits or other oil-rich plant remains, particularly those showing signs of pressing or fragmentation, directly suggests the extraction of oil (Tyreen and Stefanoudaki, 1996; Rowar, 2015; Braadbaart et al., 2016). Instances where multiple plant parts were found together within a single dataset layer (i.e., same time period and context) may indicate levels of production beyond mere consumption, such as value-added processing (Fuller and Pelling, 2018). These are known as multiple species site-phases (MSSP).

2.4.2 Methods of Analysis

The analysis of archaeobotanical macro-remains in this study integrates GIS-based spatial analysis, temporal mapping and thematic classification to systematically interpret the data. By employing these methods, this study aims to determine when and where key tree fruits first appear in the archaeological record, track changes in their presence across different site-phases and assess whether their remains suggest direct consumption or value-added processing. This analysis considers factors such as the spatial and temporal distribution of botanical remains and their associated archaeological contexts. One key approach involves identifying caches, instances where a species is found in significant quantities within a specific site-phase and stratigraphic layer. For this study, any species with more than 30 macrobotanical remains within a single site-phase and stratigraphic layer and a well-defined archaeological context was analysed collectively. This approach helps distinguish isolated finds from more substantial deposits, providing insights into potential storage or processing activities.

GIS was employed to map and visualise the spatial and temporal variations of key tree fruits

across different archaeological site-phases. Proportional circles were used to show the number of archaeobotanical remains when mentioned, while a small circle was used to represent their presence. By incorporating site names, modern country boundaries and precise geographical coordinates, GIS facilitates the identification of patterns in fruit presence or absence over time. This analysis provides insights into several key aspects. Site distribution helps determine when and where key tree fruits first appeared and how their presence fluctuated over time. Regional trends highlight clusters of site-phases where certain fruits dominate, which could indicate hubs of consumption or value-added production. Cross-period comparisons allow researchers to track continuity, change and the expansion of fruit presence and use across different periods by mapping site-phases into GIS-defined timeframes.

Beyond mere mapping, spatial analysis enables the interpretation of site-phases in relation to broader temporal trends. By structuring the dataset into chronological assignments, this study facilitates cross-period comparisons, allowing for the tracking of changes in fruit cultivation and use over time. Fluctuations in archaeobotanical evidence within a given region, whether an increase or decrease, may provide insights into shifts in consumption patterns, environmental changes or evolving economic priorities.

Thematic analysis focuses on understanding how archaeobotanical remains were used, consumed or processed at different site-phases. This involves categorising plant parts and their associated contexts to determine patterns of production and consumption. For instance, the presence of processing evidence can be inferred from concentrations of seeds, pits or pips, particularly when found near installations such as wine presses or storage jars, suggesting value-added production like oil or wine extraction. Mixed assemblages, where site-phases contain a variety of plant parts (e.g., seeds, leaves, stems), may indicate by-products of processing, such as dregs left after juice extraction. The distinction between consumption and processing is also context-dependent; large quantities of mixed seeds found near storage areas or industrial installations likely represent processing activities, while isolated remains may indicate direct consumption. These thematic distinctions provide a nuanced understanding of how fruits were utilised in ancient contexts.

2.4.3 Tree Fruit Limitations

A big benefit, in the context of this study, is that the morphological challenges of distinguishing whether a fruit is wild, domesticated or somewhere along the spectrum (e.g., size, shape or colouration) are not a concern since the focus is not on differentiating between any types (see Chapters 3 and 6). However, it is important to recognise that several other factors contribute to bias in the archaeobotanical record, which can affect both the accuracy and completeness of interpretations.

Over the past three decades, archaeobotanical analysis has gradually become a standard component of archaeological investigations. Prior to this shift, many sites were excavated without consideration for plant remains, leaving limited or non-existent datasets, particularly in regions such as Lebanon and Armenia, where research is still developing (Soubra, 2023; Hovhannisyan et al., 2015). In the eastern Mediterranean and especially the Levant, this problem was compounded by what Wheeler (1954, pp. 29–30) famously described as “sins in the name of archaeology,” including excavation along walls and the arbitrary removal of soil. Such practices likely resulted in the loss or oversight of valuable botanical evidence.

Even when excavations are more systematic, the scope of investigation often remains restricted to selected areas within a site, meaning that recovered plant materials provide only a partial picture of past activity. Recovery strategies themselves further influence the archaeological record. Differences in flotation techniques, sampling intensity and processing methods all affect the range and quantity of botanical remains retrieved (Colledge and Conolly, 2014). Some plant taxa are especially prone to underrepresentation: grape seeds are both small and difficult to detect (Megaloudi and Jones, 2006), fig seeds, though more durable than the fruit, are similarly minute and easily overlooked (Gibbons, 2006) and pomegranate seeds, likewise very small, can be missed during recovery and sampling.

Preservation issues significantly shape the archaeobotanical record. Plant materials, including seeds, skins and other organic compounds, naturally decay over time unless exceptional environmental factors intervene. Charring is the most common pathway to survival, yet this process can be highly destructive for certain taxa. Seeds with high oil content, such as those of the pomegranate, often rupture at elevated temperatures, leading to their underrepresentation in

archaeological contexts (Bates and Jiménez-Arteaga, 2024). Even when preservation does occur, the number of botanical remains is typically far lower than expected. This discrepancy reflects ongoing deterioration, limited excavation coverage and the inherent fragility of organic matter. For instance, although olive oil was economically central in the Late Bronze Age, olive remains are disproportionately scarce (Hamilakis, 1996; Renfrew and Margaritis, 2011).

Different fruits present particular preservation challenges. Grapes, which can be consumed fresh or fermented into wine without heating, are rarely charred and usually survive only under conditions such as waterlogging (Livarda et al., 2021; Salavert, 2008; Hamilakis, 1996). Figs, being soft and water-rich, face similar issues: unless dried prior to deposition, they are unlikely to survive and like grapes, their processing into wine involves fermentation rather than exposure to fire. Consequently, their preservation depends on special conditions such as waterlogging (Denham, 2007; Colledge and Conolly, 2014). Pomegranates face additional difficulties: their seeds contain about 20% oil, which accelerates degradation and hinders preservation (Stover and Mercure, 2007). Since they too are typically eaten fresh or fermented without heating, they rarely survive through charring and are most often recovered in exceptional contexts. Dates follow a similar pattern. Consumed fresh or fermented rather than cooked, they are also seldom preserved by charring. When they do char, shrinkage can cause their stones to resemble those of feral or wild varieties, complicating identification (Ashraf and Hamidi-Esfahani, 2011; Gros-Balthazard et al., 2016).

Crushing and fragmentation of fruits, stones and seeds may often reflect natural taphonomic processes rather than deliberate human action. Soil, sediment and rock layers can exert pressure that fractures or distorts remains, sometimes mimicking purposeful modification. Additional agents such as root activity, waterlogging, drying–swelling cycles and the weight of overlying strata may likewise cause breakage. As a result, what appears to be evidence of processing could instead be the byproduct of long-term burial and geological forces. For example, distinguishing intentional treatment from post-depositional alteration is particularly challenging with grape seeds. Burned or fragmentary specimens are difficult to interpret since they could result from either processing or natural breakage (Bouby et al., 2022). Compounding this problem, the by-products of wine production were highly valued as animal fodder, particularly for fattening

livestock, meaning that only a limited amount of grape-processing waste typically entered the archaeological record (Hamilakis, 1996; Salavert, 2008; Milevski, 2011).

A similar interpretive difficulty arises with olive stones. Fragments may derive from ancient processing methods such as pressing or crushing but they might also result from later damage due to natural decay, excavation or handling. Margaritis and Jones (2008) have outlined criteria for distinguishing these processes, although uncertainty remains (Foxhall, 2007). Beyond their role in classification, olive stones were also repurposed as fuel or animal feed (Chapter 3), underscoring their broader economic and cultural significance.

Processing by-products or other remains could also have been readily used as fuel for lighting or as animal feed. For instance, ethnographic parallels provide further insight: date pips have been documented as both fodder and fuel, practices that would have effectively destroyed much of the archaeobotanical evidence (Chapter 3).

Lastly, long-distance trade and transport add another layer of complexity. Highly tradeable and storable commodities such as pomegranates, dates and dried fruits (raisins and figs) could endure journeys of thousands of kilometers and remain viable for four months or longer without significant spoilage (Chapter 3) (Gros-Balthazard et al., 2023; Gros-Balthazard and Flowers, 2020). Their durability made them valuable commodities in exchange networks but it also creates challenges for interpretation: archaeologists often cannot determine whether these fruits were grown locally or imported. This ambiguity extends not only to questions of cultivation and processing locations but also to which fruits held higher social, economic or religious significance. The problem is especially pronounced for dates, since many excavations occur in regions whose climates would not have supported date cultivation, further obscuring their origins (Gros-Balthazard et al., 2016).

These factors collectively highlight the complexities and limitations inherent in interpreting the archaeobotanical record (Goldschmidt & Lasko, 2005; Bouby et al., 2022; Newport, 2016).

2.5 Archaeological Evidence of Processing Equipment (Chapter 7)

2.5.1 Data Collection and Structuring

Data collection, contextualisation and structuring were conducted systematically until July 2024, drawing from synthesised databases of archaeological evidence associated with wine and olive oil processing equipment (e.g., Callot, 1987; Frankel, 1999; Hadjisavvas, 1996; Eitam, 1986, 1996) and peer-reviewed journal articles focusing on targeted geographical areas and historical periods. Processing equipment offers some of the most direct and tangible evidence for ancient wine and oil processing industries. This study excludes ceramics and storage installations, as these have been extensively analysed in previous research and are more appropriately addressed within broader regional or economic studies. Among the regions under study, Palestine presents the most substantial dataset, both in terms of the quantity and preservation quality of processing equipment, as well as the extent of archaeological area explored per kilometer. For a broader discussion, see Chapter 7 or Section 2.5.4 below.

Given the vast volume of available archaeological data, it was not feasible to systematically catalogue all findings. Instead, data was gathered and assessed as part of a critical discussion, allowing for greater flexibility in evaluating the material and facilitating comparative assessments across regions. The diversity of equipment and its varied contexts further necessitated an adaptive methodological approach, prioritising qualitative analysis over exhaustive cataloguing. Additionally, the complexities of the dataset and the variability in available evidence required a pragmatic strategy, wherein decisions were guided by a combination of empirical assessment, reasoned judgement and contextual relevance, rather than rigid predetermined criteria. This ensured that choices aligned with the broader research objectives while maintaining analytical coherence. Time constraints also played a role in shaping this approach, as a more rigid classification system would have been impractical within the scope of this study.

2.5.2 Typologies and Selection Criteria for Equipment

The typologies developed for processing equipment in this analysis are based on functionality. Equipment is first categorised by function, whether used for crushing, pressing, collecting or separating/fermenting and secondly, by the specific mechanisms employed to accomplish each task. This dual approach ensures that both technical utility and design variability are accounted for in the analysis. Some subdivisions within these typologies, such as pressing with stone rollers

versus simple weights in lever-and-weight press installations, appear to have had significant implications for efficiency, labour intensity and output. Therefore, these distinctions were considered essential in understanding technological advancements and regional adaptations. However, the majority of the variability identified in the archaeological record was stylistic rather than functional, for instance, differences in the shape of pressing beds (pear-shaped vs. square-shaped) or variations in weight forms. These stylistic differences had limited impact on the fundamental processing techniques and were therefore noted but not prioritised in the analysis.

For inclusion in this study, only installations that were at least 50% complete were considered. This threshold was selected to ensure the integrity of the analysis and to mitigate issues associated with incomplete or poorly preserved structures. Partial remains can sometimes lead to speculative reconstructions, potentially distorting interpretations of how equipment functioned. For instance, a large stone collection receptacle does not necessarily equate to wine or oil processing. Likewise, evidence of niches and *pithoi* together do not always indicate oil processing from a simple lever and weight press (SLWP) (see Section 7.4.1 for information regarding and SLWP). By focusing on more complete installations, this study prioritises cases where structural integrity allows for confident analysis of functionality and use. Additionally, this approach ensures a more reliable comparative framework when assessing technological developments across different regions and periods.

Due to the limited archaeological evidence available for the processing of tree fruits other than olives and grapes, additional sources were used to supplement the understanding of fruit processing methods and associated equipment. Iconographic and written sources, including historical writings and painted ceramics, were examined to reconstruct plausible processing techniques and equipment. These sources provide crucial contextual information on the types of tools and installations that may have been used.

2.5.3 Dating and Chronology

The identification and inclusion of equipment in this study were based on the first recorded presence of a particular type within a given area. This approach assumes that once a piece of equipment was introduced, the associated technology was known and likely available for use

throughout that region and time. While this does not confirm its widespread adoption, it provides a framework for understanding technological accessibility.

To ensure chronological accuracy, only equipment with definitive dating was included in the analysis. Dating was primarily determined through relative dating methods, including ceramic typologies and stratigraphic associations within securely dated layers. Equipment lacking clear dating evidence or found in mixed or disturbed contexts was excluded from the dataset to avoid misleading conclusions about technological availability. The decision to focus exclusively on definitively dated equipment was necessary to maintain chronological consistency in the study. While undated or provisionally dated equipment could provide useful insights, their inclusion risked introducing chronological uncertainty, particularly in regions where relative dating frameworks are less secure. By adhering to strict dating criteria, this study ensures that technological interpretations are grounded in a reliable temporal framework, facilitating more robust discussions on the spread and use of processing technologies.

2.5.4 Methods of Analysis

By employing chronological analysis, only well-dated equipment was included to ensure a reliable temporal framework for interpreting long-term patterns in processing, consumption and technological development. Without a secure chronological framework, it would be impossible to assess how and when different processing techniques emerged or evolved over time. Understanding when specific equipment types first appeared, how long they remained in use and whether their function changed across periods allows for a more nuanced reconstruction of past processing technologies and practices.

Processing equipment was categorised based on core operational functions, including crushing, pressing, collection and separation/fermentation. This classification ensured that technological choices were analysed based on practical efficiency rather than stylistic variations. Instead, emphasis was placed on practical distinctions, such as the use of stone rollers vs. simple weights in lever-and-weight press installations, as these variations had a direct impact on productivity, labour intensity and economic viability. Moreover, functional analysis helped to refine the interpretation of processing installations and allowed for more meaningful interpretation of technological use.

Spatial analysis was needed for assessing regional patterns in the distribution and possible adaptation of processing equipment, including regional preferences and hypothesising technological diffusion. It was particularly useful in identifying technological clusters, comparing technological adoption across different regions and how that could impact the quantity and quality of the value-added product, as well as tracking technological persistence and adaptation across different regions and periods. This helped to contextualise the chronological and thematic analysis done before.

Finally, mechanical engineering principles provided a deeper understanding of technological efficiency and innovation, including force application and energy efficiency, durability and material constraints and technological innovation for improved efficiency (see Section 2.5.5 for more details). This multi-faceted approach ensures that the study's findings are not only historically accurate and contextually relevant but also technologically insightful, contributing to a more detailed understanding of ancient fruit processing industries.

2.5.5 Key Issues with Using Processing Equipment as Evidence

Several challenges arise when utilising processing equipment as archaeological evidence. One significant issue is geographical bias, since most available data originate from Palestine, where extensive research has been conducted and widely published. This regional focus limits broader comparative analyses (e.g., Frankel, 1999; Callot, 1987; Brun, 1993, 2017; Salavart, 2009; Onozuka, 2012). Additionally, uncertainties in dating, often due to imprecise or missing chronological markers, complicate efforts to establish a clear sequence of technological development, which is further linked to understanding the abandonment of processing equipment.

Identifying grape and olive processing installations presents another difficulty, as structural remains are frequently ambiguous. Such structures can relate to multiple stages of wine and oil production, particularly in the absence of diagnostic archaeobotanical evidence or clearly associated production tools (Brun, 1993). Moreover, many installations served multipurpose functions or were repurposed over time, meaning the same facility could have processed different products across different periods. This complicates interpretations of their original function.

Furthermore, research into fruit processing installations beyond olives and grapes, such as date and fig wine, is often neglected, limiting our comprehension of ancient agricultural economies and the necessary processing techniques (Broshi, 2007; Nezer, 2002; McGovern, 2009). This study prioritises examining complete or partially preserved installations with clear contextual associations, rather than isolated or unprovenanced equipment. Although informative, *ex situ* or undateable finds constitute a significant proportion of available equipment and may distort our understanding of technological patterns. Additionally, the absence of processing equipment in certain regions should not automatically imply non-existence. Instead, this absence may reflect the priorities of archaeological projects, which often focus on urban areas rather than hinterlands (Pratt, 2021, pp. 158-159).

Ancient olive oil or wine installations may have been abandoned due to various complex reasons, requiring a multifaceted analytical approach. Potential influencing factors include climate and environmental changes (e.g., shifts in temperature, precipitation, soil quality or pest populations), economic transformations (e.g., disruptions in trade routes or emergence of more profitable industries), social or political upheavals (e.g., wars, invasions, instability), cultural or religious developments (e.g., shifts in consumption patterns affecting demand), technological advancements (leading to obsolescence or integration into new methodologies), demographic shifts (e.g., population fluctuations or settlement relocation) and cultural exchanges (e.g., the introduction of new products or processing techniques). These factors are interconnected, with specific causes varying according to historical, geographical and cultural contexts.

Despite these challenges, limited or fragmentary data should not be disregarded. This research seeks to derive meaningful insights even from incomplete evidence. Processing equipment from early periods and expansive regions has not previously been systematically examined in detail, particularly regarding efficiency and functional variations. Therefore, this study aims to evaluate whether such an investigation is feasible and, if so, what valuable conclusions can be drawn from the available data.

2.5.6 Mechanical Engineering Analysis: Equations for Processing Equipment

Determining the mechanical engineering equations to assess the effectiveness and benefits of each type of processing equipment required a multidisciplinary approach. This was needed since

this process relied primarily on archaeological evidence to understand how these tools functioned within their archaeological context. Insights were drawn from the physical characteristics of the equipment, including material composition and design features, which provided clues about their operational principles and efficiency (Chapter 7). The analysis was further enriched by ethnographic evidence, which offered comparative perspectives from traditional and contemporary societies that used similar technologies (Chapters 4 and 5). Ethnographic studies helped to bridge the gap in understanding by demonstrating how such equipment might have been operated. Mechanical engineering sources (Hicks, 2006; Popov, 2010; Hanaor et al., 2021) and equations sheets (MEC Engineering Spreadsheets) served as the primary foundation for developing mechanical engineering equations, incorporating principles such as Hertz contact mechanics and tribology. Together, these sources of evidence formed a robust foundation for applying mechanical engineering principles to develop specialised and unique equations, which can be utilised by other researchers in the future when processing equipment is found and needs to be analysed.

Weights, measurements and other physical factors were derived from actual archaeological examples whenever possible to ensure the modeling remained grounded in real-world evidence. These examples include artefacts such as weights, press components and structural elements that were preserved or reconstructed from different sites. By incorporating dimensions and materials from tangible remains, the analysis avoids reliance on purely theoretical values, ensuring greater accuracy and relevance. This approach bridges the gap between theoretical modeling and historical reality, enhancing the reliability of the comparative analysis.

Everything was standardised as much as possible. For example, given the lack of data on individual body weights from the periods under investigation, a standardised assumption of 75 kg was applied consistently across examples to maintain uniformity in comparative analysis. A 75 kg estimate for the weight of an ancient male is reasonable when considering factors such as diet and nutrition, active lifestyle and physical labour of the non elite, health and stature trends and general health conditions (e.g. the absence of obesity and sedentary lifestyles in the periods under study) (Smith, 2005). This assumption mitigated variability introduced by unknown anthropometric factors, allowing for controlled modelling of hypothetical scenarios.

2.5.6.1 Sensitivity Analysis, Pivot Tables, Graphs and Heat Maps

Python 3.13 was used to write and execute code for performing sensitivity analysis, processing data and generating meaningful insights from the mechanical models. To achieve this, libraries such as NumPy and Pandas were employed for efficient data manipulation, while SciPy was used for advanced mathematical modelling and optimisation. Python facilitated the creation of pivot tables, statistical computations and numerical simulations, enabling a detailed examination of how different input variables, such as force, contact area, weight and lever arm length, affect pressure distribution in various pressing methods. Given the complexity of these mechanical systems, it identifies which factors have the greatest influence on performance. This approach can be applied in archaeological analyses to infer possible production processes (e.g., determining whether sufficient pressure was applied to press dates). Matplotlib and Seaborn were used to visualise the complex results, producing graphs and heat maps to illustrate key trends and relationships in a structured and clear way.

Python 3.13 was chosen for its flexibility, ease of use and powerful ecosystem of libraries for numerical computing, data analysis and visualisation. Unlike MATLAB, R or Excel, Python is open-source, scalable and allows for automation, making it ideal for handling large datasets and complex sensitivity analyses. Libraries such as NumPy, Pandas and Matplotlib enable efficient mathematical modelling, data manipulation and trend visualisation (Nagbal and Gabrani, 2019; Fangohr, 2004).

2.6 Archaeological Survey Work and Urartu Case Study (Chapter 8)

2.6.1 Site Selection and Data Selection

Two types of data were utilised in this analysis: (1) chronological evidence of wine-processing equipment from the study area and (2) contemporary sites dated to the Urartian period from the eastern Mediterranean (Chapter 7 data). These datasets were selected to facilitate a comparative approach that would enable a deeper understanding of regional trends in wine production and to identify possible influences, adaptations or continuities in wine-processing technologies over time.

Two types of data were utilised in this analysis: (1) chronological evidence of wine-processing equipment from the study area and (2) contemporary sites dated to the Urartian period from the eastern Mediterranean (Chapter 7 data). These datasets were selected to facilitate a comparative approach that would enable a deeper understanding of regional trends in wine production and to identify possible influences, adaptations or continuities in wine-processing technologies over time.

The study focused on the region historically associated with Urartu at its height (e.g., 9th–8th centuries BCE), encompassing modern-day Armenia, northern Iran and eastern Turkey (Earley-Spadon, 2023). This territorial scope was determined based on historical records and archaeological evidence of Urartian occupation, ensuring that the analysis remained geographically and culturally relevant. A comprehensive list of archaeological sites within this region was compiled, covering a broad chronological range from the Neolithic period (c. 7000 BCE–4500 BCE) through to the early modern period (18th century CE). This extensive timeframe reflects the scope of both the ancient periods examined in this study and the ethnographic component, allowing for an in-depth understanding of long-term cultural developments and continuities in processing technologies across millennia.

This extensive temporal framework was chosen to track long-term developments in wine production and to assess the continuity or transformation of wine-processing technologies over time. Given the absence of a dedicated database for wine-processing equipment in these regions, all available literature was systematically collected and reviewed. This process involved surveying excavation reports, academic papers and regional archaeological surveys. The collected data were organised into a structured spreadsheet to facilitate systematic analysis ([Appendix 12](#)). Each site-phase was categorised according to the following attributes:

- Site number (linked to GIS maps)
- Site name
- Province
- Country
- Coordinates
- GIS period classifications
- Exact chronological dates
- Archaeological context
- Materials used in wine-processing installations
- Type of processing equipment
- Nature of archaeological evidence

- References and sources

This structured approach ensured that the dataset was as comprehensive as possible and enabled comparative analysis across different time periods and locations. The site-phases were then integrated into GIS for spatial analysis. GIS was chosen as the primary analytical tool due to its ability to overlay multiple datasets, facilitating spatial pattern recognition that might not be evident through textual analysis alone.

The second component of the analysis focused on identifying and examining sites from the Urartian period (c. 9th–6th centuries BCE) in the eastern Mediterranean. These sites were identified during research for Chapter 7 and were selected based on their relevance to the study of wine production. However, a major challenge in this aspect of the research was the scarcity of archaeological data for Iron Age wine-processing equipment in the eastern Mediterranean. Due to this limitation, only a select number of sites were examined in detail.

The selection criteria for these sites were based on:

- Diagnostic potential: Only sites with well-preserved or well-documented wine-processing installations were included.
- Geographic proximity: Sites closest to the Urartian heartland were prioritised to assess potential technological or cultural exchanges.
- Climatic similarity: Given the importance of environmental factors in viticulture, sites located in regions with comparable post-harvest conditions were preferred.

By applying these criteria, the study ensured that the comparative dataset remained meaningful despite the limited number of available sites. The selected examples provided key insights into regional variations in wine production techniques and the possible influences of Urartian practices beyond their core territory.

Ethnographic data from Chapters 4 and 5 provided an additional interpretive layer and were employed as a heuristic tool to explore the potential functionality, scale of production and labour organisation associated with ancient wine-processing installations. While not a direct substitute for archaeological evidence, ethnographic parallels provided valuable contextual information that

could guide interpretations. Chapter 5, in particular, serves as a methodological framework for researchers, offering insights into what types of archaeological features might be expected in wine-production sites and where such evidence is most likely to be found. This approach is particularly relevant given the patchy nature of the archaeological record for specialised wine production in the region. By drawing upon ethnographic analogies, the study aimed to fill some of the interpretative gaps and refine hypotheses regarding the role of wine production in past societies.

2.6.2 Methods of Analysis

The methodological framework of this study integrates systematic analysis, thematic analysis, typology and spatial and visual analysis to ensure a structured, comparative and interpretative examination of wine-processing equipment across different periods and regions. These approaches are particularly well-suited to addressing the fragmented nature of the archaeological record and the absence of a pre-existing database dedicated to wine-production installations.

Systematic analysis enabled the standardised collection and categorisation of data, including site attributes, archaeological contexts, materials and typologies. GIS mapping was employed to identify spatial patterns and site distributions, facilitating correlations between processing sites and environmental or cultural factors. Additionally, this method allowed for the comparative assessment of sites over time and across different regions, helping to detect continuities, transformations and technological innovations in wine production. Given the data set's diverse sources and lack of a centralised database, systematic organisation ensures transparency, reproducibility and analytical rigour. It also mitigated biases from fragmented archaeological records by standardising inclusion criteria for sites and artefacts.

Thematic analysis was particularly useful for handling diverse and incomplete datasets, as it enabled the identification of key themes and patterns through qualitative categorisation. This approach helped recognise recurring features in wine-processing installations, such as architectural layouts, material choices and technological adaptations. It also facilitated the identification of functional differences in wine production, distinguishing small-scale domestic processing from large-scale industrial operations. Additionally, thematic analysis provided insights into socio-cultural influences, including possible Urartian contributions to viticultural

practices in neighbouring regions. By connecting archaeological and ethnographic datasets, this method allowed for a more nuanced discussion of production techniques, labour organisation and the symbolic or economic importance of wine. The findings from thematic analysis naturally contributed to the creation of typologies.

Typologies provided a structured framework for categorising wine-processing equipment based on shared characteristics. This classification enabled the identification of distinct types, such as presses, storage facilities and fermentation installations, as well as a comparative framework for assessing technological evolution, continuity and innovation in production methods. Typologies also facilitated cross-regional comparisons, helping determine whether specific processing equipment was culturally unique or broadly shared across different regions (Frankel, 1999; Hadjisavvas, 1996, 2020).

Spatial and visual analysis further enhanced this study by providing a quantitative and graphical means of assessing the distribution of wine-processing sites. GIS mapping allowed for the identification of clustering patterns, site distributions and their relationships with environmental features, cultural factors and potential trade networks. This method also helped visualise chronological changes, revealing when and where different types of processing equipment were used. Given the lack of a centralised database for wine-processing installations, GIS played a crucial role in synthesising disparate archaeological data and uncovering spatial relationships that textual analysis alone might have overlooked.

2.6.3 Physical Survey

As indicated in Section 2.3.2, this survey project was undertaken as part of the ethnographic project and due to restrictions imposed by the Armenian government, the results of this physical survey cannot be published until summer 2026 (subject to change). The project team consists of a project director, an assistant project director (myself), ten field archaeologists and two geophysical survey specialists. My main responsibilities included identifying suitable areas for surveying and utilising ground penetrating radar (GPR) within the constraints of our budget and the limited time we had access to the equipment. I also supervised geophysical survey specialists to ensure that fieldwork was conducted efficiently and according to protocol. Additionally, I managed and regularly updated our data management systems with all the survey worksheets and

field notes collected during the surveys. Another key aspect of my role was overseeing the proper tagging of artefacts found each day and ensuring that all items were accurately catalogued by the end of each week, maintaining the integrity and organisation of the artefact records.

2.6.3.1 Site Selection and Justification

Two separate archaeological surveys were conducted at Argishtikhinili and Aghavnadzor in 2022 and 2023, each selected for its unique historical and archaeological significance in relation to Urartian viticulture and winemaking practices. Argishtikhinili was chosen due to its significant administrative and economic role on the Ararat plain during the Urartian period; written records of grape growing and wine production; large storage facilities (i.e., 160,000 L of wine); geographical location near the Arax river and Urartian irrigation and long-standing Urartian infrastructure (see Chapter 8, section 8.6) (Piotrovsky, 1969; Martirosyan, 1974; Khatchadourian, 2007, p. 58). Aghavnadzor was picked since it was in such close proximity to some of the participants surveyed in Chapter 5; proximity to a significant winemaking site (Areni-1 cave); evidence of a nearby Urartian fortress; evidence of ancient horticultural landscapes and evidence of ritualistic wine use in Urartian burial practices surrounding the area (see Chapter 8, section 8.7) (Gasparyan et al., 2021, pp. 1-2; Gasparyan et al., 2020; Gasparyan, 2014; Hovhannisyan et al., 2015, pp. 328-329).

2.6.3.2 Methodology of Survey

Both surface (pedestrian) and subsurface (geophysical) surveys were employed to maximise the likelihood of identifying a wine press. The integration of surface and geophysical surveys was particularly suitable for this study as it enabled a non-invasive yet comprehensive exploration of the research area, minimising disturbance to archaeological deposits while increasing the chances of identifying key features.

The surface survey aimed to identify artefacts such as pottery fragments, architectural remains or other diagnostic materials that might suggest wine production activities. To ensure systematic coverage, the survey area was divided into manageable sub-areas, each subject to stratified random sampling. This method was selected to ensure representative coverage of diverse terrain types, including areas with varying elevations, soil compositions and potential land-use histories. Stratified random sampling reduces bias in artefact distribution analysis, ensuring that different

environmental and topographical contexts were equally considered (Badalyan et al., 2014; Kroll, 2006).

Within each designated sub-area, the survey was conducted using a pedestrian transect walking strategy. This involved systematic coverage of the terrain through a grid-based approach, with survey participants walking along parallel transects spaced at 10 x 10 metres. This methodology ensured comprehensive and consistent surface coverage while minimising observational bias. The regular spacing of the transects allowed for the systematic recording of artefacts. The grid-based approach was chosen for its effectiveness in standardised artefact documentation and spatial analysis (Parker, et al. 2011; Petrosyan et al., 2015; Petrosyan and Dan, 2017). By implementing a controlled survey grid, the research ensured that artefact recovery was not influenced by arbitrary movement patterns but instead followed a methodical framework, reducing the risk of over-or under-representing specific areas. This approach was particularly appropriate given the research aims, as it allowed for the precise mapping of material culture related to viticulture and wine production.

The entire team documented surface finds in situ, recording their spatial coordinates by Real Time Kinematics Differential GPS (RTK-DGPS) GPS, typological characteristics and density. Particular attention was paid to artefact clustering, as concentrations of pottery, amphorae fragments or tools could indicate potential activity zones, such as processing areas, storage facilities or trade hubs. The recording process involved both written field sheets and photographic documentation to create a comprehensive dataset. The physical field sheets, containing spatial and descriptive data, were subsequently digitised and then integrated into GIS (James et al., 2024).

To supplement the surface survey and investigate subsurface features, a ground-penetrating radar (GPR) survey was carried out. This method was chosen for its ability to detect buried structures without excavation, making it particularly advantageous for identifying subsurface architectural remains, storage vats and buried bedrock modifications commonly associated with ancient wine presses (Bárta et al., 2020). GPR is especially effective in detecting differences in soil composition, voids and dense material concentrations, all of which could indicate buried architectural elements (Lindsay et al., 2014; Conyers and Leckebusch, 2010).

The GPR survey was conducted along pre-defined transects within each sub-area, ensuring systematic coverage of areas with high potential for wine production installations (Conyers, 2023). The selection of these areas was informed by multiple factors, including:

- Proximity to ancient storage facilities – Given that wine presses were typically located near storage areas for efficiency in production and distribution.
- Sloping terrain – As gravity-assisted pressing was a common feature in ancient viticulture, sloped areas were prioritised.
- Industrial zones – Areas historically associated with production activities were included to assess the possibility of wine-related industrial activity.
- Water sources – Proximity to water was crucial for cleaning equipment and potentially for the production process itself.
- Agricultural/horticultural zones – Areas with evidence of historical or contemporary viticulture were targeted to examine potential continuity in wine production practices.

The methodological choices were guided by best practices in landscape archaeology and remote sensing, with a focus on preserving site integrity while obtaining maximal data for analysis (Bárta et al., 2020; Lindsay et al., 2022; Hadjimitsis et al., 2020).

Chapter 3 - Tree-mendous Growth: the Ecology and Ethnography of Tree Fruits

The main objective of this chapter is to explore the ecology and ethnography of tree fruits available in the regions under study, the Eastern Mediterranean and Armenia, during the period from 10,000 to 700 BCE. Specifically, it examines where species grew (in wild and/or domestic form); what is known about their growth requirements, life cycle and fruiting behaviour; the ‘traditional methods’ of cultivation, such as grafting, irrigation and tillage, used in the recent past to enhance their growth and fruiting; and how these fruits were consumed and utilised. Additionally, the chapter provides a broad analysis of the benefits of domestication and its impact on tree fruits, their processing into value-added products and the final value-added products themselves. This information will be evaluated critically to assess its relevance to the distant past, with ecological data generally offering greater insights than ethnographic data. This analysis will help clarify both the likely potential for and constraints of ancient tree fruit production and consumption. The chapter also aims to demonstrate that similar value-added products could be derived from both wild and domesticated tree fruits. Information on pre-industrial methods and equipment used in the recent past to harvest tree fruits and process value-added products, such as juice, wine, vinegar and oil, is presented in Chapter 4. Chapter 5 surveys available archaeobotanical data (recorded in terms of presence/absence) to identify which tree fruits were found in the regions and periods under study and, whenever possible, how they were consumed in each context (e.g., caches of grape pips imply that grapes were being processed *en masse*).

3.1 Wild vs. Domesticated

Wild fruit trees are not planted by humans but grow naturally within the landscape. Typically, humans are not involved in this process, although they can maintain wild tree fruits through practices such as pruning and cutting to help ensure optimal yields (Yalcin et al., 2022; Liebman, 1996). Wild fruit trees are generally found within their current natural distribution areas, whereas domesticated and feral fruit trees can often be found beyond these ranges (Fuller and Stevens, 2019). As a result, tree fruits found outside of their natural distribution areas tend to be automatically considered domesticated. This distinction between wild and domesticated forms

hinges on evolving definitions of domestication itself, which have shifted in recent scholarship, toward an ecological and evolutionary perspective (e.g., Lord et al., 2025; Allaby et al., 2022; Fuller et al., 2023; Schell, 2018).

Domestication is best seen as an evolutionary process shaped by environments that humans create or manage, rather than solely as a human accomplishment or end product. A plant population qualifies as domesticated when it can no longer survive outside these human-modified settings (Lord et al., 2025). This view shifts the focus away from definitions based strictly on human control, utility, productivity or deliberate intent (Allaby et al., 2022; Fuller et al., 2023). Instead of treating plants as either fully “domesticated” or not, it places them on a spectrum of interaction with human-shaped environments. By doing so, it avoids assumptions about domestication pathways and opens space to investigate how plants adapt to anthropogenic niches.

Within this framework of domestication as adaptation to anthropogenic niches, the tree fruits under consideration may well have resulted, at least in part, from humans selectively harvesting seeds that appeared to exhibit desirable traits, such as larger size, increased sugar content and higher calorific value, especially in comparison to their wild counterparts (Miller and Gross, 2011; Fuller and Stevens, 2019; Meyer et al., 2012) (see Table 3.1). This selection process seems likely to have contributed to or at least coincided with, expanded distribution areas, the gradual emergence of more desirable fruit characteristics and what appear to be significant genetic changes. Domestication also resulted in larger and more consistent yields in terms of both fruit size and quantity (Bonhomme et al., 2020), earlier reproductive maturity (precocity) and regular, long-term, non-alternating productivity (Goldschmidt, 2013). The domesticated tree fruits examined in this study generally have smaller seeds or stones and a higher proportion of fruit flesh (with the exception of dates). They also tend to show increased levels of oil and sugar. These traits enhance their calorific value and facilitate easier reproduction (Sethi and Sethi, 2006).

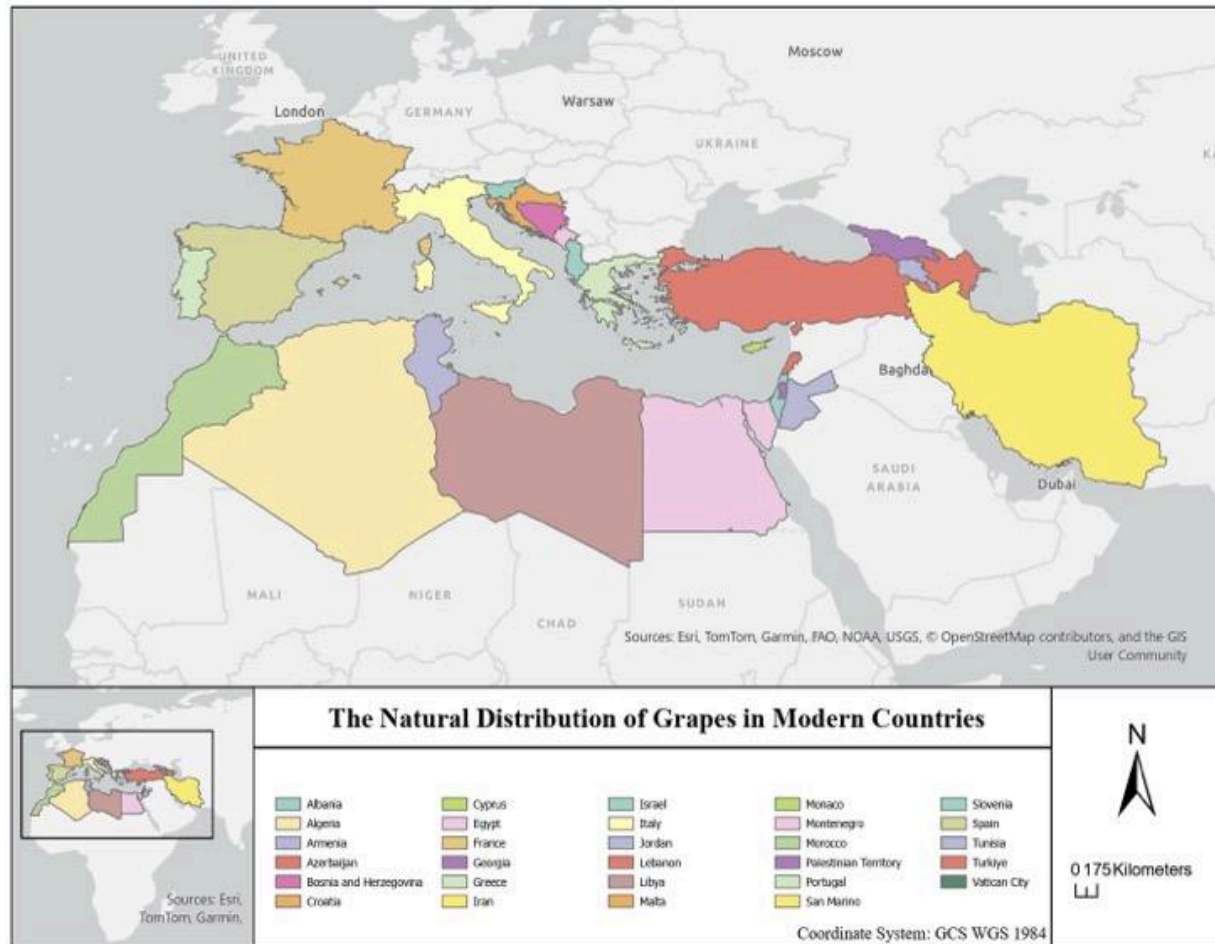
Regional variation further complicates this picture. The prevalence of wild cultivars in the geographical areas under study may have facilitated the exploitation and domestication of tree fruits. In some regions, an abundance of wild forms may have slowed or even negated the need

for domestication. Feralisation refers to the evolutionary process through which a domesticated population adapts to survive independently, without reliance on an anthropogenic niche (Gering et al., 2019). As a result, they exhibit a mix of wild and domesticated traits (Warwick and Stewart, 2005).

Aspect	Wild Fruit	Domesticated Fruit
Variation	Driven by natural processes.	Selected by humans for flavor, nutrition, transport, storage and processing suitability.
Propagation	Reproduces naturally via seeds; grows on its own roots.	Vegetative methods (grafting, budding, air-layering, cloning); often grafted onto rootstocks..
Hybridisation	Usually not hybrid; natural hybrids are rare.	Artificial hybrids are common.
Plant Culture*	Thrives with organic, permaculture-based methods; relies on natural rainfall; grows in native climate.	Sometimes grown in monocultures or specialised plots; human-managed seasonality; range expanded via breeding.
Growth/ modification	Reaches size potential based on environment.	Can be modified for harvesting or other practical purposes.
Fruit Characteristics	Small, high-fiber, sour/astringent, low sugar/calories; large seeds with little flesh.	Large, sweet, high sugar/calories; small seeds with abundant flesh.
Survival	Reproduces in the wild independently.	Requires human care to survive.

*Table 3.1: Wild tree fruit vs. domesticated tree fruit. The preceding is a generalisation/summary of many tree fruits and is subject to their constraints. * Plant culture refers to the methods and environmental conditions under which plants are cultivated, maintained and managed to optimise their growth, yield and utility. It encompasses both natural and human-influenced practices.*

3.2 *Vitis vinifera*



Map 3.1: Natural distribution of grapes in modern countries (created by V. Newson). N.B. Esri requires the labeling of this region as “Israel/Palestinian Territory.” However, the author wishes to clarify that this land is regarded as Palestine and will continue to be referred to as such throughout this work.

Vitis vinifera, the common grapevine, is the species of *Vitis* found across the Mediterranean, Central Europe and Southwestern Asia, extending from Morocco and Portugal in the west to Germany in the north and as far east as Iran (Abbo et al., 2015) (Map 3.1). Unlike some other domesticated crops, grapevines did not originate from a single domestication event (Dong et al., 2023; Bouby et al., 2013). The domesticated grapevine is closely related to *Vitis vinifera* ssp. *sylvestris*, a wild subspecies distributed across Europe and Western Asia. It is indigenous to Southern Europe, the Near East and the southern Caspian Belt. It thrives in the same climate as its domesticated counterpart but differs in having smaller fruits and lower yields. Globally, the primary grape cultivation areas are located between latitudes 30–48° north (Adam-Blondon et al., 2016) and in comparable environments in the Southern Hemisphere. However, distinguishing

between domesticated grapevines and their wild relatives is often challenging due to frequent spontaneous hybridisation between wild plants and domesticated cultivars (Terrall et al., 2010; Limier et al., 2018; Pagnoux et al., 2021; Sladonja, 2013; Bouby et al., 2013).

3.2.1 Growth Requirements

The species thrives in a Mediterranean climate but demonstrates greater tolerance for cold (e.g., in the Caucasus) and humidity than the olive tree (Zohary et al., 2012). Grapevines grow best in temperate regions with warm, dry summers, since humidity fosters vine diseases and mild winters, as severe cold can kill the plants. The optimal temperature range for grapevine growth is between 13 and 21 degrees Celsius (Lavee, 2000). Elevation plays a crucial role in determining a region's suitability for viticulture, as it directly affects the minimum and maximum temperatures within a vineyard (Williams et al., 1994). In lower-latitude areas under study, higher elevations are generally preferable. Grapevines are relatively adaptable and can grow in a wide range of soil types, including sand, heavy clay, limestone, gravel and shale (Ripoche et al., 2011; Pisciotta et al., 2022). Despite geological and geographical differences, the key shared environmental factors across all regions are sufficient water availability and good drainage (Hamman and Dami, 2000). While grapevines can survive with limited water, fruit production is significantly reduced under such conditions. The most critical periods for water availability are during flowering and fruit set, berry softening and after harvest (Zhang et al., 2014). The water requirements for grapevines are roughly equivalent to those needed for olive cultivation (see below).

3.2.2 Life Cycle, Fruiting, Productivity

In the Mediterranean and the Northern Hemisphere more broadly, the grapevine begins its annual growth cycle in the spring with bud break, followed by flowering and fruit set. The timing of these stages varies depending on the region. The onset of ripening, marking the transition from berry growth to berry maturation, typically occurs in late spring to mid-summer, a process known as *veraison* (Combe and McCarthy, 2000). By early fall (usually September or October), the ripe grapes are harvested (Photo 3.1). As autumn progresses, the vine sheds its leaves before entering winter dormancy. During this period, viticultural practices such as canopy management and vine training may be employed (Lorenz et al., 1995). The duration of each growth stage is

influenced by several factors, with climate and grape variety being the most significant (Coombe, 1995).



Photo 3.1: Grape vines in the process of fruiting in late spring, Armenia (Photo taken by V.Newson 2016).

Vines typically produce one crop of fruit per growing season and begin fruiting in their second year after planting. By the third year or later, their yield should become significant, around 7 kg of fruit per vine, though this depends on factors such as grape variety, climate and cultivation practices (Kilmartin & Oberholster, 2022). Vines generally have a lifespan of 50 to 100 years (Grainger & Tattersall, 2005; Thurmond, 2016), with their most productive phase occurring between 10 and 30 years. However, under optimal climatic conditions, suitable soil and proper viticultural practices, they can live much longer. For example, one of the world's oldest known vines, located in Slovenia, is over 400 years old (Gačnik, 2014).

To grow without constraint, a vine typically requires a planting space of about 2m by 2m. The productivity of vineyards can vary significantly due to numerous factors, including vine density per hectare, grape variety and the number of clusters per vine (Kilmartin & Oberholster, 2022).

As a result, grape yields fluctuate widely. For instance, modern specialised vineyards in Armenia can produce up to 1,000 kg of grapes per hectare, which can yield approximately 400–650 kg of wine (a 40–65% conversion rate) (Participant 43, personal communication, 2021).

3.2.3 The Benefits of Domestication

Domestication altered the genetic makeup of the grapevine through artificial selection, leading to significant morphological and physiological changes. One of the most notable adaptations was the transition to hermaphroditic (self-fertilising) and self-pollinating vines, which made cultivation easier for farmers. Domesticated vines also developed larger, densely packed fruit clusters, bigger berries and morphologically distinct seeds (Zhou et al., 2019; Zhou et al., 2017; Bouby et al., 2013). Chromosome gene sequencing conducted by Dong et al. (2023) identified shared domestication genes responsible for key traits in grapevine growth, including physiology, fruit set and resistance to biotic and abiotic stresses. These genetic modifications resulted in increased and more consistent fruit yields across larger and more diverse growing areas.

Domesticated grapes also tend to be larger, with a slight increase in sugar concentration and fewer seeds, providing more edible or processable fruit flesh (Chen et al., 2018). Compared to their wild counterparts, domesticated grapes contain a higher concentration of soluble sugars, making them more desirable for direct consumption, more durable during transportation and more suitable for fermentation, since higher sugar content facilitates the fermentation process (Xin et al., 2013). Additionally, domesticated grapes have a greater concentration of structural carbohydrates, which enhance fruit firmness and improve crushability, an important trait for processing (Guzman-Ardiles et al., 2023).

3.2.4 Uses

Vines were initially domesticated for their fruit, grapes, which are rich in sugar (15–25%), as well as for their value-added products (Akagić et al., 2020). Compared to olives and pomegranates, grapes were particularly advantageous because they could be consumed fresh without any delay or processing, making them ideal both as table fruit and for value-added production. One of the major benefits of grapes is how easily they can be converted into liquid, likely more so than any other fruit growing in the regions under study. This is due to their fleshy interior, small pips and relatively delicate skin (Zhang & Keller, 2015). Unlike some other fruits,

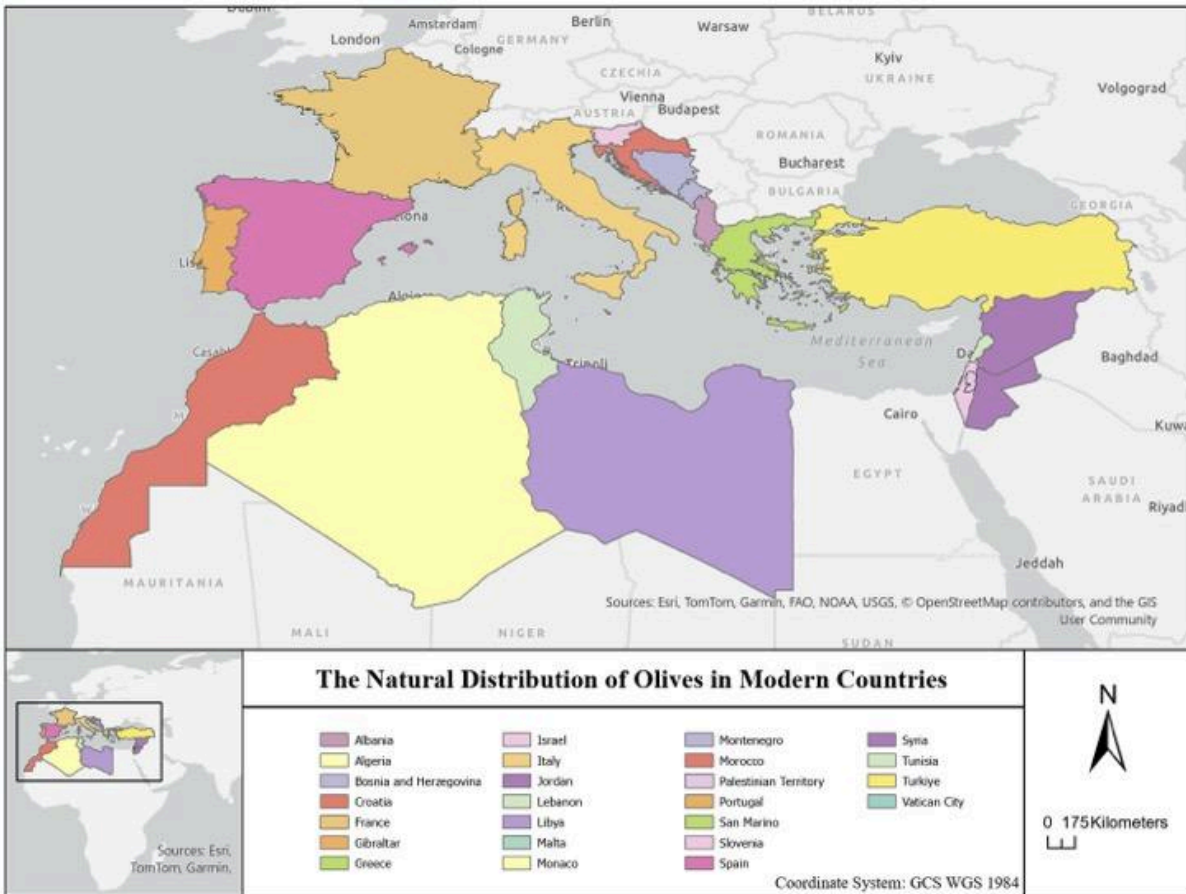
grapes do not require immediate treatment or processing after being harvested. Their naturally high sugar content also facilitates fermentation, making them especially suited for producing wine and vinegar (Claus & Mosjov, 2018). Vines, with their long life cycle, are generation-scale investments that often lead to polyculture and its associated benefits (Liebman, 1996). In addition to their fruit, vines also provide various secondary products.

Other parts of the plant were likely used, for example, sap for medicinal purposes, wood for manufacturing goods and kindling and leaves and stems for food, fodder or even dye production (see Table 3.2) (Hovhannisyan et al., 2015; Miller, 2008, pp. 943–945; Lardos & Heinrich, 2013; Johnson & Errington, 1847). However, grape cultivation comes with higher risks compared to staple annual crops. Grapevines are particularly susceptible to fungal diseases, such as mold and mildew, as well as pests. Additionally, they have a slower return on investment due to the time required for vines to mature and bear fruit (Halstead & O’Shea, 1989). Despite these risks, the cultivation of grapes was considered worthwhile due to the high value of the fruit and its processed derivatives.

Different Uses of <i>Vitis vinifera</i> Products need references (published or to Armenian project)
Food: table fruits, dried fruits, fruit leather, grape leaves, dried grapes (i.e., raisins and sultanas), vine leaves and oil (see Chapter 4)
Beverages: juice, wine, vinegar and distilled spirits (like brandy or ‘eau de vie’) (see Chapter 4)
Manufacturing: vine wood was used to build smaller items (usually), baskets, etc.
Medicine: used <i>inter alia</i> to treat respiratory issues, subacute enlargement of liver and spleen, skin and eye disease, bleeding and inflammation
Kindling: cuttings and stems used to make fire
Dye: Yellow dye can be extracted from the fresh or dried leaves
Fodder: Twigs and leaves make excellent fodder for a range of animals

Table 3.2: Different uses of *V. vinifera* products around the Mediterranean and Caucasus.

3.3 Olea europaea



Map 3.2: Natural distribution of olives in modern countries (created by V. Newson). N.B. Esri requires the labeling of this region as “Israel/Palestinian Territory.” However, the author wishes to clarify that this land is regarded as Palestine and will continue to be referred to as such throughout this work.

Olea europaea, commonly known as the olive, is native to the Mediterranean Basin, with the exception of Egypt (Weiss, 2015; Zohary et al., 2012) (Map 3.2). The domesticated olive is closely related to a collection of wild olives, known as *oleaster* olives, which are also distributed throughout the Mediterranean Basin (Besnard et al., 2018). While wild olives thrive in the same climate as their domesticated counterparts, they are distinguished by their smaller fruits, lower oil yields and lower-growing branches (Diez et al., 2014; Baldoni et al., 2006).

3.3.1 Growth Requirements

The olive tree is not overly demanding and adapts well to Mediterranean conditions, where it stands out as a defining element of the maquis flora. Olives thrive in warm climates, typically those with long, warm and dry summers but they are highly sensitive to frost. While olive trees can survive in less-than-optimal conditions, fruit production is significantly affected under such

circumstances (Breton et al., 2006). For optimal growth, olives require light to medium fine-textured soil that provides adequate aeration for root development, is permeable and has a high water-holding capacity (Carr, 2013). Sandy soils, however, pose a challenge due to their poor nutrient and water retention (Viola et al., 2012). Although olive trees can withstand drought thanks to their sturdy and extensive root systems, they require at least 400–450 mm of annual rainfall to maintain high yields. Otherwise, production declines significantly (Chiraz, 2013).

3.3.2 Life Cycle, Fruiting, Productivity

Olive trees are long-lived and slow-growing. They are typically propagated from cuttings and grafted onto wild rootstock (Abbo et al., 2015). During the first seven years of growth, an olive tree does not bear fruit but requires regular pruning. It begins to produce fruit between the ages of 7 and 15 years and reaches full maturity between 30 and 70 years (Vossen, 2013). Olive trees have remarkable longevity, living anywhere from 150 to over 1,000 years, with some, like the ancient olive tree of Vouves on Crete, estimated to be around 2,000 years old (Photo 3.2) (Bombarely et al., 2021). Additionally, olive trees possess the ability to regenerate if cut down or damaged (Lipschitz, 2007; Vossen, 2007).



Photo 3.2: An olive tree in the village of Vouves on Crete. It is probably one of the oldest olive trees in the world, at least 2000 years old and continues to produce olives today (Photo taken by V. Newson, 2015).

Domesticated olives exhibit significant variation in the size, shape and oil content of their fruits. Like other plants, the olive tree follows a developmental cycle dictated by the seasons. In the Northern Hemisphere, flowers of both sexes typically bloom in the spring. Since olives are slow-growing, they require minimal pruning; however, dead or awkward branches can be removed in late spring (Lodolini et al., 2019). Thinning out the branches also helps improve light penetration into the center of the tree (Lodolini et al., 2023). Olive fruits develop on the previous year's growth and branches. The trees follow a biennial bearing cycle, alternating between an "off year," when they produce a larger number of smaller fruits and an "on year," when they yield fewer but larger fruits (Breton et al., 2006). Harvesting typically takes place from late August to December in the Mediterranean, though this period varies depending on the region and cultivar (Weiss, 2015). For example, in southern Europe, green olives are usually picked earlier than black olives (Camposeo et al., 2013). The oil content of olives varies by cultivar, with the

pericarp generally containing 60–80% oil (Viola et al., 2012). In Crete, for instance, olive trees typically yield about 1.5–2.2 kg of oil per tree per year (Rackham & Moody, 1996). For optimal growth, each olive tree requires a minimum of 6m by 6m of land (Vossen, 2007).

3.3.3 The Benefits of Domestication

Domesticated olive trees are hermaphroditic (self-fertilising), larger and produce more oil than both wild and domesticated olive trees. In contrast, wild and domesticated olive trees allocate more of their resources to vegetative structures, such as roots, trunks, branches and leaves, rather than fruit production. As a result, their mesocarp is very thin (with diameters less than 8 mm) and contains a lower oil content (5–15% of wet matter) (Zohary et al., 2012). While domesticated olive trees, not only grow larger but also have a higher pulp-to-pit ratio (with fruit diameters ranging from 10–20 mm) and a greater oil concentration (15–30% of wet matter) (Besnard et al., 2017, pp. 392–397). Consequently, domesticated olives are not only larger but also yield more oil and are easier to process, leading to increased olive oil production. Beyond genetic modifications, domestication has also enhanced the concentration of phenolic compounds, antioxidants and fatty acids, resulting in an altered taste profile and an even higher oil content (Diez et al., 2015). Nevertheless, the degree of genetic divergence between wild and domesticated olives is noticeably lower than in other fruit trees (Cornille et al., 2014; Baldoni et al., 2006), potentially because of their extended generation times (e.g., more than 100 years for a single population turnover). Despite this, domestication has led to increased and more consistent fruit yields across different regions. The domesticated olives are also larger, making slightly greater quantities available for consumption or processing compared to wild or domesticated varieties.

3.3.4 Uses

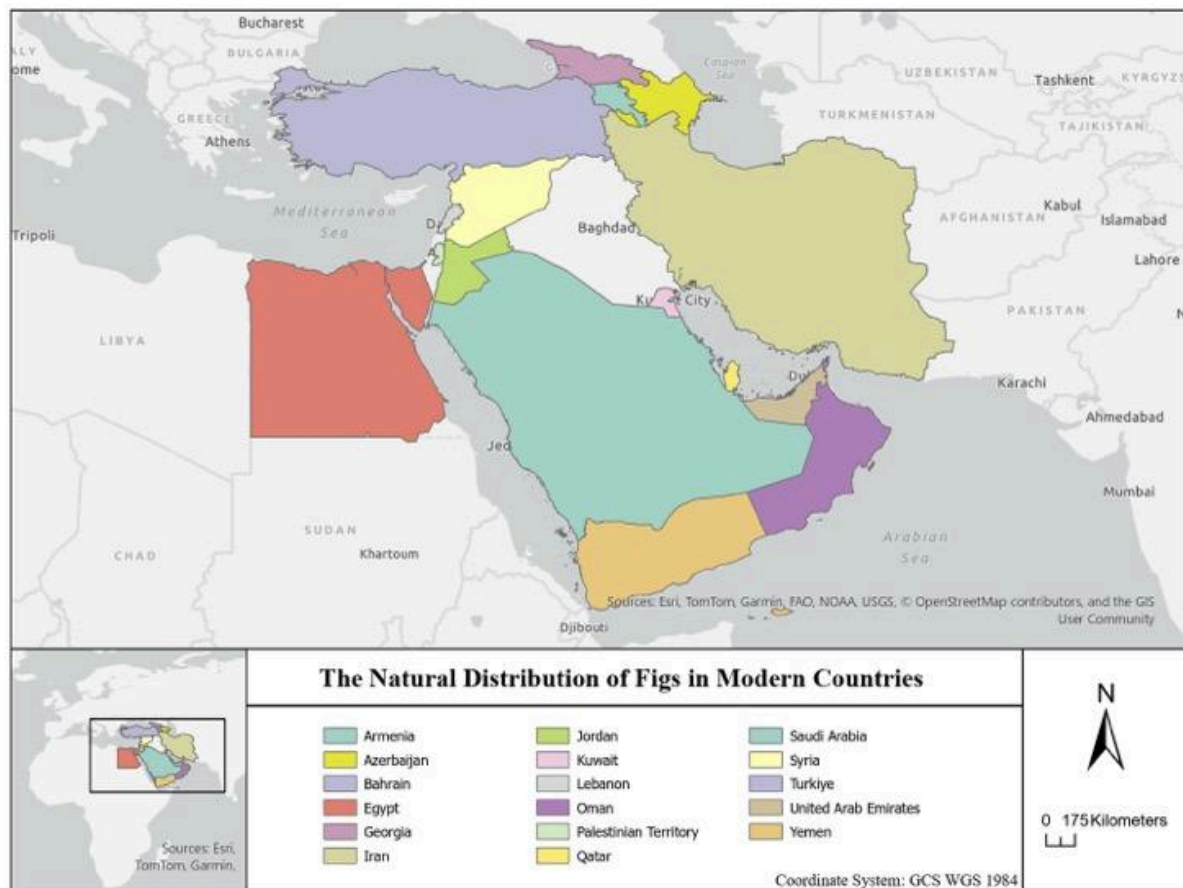
Olive trees and their fruits have long been a fundamental part of the Mediterranean agricultural economy and diet, serving as a high-caloric dietary staple (Besnard et al., 2018). However, their uses extend far beyond simple fruit consumption (see Table 3.3). Olive wood is valued for construction, while the lees, the watery sediment that settles after olive oil is pressed, can be repurposed as fodder and used for preservation, pest control and insect deterrence. Olive oil itself has a wide range of applications, including culinary use, food storage, cosmetics, textile

processing, tanning and greasing for belts, shoes and hides (Vossen, 2013; Boardman, 1976; Kaniewski et al., 2012; Uylaşer & Yildiz, 2014). Additionally, the olive branch, wreath and tree have historically symbolised peace, fertility, victory and respect throughout the Mediterranean (Rosenthal, 1994). Despite certain disadvantages compared to staple grain crops, such as the long delay before fruiting, susceptibility to diseases and biennial crop cycles, olive trees remain a highly significant crop with diverse applications.

Different Uses of <i>Olea europaea</i> Products
Food: table fruits, oil
Construction and Building: olive wood, known for being exceptionally hard, is highly valued for its durability, attractive coloration and high combustion temperature.
Light: oil for lamps (burns without smoke)
Cosmetics: perfume and soap
Industrial Purposes: textile processing, tanning and grease for belts, shoes and hides
Pesticide/Insect Control: lees prevented decay of wood (and could be used to polish wood), protected fruit trees from noxious weeds, insects and infertility
Fuel: hard wood that burns slowly (and can be burned while wet)
Preservation and Storing: lees were used to preserve various tree fruits but also grain and other plant foods, cheeses and meat products

Table 3.3: *Different uses of Olea europaea products in the Mediterranean and Caucasus.*

3.4 *Ficus carica* L



Map 3.3: Natural distribution of figs in modern countries (created by V. Newson). N.B. Esri requires the labeling of this region as "Israel/Palestinian Territory." However, the author wishes to clarify that this land is regarded as Palestine and will continue to be referred to as such throughout this work.

Ficus carica, known as the common fig, originates from the Middle East and western Asia but is now domesticated worldwide (Spiegel-Roy, 1986) (Map 3.3). The domesticated fig tree shares morphological traits with a group of wild and weedy figs that inhabit the Mediterranean basin. These wild figs, natural elements of Mediterranean maquis formations, are regarded as the ancestral form from which the domesticated fig tree descended (Weiss, 2015; Zohary et al., 2012).

3.4.1 Growth Requirements

Fig trees are well adapted to Middle Eastern and Mediterranean regions, flourishing in environments with moderate humidity and some hot, dry stretches, especially during flowering

and fruiting. They also require a cooler winter period to fully develop (Byeon and Lee, 2020). Additionally, the plant is highly tolerant of seasonal droughts, making it ideal for widespread cultivation (Ammar et al., 2014). Figs grow best on well-drained hill slopes but can also adapt to stony ground. They prefer deep, fresh soil, which requires continuous maintenance by farmers (Ferguson and Crisosto, 2007). While figs need as little as 300 mm of rainfall per year, they are often found near water sources or on well-irrigated land to ensure sufficient groundwater access (Andrada, 2014; Ammar et al., 2024). As a result, they demand significantly less watering and maintenance compared to crops like grapes and olives. The fig tree's extensive and aggressive root system, along with its large leaf area, helps protect the fruit from sun and wind, making it well suited for semi-arid environments and inhospitable locations (Mafrica et al., 2025).

3.4.2 Life Cycle, Fruiting, Productivity

The fig tree is one of the easiest fruit trees to propagate and is also a relatively fast-growing plant (Marcotuli et al., 2020). It begins producing fruit within 3–4 years (Photo 3.3) and can live for up to 200 years (Spiegel-Roy, 1986, p. 208). Once mature, it can yield up to three harvests per year, depending on the variety, more than any other fruit tree discussed here (Crisosto et al., 2011). This high productivity allows for a relatively quick return on investment, making fig cultivation highly worthwhile in terms of effort and risk. Furthermore, figs contain a high sugar content, which makes them particularly valuable for drying, fermentation and caloric yield (Veberic and Mikulic-Petkovsek, 2016). When dried, they can be stored and transported for up to 5–6 months, similar to pomegranates and dates (Irfan et al., 2013; Byeon and Lee, 2020). In contrast, many other tree fruits, such as grapes, olives and fresh figs, require processing to achieve similar storage and transportability.

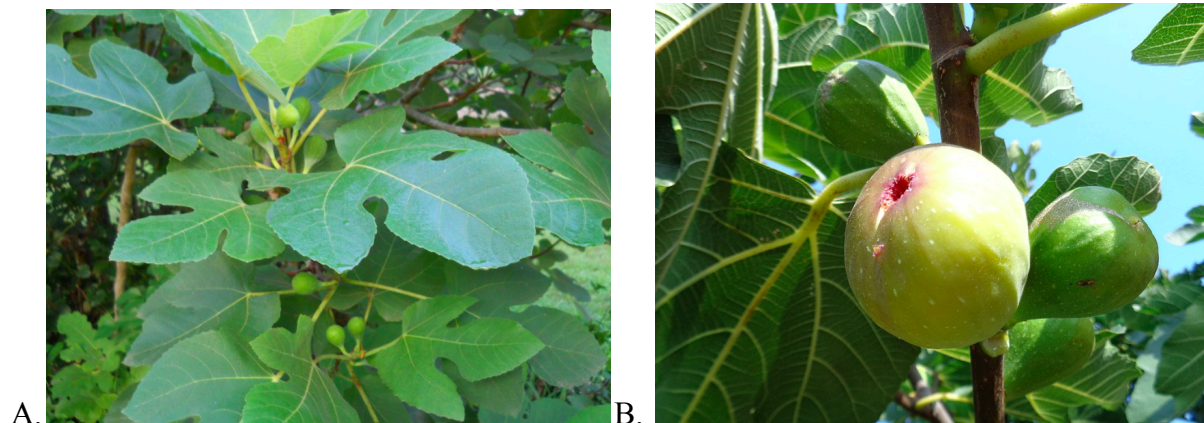


Photo 3.3: A) Fig leaves with small fruits B) Figs in different stages of growth (Photo taken by V.Newson 2016).

The leaves of the fig tree emerge in late spring. Some trees produce fruit in the spring, typically in June, from the previous year's shoot growth (Lodolini et al., 2021). However, the primary fig harvest forms on the new season's shoot growth and ripens from late summer through fall (August to October), influenced by both the variety and climate (Singh et al., 2023). The fruiting cycle generally lasts 120 to 150 days. In a Mediterranean climate, unseasonably cold temperatures may prevent the first fruits from ripening (Rosianski et al., 2016). Pruning is recommended only during the initial years due to the thickening of the tree's roots and branches (Puebla et al., 2003, pp. 148-150). Unlike other fig species and some fruit trees, the common fig does not always require pollination by wasps, making it less labour-intensive throughout its growth stages. Fig trees can be propagated through seeds, cuttings, air-layering or grafting. Depending on the variety, a mature fig tree can produce approximately 50 kg of fruit per year (Gerber, 2010; Pereira et al., 2017; Mellal et al., 2023). To reach its full potential, a fig tree requires a minimum of 6 meters by 6 meters of land.

3.4.3 The Benefits of Domestication

There is a lack of morphological differences between wild and domesticated types of figs and therefore, it is quite difficult to distinguish all the benefits of domestication (Lev-Yadun, 2022). However, it is clear that domestication led to easier methods and forms of growth of figs. Figs are pre-adapted for relatively easy domestication because the cuttings of the specifically chosen trees (optimal traits) develop roots more easily than those of other tree fruits (Kislev et al. 2006; Aumeeruddy-Thomas and Hossaert-McKey, 2024). Furthermore, due to the ease and quickness with which fig trees can grow, they could have easily been established in or around middens which may have resulted in their incorporation into the human-created ecological niches characteristic of early PPN sites in the Mediterranean/Levant (Fuller and Stevens, 2019). The domesticated fig also has a greater sugar content than its wild counterpart (Veberic and Mikulic-Petkovsek, 2016), making them not only more desirable for eating directly but also more durable during transport (both as non-dried and dried fruit) and more fermentable. All of this would have made figs a very attractive crop to the early grower and farmer.

3.4.4 Uses

Figs have historically been dried and continue to be used in this form for consumption, as fresh figs are highly perishable, lasting only 4 to 10 days before spoiling (see Chapter 4). Consequently, fresh figs typically could not withstand the long journeys required for export. In addition to their use as food, figs and their leaves have been utilised for medicinal purposes, including as laxatives and treatments for asthma, diabetes, high cholesterol and cough suppression (Table 3.4) (Mon et al., 2020; Aumeeruddy-Thomas & Hossaert-McKey, 2024; Crisosto et al., 2011; Weiss, 2015). Fig leaves are also consumed as potherbs and used as livestock feed. Beyond their nutritional and medicinal value, fig trees provide extensive shade in regions where it is needed. After pruning, their trimmed branches serve as a readily available fuel source, a practice still common in certain Levantine and Egyptian societies (Hobbs, 1989; andersen et al., 2014). However, fig wood has had limited uses beyond fuel, as it is neither sturdy nor thick and is not known to have been traded for other purposes (Lev-Yadun, 2022).

Different Uses of <i>Ficus carica</i> L. Products
Food: table fruits
Beverages: juice, wine, vinegar and distilled spirits (like brandy or ‘eau de vie’) (see Chapter 4)
Medicine: figs are used as laxatives and the leaves are used to treat asthma, diabetes, high cholesterol and act as a cough suppressant
Potherbs: leaves used as potherbs
Feed: leaves used for livestock feed
Shade: large canopy of tree gives shade
Fuel: trimmed branches and leaves were used as a fuel source

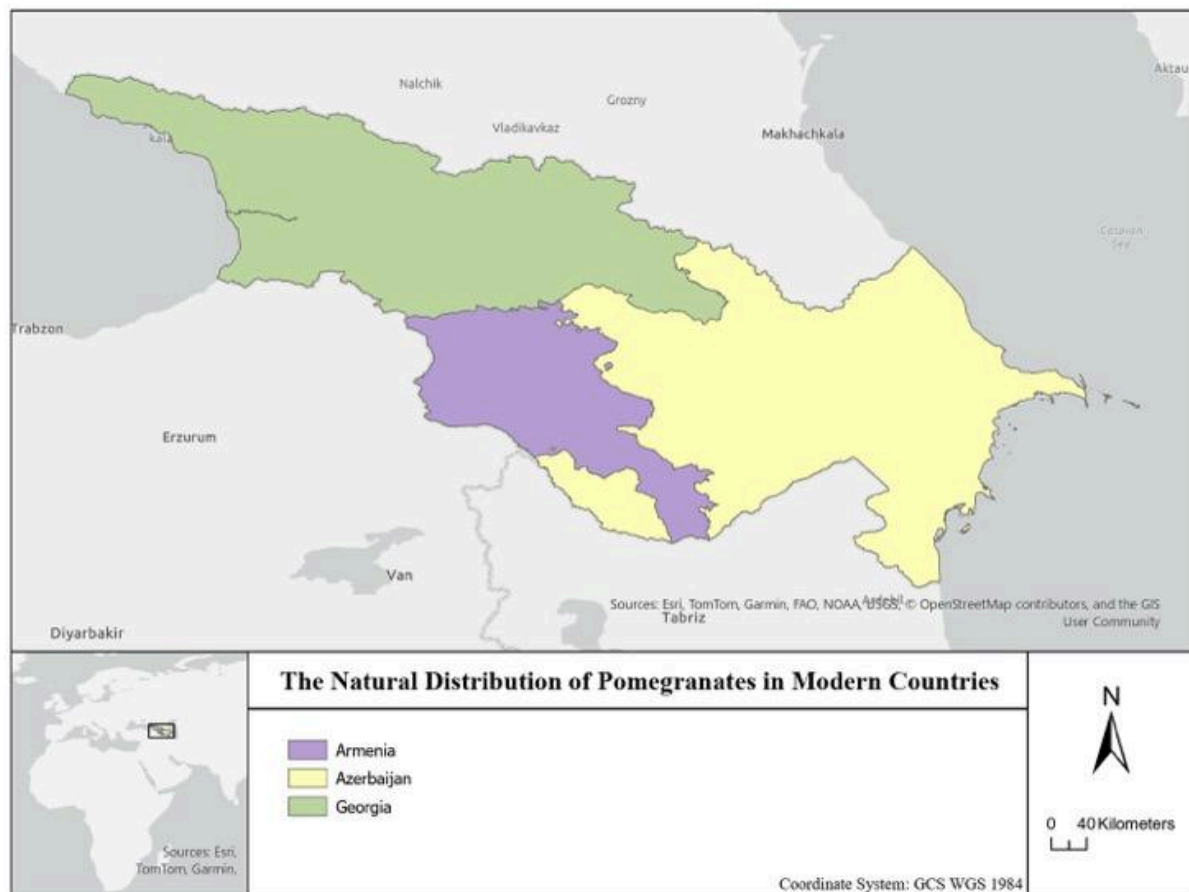
Table 3.4: Different uses of *Ficus carica* L products in the Mediterranean and Caucasus.

3.4.1 *Ficus sycomorus*

The cultivation of the sycamore fig has been primarily an Egyptian specialty (Brown & Walsingham, 1901). Wild sycamore figs still thrive in modern-day Sudan and are predominantly found in Eastern Africa, parts of the Arabian Peninsula and some areas of the southern Levant (Monselise, 2018, pp. 82–84). The two main differences between the common fig and the sycamore fig are reproduction and fruit size (Makishima, 2005, pp. 81–82). The sycamore fig reproduces from seeds and relies on pollination by the symbiotic wasp *Ceratosolen arabicas*

(Zohary et al., 2012; Galil & Eisikowitch, 1986), which is no longer present in modern-day Egypt. The tree produces a steady supply of figs, which are smaller than common figs but contain slightly more sugar (Sharaf et al., 2022; Compton et al., 2020). Historically, the sycamore fig held less prominence beyond Egypt, although it was still grown in warmer parts of Palestine and, to a lesser degree, in Lebanon, Cyprus and Tunisia (Eisen, 1901).

3.5 Punica granatum L.



Map 3.4: Natural distribution of pomegranates in modern countries (created by V. Newson). N.B. Esri requires the labeling of this region as "Israel/Palestinian Territory." However, the author wishes to clarify that this land is regarded as Palestine and will continue to be referred to as such throughout this work.

The wild forms of *Punica granatum* (pomegranate) grow in the South Caspian belt and the Caucasus (Doijode, 2001; Stepanyan-Gandilyan, 2009) (Map 3.4). The pomegranate originated in the Caucasus region and has been domesticated since ancient times, possibly as early as the 5th millennium BCE (Levin, 2006; Still, 2006, Chapter 6). While highly valued in traditional

Mediterranean horticulture, it remained a minor crop, except in the South Caucasus, where it was widely grown (Stone, 2017).

3.5.1 Growth Requirements

The pomegranate is a hardy, low-maintenance plant once established, as it allows for both self- and cross-pollination by insects and birds (Stover & Mercure, 2007; Ward, 2003). It is highly adaptable, thriving in poor soils but performing best in well-draining soil (Badizadegan, 1975, pp. 228–231). Drought-tolerant, it can grow in dry regions with either a Mediterranean winter rainfall climate or a summer rainfall climate. It also withstands moderate frost, high sodium levels and temperatures up to 45°C (İkinci et al., 2014, pp. 134–136; Soloklui et al., 2017, pp. 560–565; Stover & Mercure, 2007). A pomegranate typically requires 700–930 mm of water per year to avoid stress, though this varies depending on region, soil conditions, temperature and climate (Adiba et al., 2024, pp. 889–890; Stover & Mercure, 2007). It needs less water than many other fruit trees and adapts well as long as it is not overwatered.

3.5.2 Life Cycle, Fruiting, Productivity

Pomegranate trees typically take 2–4 years or longer to bear fruit, with peak production lasting until about 15 years of age (Holland et al., 2006). While fruiting continues beyond this age, flavour quality declines. Maintaining high-quality fruit traits depends on clonal propagation and cross-pollination (Holland et al., 2018). In winter, light pruning encourages new spur growth. Flowering begins in late spring and extends into summer, varying by region (Photo 3.4) (Stepanyan-Gandilyan, 2012, 2014). High temperatures are crucial during fruit development, as flowers form on same-year branches, primarily on spurs (Melgarejo et al., 2021). Harvest occurs in fall, typically from September to October, about 6–7 months after flowering (Holland et al., 2009). Fruits must be picked before full maturity to prevent cracking caused by humidity, wind dehydration, rain or insufficient water (Adiba et al., 2024, pp. 889–890; Stover & Mercure, 2007). When harvested early, pomegranates can be stored or transported for up to 5–6 months, similar to dried figs and dates. Their quality improves when kept in a cool, well-ventilated space. A mature tree can yield 40–50 kg of fruit per season (Holland, 2009; Stepanyan-Gandilyan, 2014, pp. 361–365). To thrive, each tree requires at least 5m × 5m of space (Melgarejo-Moreno et al., 2000).



Photo 3.4: Pomegranates growing in August in Armenia in Vayots Dzor, they will be harvested within a couple of months (Photo taken by V. Newson, 2021).

3.5.3 The Benefits of Domestication

Due to domestication, pomegranate fruits are larger (while pith size remains unchanged), have thinner rinds (which may allow more room for growth), slightly higher sugar content and lower acidity than their wild counterparts (Khadivi et al., 2020; Ashrafi et al., 2022). The larger arils and higher moisture content of domesticated pomegranates result in greater fruit and liquid yield upon processing (Zohary et al., 2012; Weiss, 2015). Their thinner rinds provide more space for aril development, contributing to increased fruit production (Khadivi et al., 2020).

In contrast, wild pomegranates have higher acidity and slightly lower sugar levels than domesticated varieties (Sharma & Thakur, 2018), which can negatively impact the production of value-added products. Acidity and pH influence juice and wine stability during fermentation and maturation, while higher sugar content facilitates fermentation. Incorrect pH levels can lead to bacterial contamination, causing spoilage of juice, wine and vinegar (Stephanyan, 2008). This also affects taste (Abbo et al., 2015). Additionally, the higher acidity of wild pomegranates impacts storage and transportability, with a shelf life of 1–3 months compared to 5–6 months for domesticated varieties (Stephanyan-Dandilyan, 2014). Overall, domesticated pomegranates differ from wild ones in taste (sugar and acidity levels), storability and fruit yield.

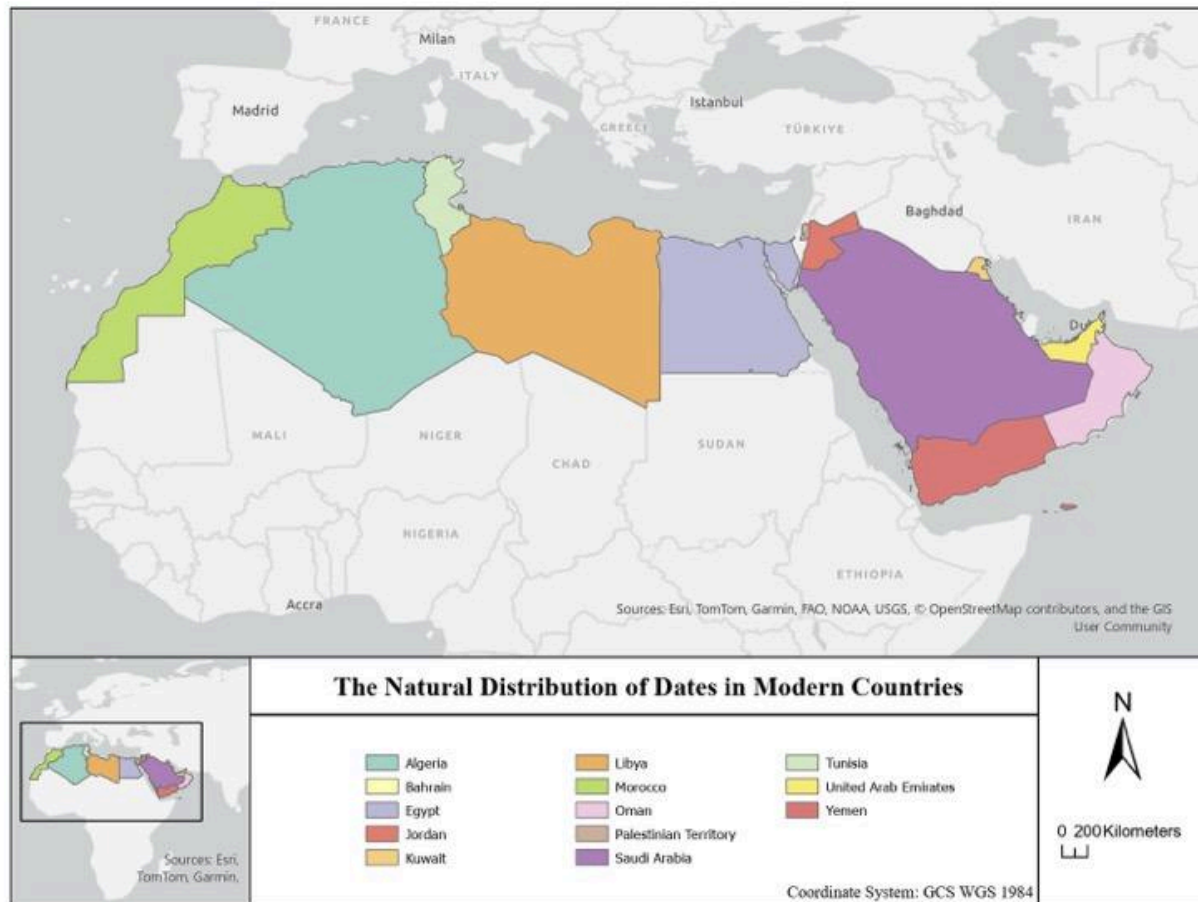
3.5.4 Uses

The pomegranate has long been consumed as food and beverage (see Table 3.5) due to its rich nutrient content, including vitamin C, phosphorus, iron, sugars and proteins (Vincent & Meena, 2015). It is also valued for its medicinal properties, such as treating tapeworm infections and other ailments and may offer anti-inflammatory benefits, lower blood pressure and help combat certain cancers, arthritis and bacterial and fungal infections (Asgany et al., 2014; Giménez-Bastida et al., 2021; Melgarejo-Sánchez, 2015, pp. 328-331; Sharma & Thakur, 2018). The bark serves as a strong purgative, while the rind and flowers are used as dye, including for colouring Easter eggs (Stephanyan-Gandilyan, 2014). Although the pomegranate tree is not typically harvested for timber due to its thin trunk and branches, it is hard, workable wood is favoured by woodcrafters for small items such as cooking utensils and bowls (Stephanyan, 2008; Stephanyan, personal communication, 2020).

Different Uses of <i>Punica granatum</i> L. Products
Food: table fruits, preserves, fruit leather, oil (12-20% of the seed is oil)
Beverages: juice, syrup, wine, vinegar and distilled spirits (like brandy or ‘eau de vie’) (see Chapter 4)
Medicine: curative properties (i.e., treatment of tapeworm and other infections) and help fight against other maladies
Bark: used as a strong purgative, used to cure leather, used to produce insecticide
Dye: the rind of the unripe fruits and the flowers are used as dye
Wood: woodworking for smaller items like cooking utensils/bowls

Table 3.5: Different uses of *Punica granatum* L products in the Mediterranean and Caucasus.

3.6 *Phoenix dactylifera*



Map 3.5: Natural distribution of dates in modern countries (created by V. Newson). N.B. Esri requires the labeling of this region as “Israel/Palestinian Territory.” However, the author wishes to clarify that this land is regarded as Palestine and will continue to be referred to as such throughout this work.

Phoenix dactylifera, date palm, is indigenous to an area from North Africa through the southern Levant and Arabian Peninsula (Gros-Balthazard et al., 2016)(Map 3.5). The precise origin of the domesticated date is uncertain. Given its economic importance and exchange over large areas, the seeds were dispersed all over the Middle East and other regions, thus blurring the original distribution of the species (Gros-Balthazard and Flowers, 2020; Weiss, 2015). However, it probably originated from the Fertile Crescent region, most likely in the Lower Mesopotamian Basin (Tengberg, 2012). According to Zohary and Spiegel-Roy (1975), the date palm is likely one of the earliest fruit trees to be grown in the Old World.

3.6.1 Growth Requirements

The date palm's tolerance for high temperatures enables it to thrive in desert oases and other environments inhospitable to most fruit trees (Barrow, 1998). It adapts well to long, extremely hot and humid summers (including warm nights) but is less tolerant of low winter temperatures than other Near Eastern fruit trees, such as grapevines and pomegranates. Date palms require temperatures above -6°C to survive, while pollination occurs at 35°C (Alotaibi et al., 2023). Although the tree can survive in saline environments, studies indicate that salinity negatively impacts its growth and yield (Tripler et al., 2011). Consequently, date palms in regions with mild summers, such as the Mediterranean coastal areas of Palestine and Lebanon, are unlikely to produce high-quality fruit (Al-Khayri et al., 2015). A steady water supply is crucial for cultivation, as date palms lack deep root systems and rely on irrigation or high groundwater levels for moisture (Carr, 2013; Alotaibi et al., 2023). They require well-drained, deep sandy loam soils capable of retaining moisture and free from calcium carbonate (Chao & Krueger, 2007; Mardhi Alenazy, personal communication, 2020). As a result, date cultivation is concentrated in deserts, particularly along the Near Eastern fringes and south of the Mediterranean. Notably, dates are the most sugar-dense tree fruit discussed, making them valuable for drying, fermentation and caloric intake (Krueger et al., 2021).

3.6.2 Life Cycle, Fruiting and Productivity

Date palms typically begin bearing fruit four to eight years after planting and generally take seven to ten years to achieve commercially viable yields (Jonoobi et al., 2019; Shaheen et al., 2022). They typically live for 50–100 years (Hodel & Johnson, 2007, pp. 13–14). Old leaves should be pruned in June to encourage new growth for the following year. Additionally, the trunk must be pruned annually after harvest to promote height growth and propagation (Alemayehu, 2023, pp. 156–159). The flowering period generally begins in March and lasts until April within its natural range, while fruiting occurs from spring to early autumn (Jdaini et al., 2022). Since dates do not ripen simultaneously, multiple harvests are required between August and early December, depending on the region (Chao & Krueger, 2007; Alemayehu, 2023). As a result, date harvesting is more labour-intensive than for most traditional fruit trees due to its extended duration.

For marketable fruit quality, date bunches must be thinned, ensuring adequate flowering the following year and preventing delayed ripening and bagged or covered before ripening to protect them from weather and animals (see Photo 3.5a) (Al-Shahib & Marshall, 2003, pp. 247–259; Mardhi Alenazy, personal communication, 2020). Date palms are highly productive, with potential yields of 100–200 kg per tree annually, though an average yield is 50–60 kg per tree (see Photo 3.5b) (Aleid et al., 2015; Mardhi Alenazy, personal communication, 2020). The number of green leaves on a date palm is crucial for healthy growth and high fruit yield, as fewer leaves result in lower-quality fruit. Date palms require at least 6m × 6m of space for root development and propagation (Mardhi Alenazy, personal communication, 2020).



Photo 3.5: A) A young date palm tree, approximately 11 years old, with a bunch protection (bag) B) Older palm trees that have grown and developed over decades who produce the greatest quantity of dates (Mardhi Alenazy, 2020).

3.6.3 The Benefits of Domestication

Domesticated dates not only have larger seeds but also contain more flesh than wild dates, allowing for increased product processing (Gros-Balthazard et al., 2016). They also have thinner skins and softer flesh compared to wild dates, making them easier to consume as table fruit and simpler to ferment into wine (Bohomme et al., 2020). Additionally, domesticated date palm trees are shorter than wild varieties, facilitating easier harvesting. Wild dates tend to have a stronger,

more astringent taste due to higher tannin levels and other compounds (Zaid and de Wet, 2002). Domesticated dates, in contrast, have a higher sugar content, making them more desirable for direct consumption, more durable during transportation (lasting up to 5-6 months) and more fermentable (Jonoobi et al., 2019).

Domestication has increased yield productivity while reducing interannual variability, resulting in both greater product availability and a more stable fruit supply (Gros-Balthazard and Flowers, 2020). Since domesticated dates do not all mature simultaneously, multiple harvests are required between August and early December, depending on the region. This staggered ripening ensures a continuous supply of fresh fruit and value-added products throughout the year (Jdaini et al., 2022, pp. 553-557; Krueger et al., 2021, pp. 17-21).

Domesticated date palms are commonly propagated through asexual methods such as vegetative propagation, allowing growers to grow trees with desirable traits like higher yields and superior fruit quality. In contrast, wild date palms rely solely on sexual reproduction (Lemlem et al., 2018; Goldschmidt, 2013). Unlike wild date palms, domesticated varieties are primarily hermaphroditic, producing both male and female flowers on the same tree, which simplifies and accelerates reproduction (Lemlem et al., 2018; Salomon-Torres et al., 2021).

3.6.4 Uses

The date palm provides a nutritious, high-calorie food that can be easily stored year-round. By providing shade and shielding against desert winds, these trees help establish a more comfortable environment (Tengberg, 2012). Moreover, date palms supply a variety of products for agriculture, domestic purposes (e.g., fuel, rope, cosmetics), architectural uses (construction and manufacturing) and medicinal applications (see Table 3.6) (Gros-Balthazard et al., 2018; Shelef et al., 2016, pp. 214–218; Yalcin et al., 2022; Chao & Krueger, 2007; Ekué et al., 2010). Nearly every part of the palm serves a useful purpose.

Different Uses of <i>Phoenix dactylifera</i> Products
Food: fruits, put into dishes, paste, sap, syrup, additive for coffee, animal feed (pits/stones)
Beverages: juice, wine (sugar content of 60-70% makes it ideal for wine) and vinegar
Medicine: treatment of diarrhoea, cough, breathing problems, alcoholic intoxication; roots are used against toothache and pollen supplies oestrogen.

Cosmetics: cosmetics and dermatological applications, including perfume (for their scent)
Construction/Fabrication: making huts, insulating board, mats, screens, baskets, fans, stocks, brooms and fishing floats.
Fuel: dried leaf petioles
Fibres: rope, feed for livestock, coarse cloth, sandals, wigs and large hats
Leaves: religious activities

Table 3.6: Different uses of *Phoenix dactylifera* products in the Mediterranean and Caucasus.

3.7 Traditional Methods of Domestication

The successful cultivation and economic yield of fruit trees required the development of both general and species-specific agro-techniques. While a comprehensive discussion of all techniques applied to individual species is beyond the scope of this study, three key stages of cultivation have been selected for review based on their significance, as highlighted by Zohary and Spiegel-Roy (1975), Carr (2013), Kislev et al. (2006), McKyes (1985), Lewis (2012), Goldschmidt (2013) and Abbo et al. (2015). These stages, tillage, irrigation and asexual propagation, represent fundamental agricultural practices essential for successful fruit tree cultivation.

3.7.1 Tillage

At the household level, where only a small number of trees sustain domestic consumption, the soil around the trees may be manually tilled using hand-held tools such as shovels, picks, mattocks, hoes and rakes. In contrast, trees growing at the edges of fields may benefit from ploughing the entire field with draft-animal power. For fruit trees in orchards and vineyards, however, the choice of tillage method depends largely on the spacing between rows (Lewis, 2012; Birkás et al., 2017; Cerdà et al., 2020; McKyes, 1985, pp. 1–9; Gebregziabher et al., 2006). The tools mentioned above were common agricultural implements and could be used across various crops. However, the use of ploughs and draft animals was often limited in small to medium-sized plots, as well as in regions with steep slopes, narrow terraces or natural obstacles such as large rocks or boulders. Additionally, their effectiveness depended on the crop's stage of development, for instance, whether the land was being prepared for initial cultivation or already supporting mature trees (Halstead, 2014; Brun, 2003). In areas where fruit trees or vines were closely spaced, ploughing was slow and often inefficient due to frequent interruptions between

trees. Smaller orchards, in particular, were often not worth ploughing, as manual digging or hoeing around individual trees or vines would still be necessary (Lewis, 2012). Even when ploughing was a viable and efficient option, some farmers lacked the economic means to maintain draft animals or invest in additional labour. Consequently, ploughs and draft animals were primarily used on large plots of land where neither terrain nor crop density posed significant obstacles (Halstead, 2018).

3.7.2 Irrigation

As previously discussed, fruit trees require a certain amount of water, although grapes, olives, figs, pomegranates and dates growing in their original distribution areas can typically survive on rainfall alone. In order to grow tree fruits in areas that have inconsistent or little rainfall during key months, irrigation may be needed with different methods of irrigation being applied across the eastern Mediterranean and Caucasus. Not only does irrigation help crops to grow but it may also contribute to landscape stability by enabling revegetation of disturbed soils. Irrigation can also protect against frost and prevent soil compaction (Farrington, 1980, pp. 291-299; Harrower, 2008). Three main factors influence the irrigation methods used in each micro-region: (1) the landscape (i.e. mountain/ hills, weather conditions, indigenous vegetation and human structures); (2) accessibility to water from lakes, streams, groundwater (i.e., springs and wells) and harvesting of run-off or rainfall (i.e., artificially constructed catchments and rooftops); and (3) distribution devices and techniques (i.e., hoses, pipes, buckets, terracing, channels, pack-animals) (see Photo 3.6) (Adrianov, 2016; Angelakis, 2020; Kelly 1983). It should be noted that irrigation has become much more common and widespread since mechanisation. Prior to this, it was usually restricted to garden scale, in areas with little water and in areas with little to no rainfall in the eastern Mediterranean and Caucasus. Several regions have notable historical irrigation practices. For instance, in early Syria and Lebanon, terrace irrigation involved channeling water through a network of small conduits to continuously water crops throughout the growing season (Angelakis, 2020; Hill, 2013). Beginning in the 9th century BCE, Urartu constructed irrigation canals to convert less suitable land into fertile farmland (Piotrovsky, 1959; Arutyunyan, 1964; Hovhannisyan et al., 2015). Meanwhile, Egyptians employed basin irrigation for at least 6000 years, using the Nile's annual flood to inundate designated plots (Cook, 2011; Malouta and Wilson, 2013).



Photo 3.6: Clay pipes are used to get water from the well, then channels are used to disperse the water in Saudi Arabia (Mardhi Alenazy, 2020).

3.7.3 (Asexual) Propagation

All of the aforementioned fruits are well-suited to vegetative (clonal) propagation (Zohary et al., 2012; Zohary and Spiegel-Roy, 1975). This form of asexual reproduction typically involves methods such as cuttings, grafting and layering. In this process, a vegetative part of the plant, such as a root or stem, is placed in an environment conducive to growth, allowing it to develop into a new plant (Chong, 1992; Love et al., 2017). While cuttings are effective for certain trees, such as figs, olives and grapes, this technique has traditionally had a low success rate for most fruit species, making it an impractical propagation method (Adhikari et al., 2022; Goldschmidt, 2013). Grafting, a horticultural process in which two plants are joined to grow as one, is the most commonly employed and effective method of propagation for nearly all fruit tree species, including those previously mentioned. Generally, a wound is created on one plant, into which another plant is inserted, enabling their tissues to fuse and develop together (McKey et al., 2010).

Commonly, vines, olives, figs, pomegranates and dates are domesticated using this method, often on their own rootstock (see above). The primary advantage of vegetative propagation methods, particularly grafting, is the genetic uniformity between the parent plant and the propagated offspring, ensuring consistency in growth, fruit yield and quality (Ak et al., 2021). Additionally, plants propagated in this manner typically bear fruit earlier than those grown from seeds (Miller and Gross, 2011).

Moreover, budding and grafting techniques contribute to the development of disease-resistant plant varieties and more resilient rootstocks. However, compared to seedling-grown trees, grafted plants exhibit less vigorous growth and have a shorter lifespan, undergoing fewer reproductive cycles (McKey et al., 2010). Another limitation is that this method does not facilitate the development of new plant varieties (Abbo et al., 2015). The tools required for grafting include sharp metal cutting instruments, while materials such as wood, cloth, string and rope are used to secure grafts in place (Mafrika, 2015; Ak et al., 2021). However, these tools are standard agricultural implements and, when encountered in archaeological materials, written records or iconographic references, they do not provide definitive evidence of specific crops or agricultural processes (Sable, 2020).

3.8 Discussion of Tree Fruit Benefits and Shift to Large-Scale Cultivation

Grapes, olives, figs, pomegranates and dates are highly valuable and sustainable crops due to their resilience, adaptability and longevity. Their durability makes them viable in diverse agricultural settings. Grapes, for instance, require minimal processing to yield liquid directly from the vine, thanks to their high flesh-to-skin ratio, making them an efficient source of sugar and calories. They thrive in various soils, tolerate low water conditions and can live for 50 to 100 years. Likewise, olives offer a high caloric return, extensive industrial applications and exceptional hardiness, making them a reliable and long-lived crop. Figs, pomegranates and dates also provide high caloric yields and can be easily processed into juice, wine or vinegar (see Chapter 4). Their storability and ease of transport further enhance their agricultural significance.

A shared advantage among these fruit-bearing trees is their long lifespan, making them essential staples for sustainable agriculture.

Domestication significantly increased fruit availability. Wild fruits, once scattered and sporadically domesticated, became more consistently and widely grown. This shift led to the development of cultivars bred for specific traits, such as enhanced sweetness or bitterness, seedlessness (parthenocarpy), increased nutritional value (e.g., higher fatty acid yields) and greater resistance to pests and diseases.

Orchard management practices, including irrigation, pruning, propagation, trellising and fruit thinning (see Section 3.7) (Ekue et al., 2010), further boosted fruit production and stabilised yields, making cultivation more secure and efficient. As a result, fruit farming expanded, laying the foundation for large-scale, value-added tree fruit industries. This transformation had lasting economic and agricultural impacts, solidifying domesticated tree fruits as generational investments capable of sustaining productivity and profitability for centuries.

3.9 Wild and Domesticated Tree Fruit: Similar Value-Added Products

Cultivation and domestication are not prerequisites for winemaking, vinegar production, oil extraction or other related industries (see uses above). Both wild and domesticated fruits can produce comparable value-added products, such as dried fruits and fermented liquids. The key factors affecting the ability to process wild fruits into the same products include sugar content, taste (influenced by molecular composition, colour and aroma) and quantity (availability, seed/stone size and fruit flesh volume) (Akagić et al., 2020; Trade et al., 2017; Nafees et al., 2020; Broshi, 2007).

Wild and domesticated varieties of grapes, figs, pomegranates and dates contain similar sugar levels (see Table 3.7), making them equally viable for drying, fermenting and maintaining comparable taste profiles. Experimental work by Mangafa and Kotsakis (1996) demonstrates that wild grapevines can yield value-added products. While glucose and fructose levels in wild and domesticated grapes are nearly identical, their acidity differs slightly, with wild grapes containing more tartaric acid (Kui et al., 2020; Trade et al., 2017; Trad et al., 2021). Similar

findings apply to pomegranates (Nafees et al., 2020; Zhang et al., 2022). Historically, fruits could have been dried and additional sugar sources, such as honey or naturally sweet fruits like figs, may have been used to enhance fermentation (McGovern et al., 2009). Given the high sugar content of figs and dates (30–70% in both wild and domesticated forms), fermentation could be repeated frequently over short periods while maintaining flavour consistency (Mirheidari et al., 2020; Broshi, 2007). For instance, an ethnographic study in 20th-century Iraq found that date fermentation lasted two days, yielding an alcohol content of 9% (Barreweld, 1993, pp. 2–3).

The organoleptic properties of wild and domesticated olives and their oils differ significantly. While both contain the same fatty acids, wild olives have higher levels of phenolic compounds, vitamin E, antioxidants and omega-3 and omega-6 fatty acids (Dabbou et al., 2011, pp. 191–199). These differences affect taste but not processing methods. Archaeobotanical and archaeological evidence suggests wild olives were processed into olive oil as early as the 6th millennium BCE and consumed as table fruits by the 5th millennium BCE (see Chapter 5).

	Grape	Fig	Pomegranate	Date
Sugar/100g (table fruit - wild)	12-14g	27-31g	10-13g	22- 52g
Sugar/100g (table fruit - domesticated)	12-17g	30-34 g	13-15g	31-68g
Sugar/100g (dried - domesticated)	55-61g	50-52g	7-9g	72-77g

Table 3.7: Tree fruits and their sugar content amounts based on 100g, including wild, domesticated and dried fruits.

Domesticated fruits typically offer a wider range of value-added products because they yield more than their wild counterparts. However, this does not mean that wild fruits cannot produce sufficient value-added products for household or village use and possibly more. For instance, producing 1 kg of olive oil requires approximately 4–6 kg of domesticated olives but 12–18 kg of wild olives (Kalbasis, personal communication, 2021; Vossen, 2007; Besnard et al., 2017). This difference is due to the larger fruit size and higher oil content in domesticated varieties.

Similarly, there is little difference in the quantity of grape juice, wine or vinegar produced from wild versus domesticated grapes. For example, 1.5 kg of domesticated grapes (This et al., 2006, pp. 516-519; This et al., 2007, p. 726) or 1.8–2 kg of wild grapes (Tadovysian, personal

communication, 2020) are needed to produce 1 liter of juice, primarily due to berry size. While wild fruits can be used for value-added products, large-scale production or inter-regional trade of items like olive oil or wine generally requires cultivation or domestication. The size difference between wild and domesticated pomegranates is unclear, making it uncertain whether there is a significant difference in seed quantity. However, studies suggest that wild pomegranates are only slightly smaller than domesticated ones and contain a similar number of seeds, meaning they could yield comparable amounts of liquid (Riyali et al., 2011). Likewise, the production of juice, wine and vinegar from wild and domesticated figs and dates is nearly identical, as both require water as the primary base liquid (see Chapter 4), unlike grapes and pomegranates.

Cultivation or domestication is not strictly necessary for producing these value-added products. However, it allows for larger fruit yields and easier processing, particularly due to higher sugar content. This process, though labour-intensive and potentially risky, can lead to long-term agricultural productivity. Conversely, relying on wild fruits involves less risk, management and resource investment but may be less reliable in terms of quantity and consistency.

3.9.1 Advantages and Disadvantages of Date and Fig Value-Added Products

Date and fig wines and vinegar offer several advantages, particularly in regions where grapes are scarce or unsuitable for cultivation. One key benefit is their shorter fermentation period compared to other fruit wines. This accelerated process enables faster production, meeting demand quickly and allowing larger batches to be completed in less time. Another advantage is the efficient reuse of dates and figs as raw materials. With sugar content reaching up to 70% in some cases, these fruits can undergo multiple fermentation rounds, maximising yield from a single batch (Barreweld, 1993, pp. 2-3; Broshi, 2007). This reusability, often unachievable with other tree fruits, reduces raw material costs, minimises investment in fruit cultivation and land and enhances efficiency in regions where dates are abundant but other resources are limited.

Additionally, date and fig wine production requires only basic equipment and minimal labour, making it accessible to a wide range of producers. Unlike grape wine, which demands complex processes and specialised equipment, date and fig wines can be produced with simple tools, allowing large-scale production with minimal effort. This ease of production made them widely available, particularly in regions such as Egypt and the Levant, where grape cultivation was

difficult. As a result, date and fig wines became staple beverages, providing an affordable, high-sugar alternative to grape wine.

Beyond accessibility, date and fig wines are also valued for their high caloric and energy density, making them essential in times of food scarcity or instability. In arid and semi-arid regions, where these fruits thrived even during poor harvest years, such nutrient-dense products were crucial for sustaining physical labour and nutrition. This high caloric value contributed to community resilience, population stability and economic trade, helping ancient societies adapt to environmental challenges and seasonal fluctuations.

However, date and fig wines have notable drawbacks that may limit their appeal, particularly in comparison to grape wine. One key disadvantage is their lower perceived quality. In regions where both types of wine were available, date and fig wines were often considered inferior and associated with lower social classes (Broshi, 2007). While they provided an accessible alternative, they did not always meet the expectations of consumers seeking premium wines.

Unlike grape wine, which improves with age and develops complex flavours, date and fig wines do not benefit from aging and must be consumed soon after production, typically within a few days to a week (see Chapter 4). Their short shelf life and lack of preservative qualities make them unsuitable for long-distance trade. Given their volatility, they were primarily consumed within a limited radius, often within 100 kilometers, the typical distance a donkey could travel in two days (Goulder, 2015, 2019). Consequently, date and fig wines were mostly produced and consumed at the household or village level, limiting their market potential. While date and fig wines serve specific needs and contexts, their limitations in quality, preservation and marketability make them less favorable than grape-based wines. Despite their advantages in certain regions, their practicality remains constrained by their perishability and lower status in the hierarchy of alcoholic beverages.

3.10 Conclusion

Perennial tree fruits such as grapes, olives, figs, pomegranates and dates are highly valuable crops. They provide significant caloric benefits, thrive in diverse soils and require minimal water. Many of these trees bear fruit once or multiple times per year with relatively low maintenance.

Their resilience and productivity make them sustainable investments with long-term economic potential.

Grapes, rich in sugar and juice, are ideal for producing value-added products like wine and vinegar, which are easily stored and transported, making them a lucrative crop. Olives and their oil have widespread industrial applications and, once processed, are also easy to store and transport. Figs, with their high sugar content, can be quickly converted into juice, wine or vinegar with the addition of water. The same applies to pomegranates and dates, which have the added advantage of being easily stored and transported in their raw form, unlike grapes, olives and figs (see Chapter 4). Each of these fruits possesses qualities that make them essential and sustainable agricultural resources.

Domestication has enhanced these tree fruits by slightly increasing sugar and oil content, improving liquid yield and refining their chemical composition. It also introduced reproductive advantages such as parthenocarpy (seedless fruit) and asexual propagation, ensuring faster growth and earlier maturity. Additionally, improved management techniques, such as irrigation, pruning, propagation and thinning, have enabled stable and increased production. Domestication expanded the cultivation range of these trees, leading to the development of cultivars selected for traits like sweetness, bitterness, seedlessness, enhanced nutritional value (e.g., higher fatty acid yield) and resistance to pests and diseases. Once established, domesticated tree fruits require relatively low maintenance. For example, date palms need annual pruning but little else. Orchard productivity is influenced by various elements, including tree density, cultivar selection, yield per branch and the labour involved. Under favorable climate conditions, adequate water supply and proper cultivation methods, these trees and vines can continue to flourish for decades or even centuries.

As domesticated tree fruits became more widely available, their cultivation expanded, supporting large-scale industries producing value-added products like wine, vinegar and oil. However, domestication and cultivation were not prerequisites for these products, wild fruits could also be used, albeit with slight differences in quality, sugar content, fatty acid composition and taste. Domesticated tree fruits increased the number and distribution of trees and vines, leading to greater fruit yields and, consequently, a slight rise in the production of value-added products,

most notably olive oil. By enhancing productivity and ensuring a stable supply, domesticated tree fruits have proven to be long-term agricultural assets, offering both economic and nutritional benefits for generations.

Chapter 4 - Pulp Friction: the Ethnography of Processing Equipment

Following the discussion in Chapter 3 of the ecology of fruit trees and ethnography related to their cultivation and exploitation, this chapter examines the different kinds of traditional or pre-industrial methods, along with the tools and facilities used in the processing of tree fruits, from initial harvesting to storing the value-added products, in the Mediterranean and Caucasus regions in the recent past. This analysis provides a heuristic framework for interpreting and analysing surviving archaeological equipment discussed in both Chapters 7 and 8. Specifically, this chapter details the primary processes involved in preparing tree fruits for various forms of consumption, including dried fruits, juice, wine, vinegar and oil as a means to understand more clearly what may have been the aims and consequences of practices and labour investment in the distant past. A significant outcome of this analysis is that large-scale fruit processing typically involves specialised equipment which is both more likely to be preserved archaeologically (i.e., made of stone or fired clay) and more likely to be functionally interpretable than non-specialised tools. Particular emphasis is placed on wine and olive oil production due to robust archaeological evidence.

The chapter also incorporates ethnographic accounts describing the methods of harvesting, processing and storing raw fruits. The methods vary significantly, for example, in the ways fruits are mashed and fermented. These variations are intricately interconnected with equipment choices, labour practices and the nature of the resulting products, although it is not always clear which factor drives the others. Such interrelationships can be deliberate or incidental.

The transformation of raw materials (fresh fruit) into finished products can be understood through the concept of a *chaîne opératoire*, where each phase represents a technical sequence involving specific actions, instruments and participants working towards a defined outcome (Lemonnier, 2013). For instance, the chemical processes that convert starch into sugar, sugar into alcohol and alcohol into vinegar determine many stages of production. Although the types of tree fruits and the available materials limit what can be produced, it is ultimately the choices made by the producers that shape the development of the technical system.

4.1 Basic Processes

Figure 4.1 outlines the main processes involved in producing fresh fruit, dried fruit, juice, wine, vinegar and oil (Lozano, 2006). It is important to note that there are numerous traditions and types of equipment used in the harvesting of tree fruits and converting them into a wide array of value-added products. A comprehensive analysis of all this variability, which often differs only slightly, is beyond the scope of this study for which a simplified approach suffices, focusing specifically on the primary categories of value-added products and the principal methods for creating them.

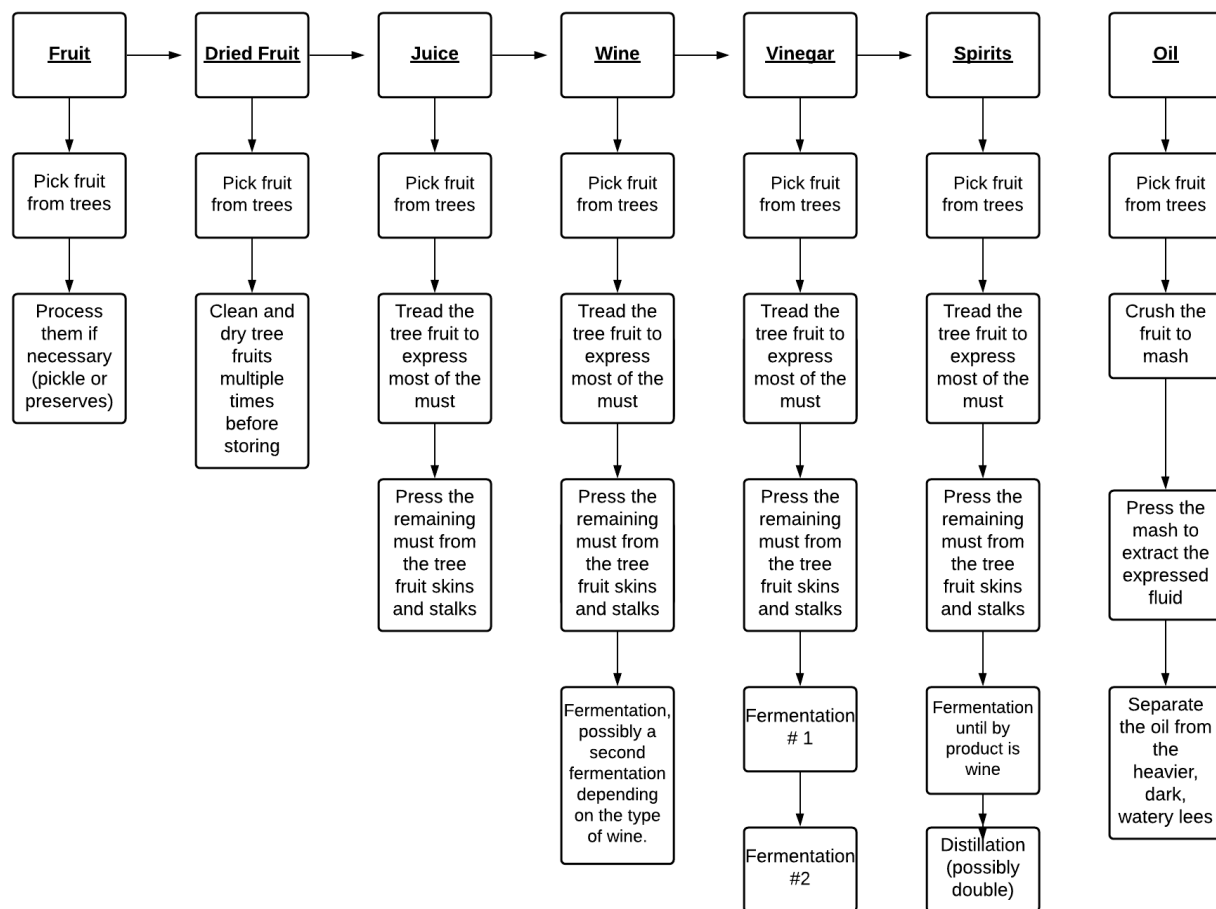


Figure 4.1: Each column is intended to be read vertically (independently). The figure illustrates the progression from harvesting tree fruits solely for immediate consumption to the processes and resources necessary to convert these fruits into value-added products. It is important to note that transforming tree fruits into value-added products does not inherently depend on scale. For example, products such as wine and vinegar can easily be produced both on a small-scale for household consumption and on a larger scale for commercial sale or exchange (created by V.Newson).

Stages of processing tree fruits into value-added products include the following:

Stages	Wine	Oil
Stage 1	Treading grapes to express the must	Crushing the olives to a mash
Stage 2	Pressing the remaining must from grape skins and stalks	Pressing the mash to extract the expressed fluid.
Stage 3	Fermenting the liquid in collection vats or <i>pithoi</i>	Separating the oil from the heavier, dark, watery lees, 20-30% was oil, the rest was loss (Frankel, 1999, p. 41)

Table 4.1: Stages of processing tree fruits into value-added products.

The first two stages in both processes were similar but with two important differences: (1) in the case of the grape, most of the must was extracted in the first stage, whereas in that of the olive it was only in the second; (2) grapes were almost always trodden by foot, olives were usually crushed by some form of mechanical means, like mortar and pestle, stone weights (Table 4.1) (Frankel, 1999). Despite these differences, both grape and olive processing initially utilised similar, less sophisticated production methods, employing basic, non-specialised tools and simple, rock-cut installations. As techniques evolved, especially in more recent times, distinct types of equipment and specialised installations developed for each product, aligning specifically with each of the three stages of production, as discussed below. However, this does not mean that a piece of equipment could not be used for different types of tree fruit production.

4.2 Processes and Equipment for Tree Fruit Consumption

Below, we consider the processes and equipment used for harvesting tree fruits, particularly olives, grapes, figs, pomegranates and dates, as well as the stages involved in transforming these fruits for consumption, whether fresh or dried.

4.2.1 Olives

Traditionally, tarps or cloths made of durable linen, as used in regions like Messenia, are first placed beneath the olive trees (P. Halstead, personal communication, 2019; Bernardi et al., 2018). Workers then dislodge the olives from the branches by using rods to strike the fruit-bearing twigs rather than the thicker, immovable boughs typical of mature trees (Simaan,

2017). Once detached, olives fall onto these tarps or, more recently, onto nets designed to wrap around the tree trunk, opening outward like an umbrella to catch the falling fruit. Workers subsequently collect the olives from these nets and transfer them into baskets, usually crafted from wicker, wood or other organic materials or into wooden crates or bags (Vossen, 2007; Simaan, 2017). Alternatively, olives can be harvested by hand, often with the assistance of ladders. In this method, workers pick the olives directly, placing them into bags or buckets attached around their waist, arm or neck. Although this approach is more time-consuming, it effectively reduces bruising to the fruit (Nasini & Proietti, 2014; Theodossopoulos, 1999). On Crete, another traditional harvesting method involves an old variety of olive tree that is typically left unpruned, causing it to grow similarly to a weeping willow. Its ripe olives naturally fall to the ground, where they are later collected (Kalimatis, personal communication, 2019). Currently, about 90% of the olives harvested are converted into olive oil, while the remaining 10% are used as table olives (International Olive Council, *Olivae* 127).

Olives are naturally very bitter when eaten raw due to the presence of oleuropein, a bitter phenolic compound concentrated in the pit (Bernardi et al., 2018). To become palatable, olives must undergo processing, typically through curing and fermentation, which significantly reduce oleuropein levels (Khalil et al., 2024; Theodossopoulos, 1999). Common methods for rendering olives edible include curing in lye or brine, fermentation or drying. Lye, a strong alkali traditionally obtained by leaching wood ashes, removes bitterness when applied for several days, while brine curing requires a period of several months (Gordillo et al., 2023). During fermentation, yeast plays a key role and bacteria in the brine enhance flavour and lower the pH, acting as natural preservatives by inhibiting spoilage-causing bacteria (Fendri et al., 2013, pp. 187-191; Corsetti et al., 2012). In the Mediterranean region, olive preparation methods vary by area and often reflect local tastes and traditions, as summarised in Table 4.2.

Areas	Types of Preparation	Sources
Lebanon, Cyprus	Olives are bruised, soaked in salt water for 1–2 days, then stored up to a year in brine with lemon juice, peel, olive leaves and spices.	Botta and Cocolin, 2012

Spain	Olives are soaked in lye for 8–10 hours, rinsed to remove it, then fermented in brine for about a month with regular changes. They're placed in fresh brine for consumption. This method produces around 60% of the world's table olives.	Botta and Cocolin, 2012; Fernandes et al., Adams 1997
Italy/ Greece	It follows the Spanish method but skips the lye treatment, placing olives directly into brine, which is regularly replaced during fermentation.	Kailis and Harris, 2007
Morocco, Turkey and other Eastern Mediterranean countries	Only mature olives are harvested, washed and packed in salt, which dehydrates and shrinks them. Yeast is added to ferment them and they are sold cured, with no additives.	Fernandes et al., 1997
Mediterranean	Olives are soaked in lye for 10–72 hours, then rinsed and placed in a brine that's regularly refreshed. Fermentation occurs but is milder than with other methods.	Kailis and Harris, 2007
Western Mediterranean	Olives are soaked in water or light brine for 10–14 days, with the liquid changed daily to leach out bitter oleuropein. Natural fermentation occurs during soaking, often accelerated by cracking the olives.	Botta and Cocolin, 201

Table 4.2: Different types of table olives and their different processing techniques and stages/types of preparation in various geographical contexts across the Mediterranean. The different types of preparation involve largely similar ingredients and time with slight variations.

4.2.2 Picking of Grapes, Figs, Pomegranates, Dates and other Tree Fruits

Workers harvest fruits as they ripen, typically by hand or using sharp blades to cut the fruit with stems attached, helping to delay spoilage. Tarps are often placed underneath to catch falling fruit. Tools commonly used for harvesting include knives, hooks, pruning instruments and clippers, many of which also have applications beyond tree fruit management (Brunner, 2021; Betz, 2021). After collection, fruits are stored in baskets, boxes, sacks or wooden shelves. Depending on the terrain, they may then be transported to markets or processing facilities by wagons drawn by humans or animals, sold for immediate consumption or converted into value-added products (Peña-Chocarro et al., 2015; Saleh, 2014; Hovhannisyan et al., 2015). In particularly steep or challenging terrains, pack animals replace wagons, while small quantities for personal or domestic consumption may simply be carried by hand, in baskets or in a pinafore (Famiani et al., 2020). In non-selective harvesting methods, entire fruit bunches are cut using a sickle or knife and lowered to the ground, where the fruit can then be shaken or manually separated.

Alternatively, depending on the labourer's skill, fruit may be shaken directly from the tree (Turker et al., 2009; Aboonajmi, 2004). Dates can be harvested similarly to other tree fruits through selective hand-picking, particularly with younger trees, which grow approximately one meter per year. However, mature (taller) date palms require different techniques. Workers must climb these trees using ropes and take advantage of trunk scales that protrude enough to serve as footholds. Fruits are then carefully hand-picked and placed into buckets, which are subsequently lowered to the ground by rope (Bahrami, 2023; Gros-Balthazard, 2023; Yateem, 2009). Harvesting dates is significantly more labour-intensive, demanding experienced workers and resulting in lower productivity per labour hour compared to other tree fruits.

4.2.3 Drying of Tree Fruit

Dried tree fruits are popular due to their sweet taste, ability to retain most of their nutritional value, including high caloric content and long shelf-life. The most commonly consumed dried fruits are raisins, along with other grape varieties such as currants and sultanas, followed by dates and figs. Traditionally, water is removed from the fruits through evaporation methods like air-drying, sun-drying, smoking or wind-drying (Esmaili et al., 2007). Sun-drying in the shade is an inexpensive method but it is slow and highly susceptible to environmental contamination, such as insect infestation and microbial spoilage, often resulting in lower-quality products (McBean, 1976; Saleh, 2014). In wind-drying processes, fruits are typically hung upside down using ropes and wooden structures and protected by screens or walls with small perforations to facilitate airflow while preventing contamination (Christensen and Peacock, 2013; Esmaili et al., 2007). Smoke-drying is another traditional method used for tree fruits. For example, in Gata de Grogos, grapes were historically placed above a fire pit enclosed by bricks and allowed to dry via smoke (Valencian Museum of Ethnology). After the drying process, fruits are ideally cleaned with water to remove impurities and subsequently dried again to eliminate moisture. Finally, dried fruits are stored in jars or covered baskets in locations with stable temperatures until they are ready for trade or consumption (Saleh, 2013; Kuijt, 2009; Famiani et al., 2020; Peña-Chocarro et al., 2015).

4.2.4 Production of Fruit Leather

Traditionally, in Mediterranean and Caucasus regions, when tree fruits became overripe, either while still on the tree or after being harvested and were no longer suitable for fresh consumption or processing into other value-added products, they were converted into a type of fruit 'leather' (Diamante et al., 2014; Hovhannisyan et al., 2015; da Silva Simão et al., 2020) (Photo 4.1). Fruit leather could be stored for extended periods, especially during the winter months when fresh fruit was scarce, providing an important caloric source. The preparation process involved first washing the harvested fruit and placing it whole or cut into pieces (including pits or seeds) into a pot with a small amount of water added to prevent burning. The fruit was then cooked with a lid, stirring occasionally until it fully broke down and thickened (Kaya and Maskan, 2003, pp. 295-299). After cooking, the mixture was cooled and seeds or pits were removed using a sieve or spoon. The resulting puree was then dried to remove moisture, causing it to solidify (Bandaru and Bakshi, 2020; Tontul and Topuz, 2018).

Two traditional drying methods were commonly employed: the mixture could either be spread onto sheets and placed in the sun or oven or poured onto large pieces of cloth and hung in the sun, much like laundry. Drying typically took between 6 to 9 hours (M. Garebedian, 2017, personal communication; Srinivas et al., 2020). Once dried, the fruit leather was cut into long rectangular strips with a sharp knife. These strips were then rolled up in cloth or special paper and secured with twine (Khan et al., 2023; Bandaru and Bakshi, 2020). Sometimes, these rolls were displayed by hanging at markets or homes, though ideally, they were stored in dark and cool locations. In Armenia, production traditionally involved one or two women, usually the family matriarch and a younger family member. The process required minimal time and financial investment and utilised common household or kitchen equipment (Hovhannisyan et al., 2015; Participants 34 and 78, personal communication).



Photo 4.1: A. Pastegh/bastegh (traditional fruit leather) hanging from a market stall in Yerevan, Armenia (Photo taken by V.Newson, 2020). These rolls can last for a couple of months.



B. Fruit leather being wrapped at home (Vayots Dzor, Armenia) (Photo taken by V. Newson, 2020)

4.2.5 Equipment

The items of equipment described in section 4.2 for harvesting tree fruits and processing products such as table olives, dried fruits and fruit leather are predominantly non-specialised. They cannot be conclusively associated with these specific processes or products, as they could easily have served other unrelated functions. Furthermore, most of this equipment typically does not survive archaeologically because it was primarily crafted from organic materials rather than metal or stone. Such items required minimal financial investment, as they were generally multipurpose tools readily available within a household. In contrast, producing and transporting value-added products required greater investment in both equipment and labour resources. For instance, the process of transporting dates from an oasis, where dates were the primary cash crop, to ports for shipping incurred substantial labour and financial expenses (Alkhamaly 2020-2021, personal communication). These additional costs included: (1) supplementary storage vessels made of organic materials or clay; (2) expenses related to pack animals (i.e., horses and camels) and animal-powered transport methods (i.e., wagons and camel trains), including water, food, labour (wear and tear on the animal), rest time and time away from the farm, which can also

extend to the need for more animals (Barreveld 1993; Goulter, 2019); and (3) increased human labour requirements, particularly for supplying water and fodder to animals during journeys spanning from one day up to several weeks (e.g., the distance from Farafra in Egypt to the Nile Valley could take between 7-8 days) (Fakhry 1974; Eichorn et al. 2005; Goulter, 2015).

4.3 Processes and Equipment for Juice Production

Producing juice from tree fruits, excluding olives, involves a two-step process: (1) pressing the fruits; and (2) collecting the resulting juice into containers such as glass jugs, ceramic *pithoi* or wooden barrels. In contrast, olive oil extraction (olive juice) requires a three-step process: crushing followed by pressing and then collection. If the tree-fruit juice is not intended for immediate fresh consumption, it undergoes pasteurisation, typically at temperatures below 100 °C (212 °F) for approximately 15 to 30 minutes. This step prevents fermentation and eliminates pathogenic organisms and enzymes responsible for spoilage and disease (Mandha et al., 2023; Taylor, 2004). Following pasteurisation, the juice is prepared for bottling and sale (Shaw, 2000). Alternatively, pasteurisation can occur after the juice has already been packaged. When the goal is to produce wine (one fermentation), vinegar (two fermentations) or other fruit-derived products such as preserves and fruit leather, additional processing steps are required (Mushtraq, 2018). The equipment employed for producing tree-fruit juice is identical to that used in wine production (see section 4.4.1).

4.4 Processes and Equipment for Wine Production

Wine production from tree fruits employs processes and equipment similar to those used in fruit juice production, with the additional step of fermentation, which eliminates the need for pasteurisation. Traditionally, only undamaged and fully ripe fruits are selected for winemaking, whereas damaged or unripe fruits are typically reserved for fresh consumption, raisin production or fruit leather making. Although fundamental practices are common across all tree-fruit winemaking, the resulting wines can differ significantly depending on the specific fruit used. Furthermore, each winemaker uniquely integrates local traditions, personal expertise and accumulated experience, thereby creating distinctive styles of wine (Maicas and Mateo, 2020; Hovhannisyan et al., 2015).

The conversion of sugar into alcohol begins rapidly once sugar-rich juices from tree fruits come into contact with natural yeasts present on the fruit skins and stems, as well as on winery jar walls. The fermentation of tree-fruit wine involves a complex interplay of bacteria, fungi and molds, which collaboratively transform sugars into alcohol (Jackson, 2020). This process involves three distinct microbial transformations: (1) yeasts convert sugars into ethanol (ethyl alcohol); (2) acetic acid bacteria transform ethanol into acetic acid; and 3) specific strains of lactic acid bacteria transform malic acid into lactic acid (Kunkee, 1984; Boulton et al., 1999; Waterhouse et al., 2024).

The most common method of wine production involves fermenting grape juice in a brief but turbulent process at temperatures ranging from 15 to 25°C, primarily to manage yeast activity (Stevenson, 2005). Typically, red wines ferment at higher temperatures of 22-25°C, whereas white wines ferment at lower temperatures of 15-18°C, both within the yeast's viable temperature range of 15-35°C (Jackson, 2014; Bird, 2011). The duration and temperature of fermentation significantly impact the characteristics of the resulting wine. A short fermentation period of 1-2 days usually produces lighter wines. In contrast, extended and hotter fermentation periods, ranging from 1-20 days in regions like Spain and 10-15 days in Armenia, are employed to extract maximum colour and tannins from grape skins, resulting in wines intended for aging and maturation (Unwin, 1991; Jackson, 2014; Danielyan et al., 1973; Hovhannisyan et al., 2015, pp. 182-198).

Wines designed to be consumed young often undergo an early separation process, where the must (fermenting juice) is removed from the skins, seeds and stalks after a few days. The juice then continues fermentation in a separate vessel. Alternatively, once the fermentation process has entirely transformed the sugars into alcohol, the grape skins and stems left at the bottom of the vat can be pressed again. This secondary pressing yields a darker, more tannic and acidic wine (Zoecklein, 2012). Traditionally, red wines are produced by fermenting a mash consisting of pressed grape juice along with fruit pulp and skins. White wines, however, are typically made from pressed grape juice alone, known as must (Prive, 2003; Stevenson, 2015). Ultimately, these by-products may serve as fertilizer or animal fodder. In some cases, water is added to these by-products and a secondary fermentation occurs, producing a low-quality, low-alcohol beverage (Hovhannisyan et al., 2015, pp. 193-195).

The second fermentation is a long and slow process, typically taking between 3 to 6 months. During this stage, sediments are separated by either transferring the wine to other containers (2-3 times) or by periodically stirring the liquid (commonly with a wooden or metal paddle). Stirring briefly oxygenates the wine and evenly distributes the fermenting agents throughout the batch (Casanova, 1966, 1968, 1990). Throughout the secondary fermentation, the wine is kept under an airlock to protect it from oxidation. Proteins originating from the grapes are gradually broken down, allowing residual yeast cells and fine grape particles to settle (Nagodawithana and Reed, 1988, 1990). Consequently, the initially cloudy wine gradually becomes clear. After settling, the wine may be racked, a process that involves transferring the wine from one container to another to remove sediments, primarily fruit particles and dead yeast cells known as 'lees'. The optimal temperature range for this stage is 6–12°C (Jackson, 2014; Danielyan et al., 1973). Therefore, wines undergoing secondary fermentation are ideally stored in cool environments, such as underground spaces or cellars. This fermentation typically occurs in oak barrels or glass jars, with ceramic *pithoi* being used less frequently, depending on the winemaker's objectives. Small-scale producers commonly use glass jars with capacities of 4.5–5 liters (Prive, 2003; MacNeil, 2001).

The next stage in winemaking is filtration, which achieves two primary objectives: clarification (the removal of large particles affecting visual clarity) and microbial stabilisation (the removal of organisms that might cause re-fermentation or spoilage). Filtration is conducted either through heating, sieving and cooling the wine or solely through sieving. Following filtration, the wine requires approximately one month to settle fully and attain clarity. Afterward, it can be bottled or transferred into barrels (Jackson, 2014; Danielyan et al., 1973). No chemical additives are necessary during this process. An alternative method of wine production, particularly suited to pitted and harder fruits such as dates, apricots and figs, involves boiling fruits placed securely in cloth bags within a pot or cauldron over a heat source. Once softened, the fruits are mashed using a pressing tool, often a kitchen utensil or stone, to extract maximum juice. The mixture is then allowed to ferment for about seven days, after which the cloth bag is removed and the juice is transferred into a glass container for continued fermentation to produce wine. If juice rather than wine is the intended final product, pasteurisation is required to halt fermentation prior to bottling. Conversely, producing vinegar involves initiating a second fermentation. These traditional

techniques have typically been employed in domestic settings or small-scale production (Ashraf and Hamidi-Esfahani, 2011; Ali and Dirar, 1984; Prabha, 2018).

A third technique involves placing tree fruits, usually pitted or harder varieties such as figs, apricots and dates, which contain relatively little juice, into a collecting receptacle like a jar, barrel or large *pithos*. The fruits are then either crushed, releasing some pulp juice or bruised before being submerged in water. Subsequently, the opening of the container is securely covered with cloth tied with twine or sealed with a lid made of wood, stone or ceramic. This covering method prevents contamination from dirt and insects while still allowing airflow necessary for fermentation. Fermentation then occurs naturally (see Photo 4.2). After fermentation, the mixture is sieved, pasteurised and stored. If vinegar production is desired, an additional fermentation step is required (Segura-Borrego et al., 2024; Cejudo-Bastante et al., 2013; Broshi, 2007). The scale of production using this technique is dependent on both the quantity of fruit available and the size of the fermentation vessel. For example, in Negev villages, traditional date wine is prepared collectively using a large vat with a capacity of 7.84 cubic meters to accommodate the entire community's production (Netzer, 1989). This traditional fermentation method continues to be practiced today in regions such as the Levant, Armenia, France, Italy and Spain (Frankel, 1999, pp.156-163).

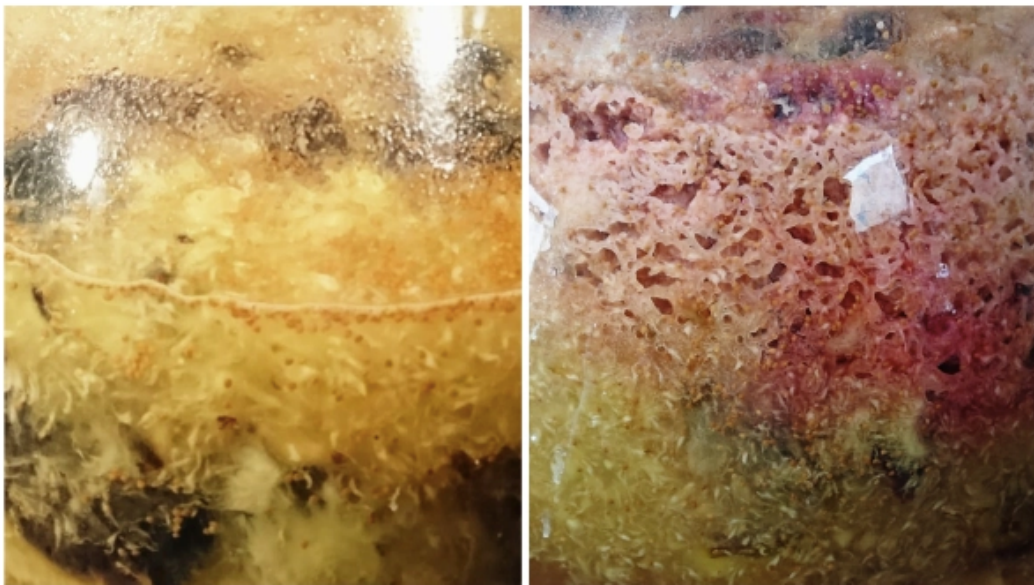


Photo 4.2: Fermentation of fig wine on day 1 and day 7 using the jar method. The red colour slowly builds and leaches out of the skins (Photos taken by V.Newson, 2019). This involved using water and figs (as described above).

4.4.1 Equipment Used for Extracting Juices

4.4.1.1 Non-Mechanical Methods

In the first stage of fruit processing, tree fruits suitable for crushing, such as grapes and pomegranates, are placed into a treading area where barefoot labourers trample them (Photo 4.3). Treading typically occurs on a specialised treading floor or within a trough constructed from wood or stone or even carved directly into bedrock. To ensure the safety of the workers, a bar or rope is usually positioned across the top of the tub to prevent falls (Amouretti and Comet, 1991; Amouretti and Brun, 1993; Hadjisavvas, 2020). This process requires both skill and strong feet to extract as much juice as possible from the fruit.

Various equipment types were used for treading across regions. For example, a four-sided wooden box, commonly used in Italy and the Levant, was open at both the top and bottom and could be easily assembled or dismantled, especially for small-scale operations (Drachman, 1932, p. 19, fig. 18). Its modular design allowed workers to adjust the height by adding or removing planks, making it highly adaptable to the specific type and quantity of tree fruits being processed. Another method of treading, found in Dalmatia and Italy, used a thick rope wound spirally into a cylinder around the material intended for crushing, typically contained within bags or cloths (Brondsted, 1928). Such flexible methods illustrate the diverse equipment and techniques developed across different regions.

Treading gently presses the fruit with low energy input, preserving flavours and colour, while fostering a close connection between winemakers and their product. It requires little financial investment in equipment and uses less water, making it cost-effective. Despite these advantages, it is highly labour-intensive and may incur high costs due to the need for manual labour. The process is also time-consuming, requiring more time per unit of output compared to mechanised methods. It may result in uneven pressure application and high oxygen exposure to the must, potentially affecting quality. Archaeologically, treading often leaves little trace and is difficult to interpret due to the non-specialised nature of the tools. Nonetheless, treading can produce larger quantities of wine than other simple methods and treading floors remain integral to wine production facilities, underscoring their continued relevance and utility in fruit processing.



Photo 4.3: Two women treading grapes at wine festival in Vayots Dzor (photo by V. Newson, 2016).

According to Hovhannisyany et al. (2015), an area of 0.8 m² per person is required to tread grapes safely and productively. Therefore, the maximum number of workers who can simultaneously tread grapes can be estimated by considering the total area of the treading floor. In regions like Palestine and Georgia, the typical workforce involved in grape treading ranges from one to five individuals. Table 4.3 below illustrates grape juice outputs from various geographic locations where traditional methods are still practiced. The data in this table suggest that productivity tends to be higher when smaller batches are processed by fewer workers (i.e., one to three individuals). Larger workgroups appear to handle bigger batches by extending their working hours, resulting in lower overall productivity per worker. Although additional details regarding the age and gender composition of the workforce would enable a more comprehensive evaluation, the

productivity figures presented in Table 4.3 (ranging from 66 to 133 kg/hr/worker) demonstrate a notable consistency across different scenarios.

Location	Workers	Amount (kg)	Time (Hr)	Output (Kg/hr/worker)	Sources
Hebron (Levant)	1	100 kg	0.75 hrs	133 kg/hr/worker	Dalman 1928-1942; Dalman 1908
Balat (Levant)	2	275 kg	1.5 hrs	92 kg/hr/ worker	Dalman 1928-1942
Masada (Levant)	5	1000 kg	3 hrs	66 kg/hr/worker	Avitsur 1976
Kvareli (Georgia)	4	800	2.5 hrs	80 kg/hr/worker	Abasadsse 2020, Personal Communication
Telavi (Georgia)	3	550	1.75 hrs	105 kg/hr/worker	Datuna 2020, Personal Communication

Table 4.3: The amount of juice output by workers (kg per hour per worker) in the Levant and Georgia.

Other ways to crush tree fruits included the use of: (1) rollers; (2) weights; and (3) torsion. Notably, treading, rollers, weights and torsion methods could all be utilised either on a treading floor or within a trough.

Cylindrical stone rollers with handles of wood or metal, are specifically employed by rolling them over fruits placed on a hard surface, such as a stone treading floor, to effectively crush them (Image 4.1). Such rollers remain in use today in regions like Palestine (e.g., Hebron) and Syria (e.g., Qiruobisa). To prevent scattering during crushing, the fruit mash is placed in frails, cloth bags or cloth coverings directly on the crushing surface. The primary equipment traditionally used throughout the Mediterranean region (including Palestine and Syria) and the Caucasus (e.g., Armenia) is a flat, round frail with a circular opening on top. Historically, these frails were loosely woven from thick threads made of date palm fibers, reed grass or other natural materials. The fruit destined for pressing is manually packed into these containers. Typically, up to ten fully packed frails might be stacked atop one another. Alternatively, the pulp, grape skins and stalks can be placed onto a square cloth, with corners subsequently folded inward (Dalman, 1928-1942; Dawkins, 1902; Frankel, 1999).

This method applies strong, consistent pressure to the fruit, which is ideal for tougher produce like figs and dates but can be risky for softer fruits such as pomegranates or grapes, as excessive force may break the pips and affect the taste. While the equipment involves little initial financial investment, the process is high energy, highly labour-intensive and time-consuming compared to mechanised alternatives. The output is typically medium in volume. Archaeologically, stone rollers are more likely to be preserved due to their durable material but they are often moved or repurposed and as non-specialised tools, they are not easily interpreted in context.

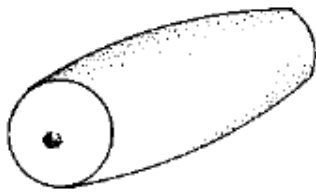


Image 4.1: A stone roller with a horizontal hole going throughout it based on an example from the Levant (created by V. Newson).

The second method involved placing weights, typically stones with horizontal or vertical holes, on wooden boards to crush the fruit material positioned underneath, usually contained in frails or cloth bags (Casanova, 1968, 1990) (Image 4.2). The juice released from the fruit then flowed into a collection receptacle. This traditional method is still employed in Mediterranean regions, such as Spain, France, Italy and Croatia, as well as in the Caucasus countries like Georgia and Armenia (Tufnell, 1953; Hirschfield, 1983; Macalister, 1912; Maurin, 1964; Couprie, 1959; Hovhannisyan et al., 2015). This method of pressing fruit uses low energy, applying gentle to firm pressure depending on the weight used, which helps to incorporate colour and flavour while maintaining consistent pressure throughout the fruit mash. It requires little financial investment in equipment, particularly up front, making it an accessible option. However, the process is highly labour-intensive and demands significant manual effort. From an archaeological perspective, the tools used, such as weights and wooden boards, often leave little to no trace. Weights may not appear as such, especially if they lack holes and wooden components rarely survive, making the setup difficult to interpret functionally. The method is also time-consuming compared to mechanised techniques and generally yields medium volumes of product (Hadjisavvas, 2020, Frankel, 1999, Brondsted, 1928).

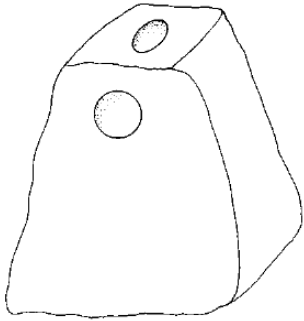


Image 4.2: An example of a stone weight with a vertical hole based on an example from Cyprus (created by V. Newson).

The third method, torsion, placing very ripe tree fruits or fruit mash into a large sack, typically crafted from goat hair, which is then set into a wooden trough (Image 4.3). Two individuals use a pair of sticks to twist the sack, applying pressure that extracts juice from the fruit. This juice collects in the trough and later flows into a receptacle. The sack is twisted several times, with hot water added in the final stage to draw out any remaining juice. This twisting technique continues to be used today in Italy, Armenia, Spain and Croatia (Casanova, 1966; Amouretti, 1981, 1986). This method requires little financial investment in equipment, particularly at the outset, as it often makes use of readily available household materials. However, it is highly labour-intensive, demanding significant manual effort. From an archaeological perspective, it leaves little to no trace, especially when organic or perishable materials are used and the tools involved are generally non-specialised and not functionally interpretable. In terms of efficiency, the process is time-consuming, producing small volumes of product per unit of time. Additionally, it tends to apply uneven pressure across the fruit mass and often exposes the must to high levels of oxygen, which can affect the quality of the final product (Hadjisavvas, 1992; Dalmar, 1928-1942).

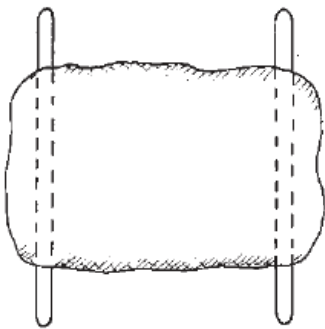


Image 4.3: A cloth sack with wooden pole handles using the torsion method based on an example from Italy, Corsica, France and Egypt (created by V. Newson).

Crushing may also involve a hybrid approach that utilises a combination of tools and equipment. For example, at a small-scale winery producing wine primarily for household or village consumption in Armenia's Ararat Valley, the initial pressing of grapes was performed by a single individual treading grapes on a small floor. Subsequently, a roller, which was also utilised for other household tasks, was employed on a *tarapan*, a traditional stone structure specifically designed for extracting must from pressed grapes, to further crush the grape mash in preparation for fermentation (Hovhannisyan et al., 2015; Garabedian, 2020, personal communication). Different types of equipment could be effectively used with minimal financial investment and these methods were largely interchangeable, as they typically produced similar yields within comparable timeframes. However, the choice of a specific crushing method often depended on the desired characteristics of the final product. For instance, at a local winery in Vayots Dzor, Armenia, red wine grapes were initially trodden by two women and subsequently pressed using a basket press. In contrast, additives such as pomegranates and wild berries were pressed by hand using a cheesecloth strainer and torsion movements (Participant, 7 personal communication, 2020).

4.4.1.2 Mechanical - Batch Presses

Mechanical wine presses are generally categorised into two primary types: batch and continuous. Batch presses involve pressing a predetermined amount of fruit mash, after which the remaining pomace or cake (composed of leftover skins, seeds and stems) must be manually removed before the next batch is loaded. Continuous presses, on the other hand, use a screw mechanism to press the grapes, compact the cakes and then remove the cakes through an exit mechanism, all in one continuous movement. Although numerous variants of both batch and continuous presses exist, the focus here will be on the most commonly employed types. Specifically, three batch press types are prevalent across the Mediterranean and Caucasus regions: (1) basket presses; (2) moving-head presses; and (3) pneumatic presses. Each type has distinct production capabilities, processing methods, output quantities and impacts on the quality of the juice or wine produced.



Photo 4.4: Example of a basket press from the Sicilian Ethnographic Museum (photo by S. Nash).

A basket press is essentially a large wooden container filled with tree fruits, typically grapes. It works by applying vertical pressure using a plate made of metal, wood or stone that is pushed down onto the fruit (Photo 4.4). This pressing force is usually generated by a mechanism such as a screw, a capstan or a hydraulic system that utilises water or steam. The juice passes through the basket's openings and is gathered separately. Because the pressing process is relatively enclosed, it minimises contact with oxygen, helping to preserve juice quality and reduce oxidation (Bird, 2010; Maicas and Mateo, 2020). However, the design may still expose the must to significant oxygen levels and uneven pressure can be applied across the fruit mash compared to other press types, leading to inefficiencies. If excessive force is applied too rapidly, the press may fail structurally.

The press is capable of gently pressing fruit, though its effectiveness varies with scale. It can achieve high hourly output and is suitable for both small and large-scale operations, in terms of labour and product output. Larger installations may be mechanised using water or steam power and many variants of the basket press exist, offering flexibility in usage. The process can be

mechanised using water or steam power and there are many variations of the equipment available. While initial financial investment can be high, depending on material, size and scale (the amount of grapes that can be pressed for an output), the product output is often consistent.

This method ensures even pressure on the grapes, contributing to quality. However, the process can produce a thick cake of grape solids that may become too compact, hindering juice flow through the screen and reducing efficiency. Labour requirements remain variable, depending on mechanisation but can be intensive in smaller setups. Historically, simple manual basket presses required only two operators (De Serres, 1803). The advent of steam-powered machinery in the 19th century revolutionised wine production by increasing pressing efficiency, output and reducing labour demands (Margalit, 1996). Basket presses remain widely used across Mediterranean countries such as France, Spain and Germany, as well as in the Caucasus, including Russia, Georgia and Armenia (Johnson, 1989). Despite their historical significance, archaeological evidence of basket presses is limited or absent due to the perishable nature of the materials used in their construction.



Photo 4.5: An example of a moving-head press from a winery in Vayots Dzor, Armenia (photo by V. Newson).

The moving-head press operates similarly to the basket press but employs a fundamentally different method of applying pressure. Instead of vertical pressure, it features horizontally moving plates positioned on opposite ends of a cylindrical container, which compress the grape mash evenly from both sides (Photo 4.5). This method of grape processing offers even pressure

on the grapes, contributing to consistent quality. This homogeneous horizontal compression often uses ropes or chains connecting the two plates to facilitate breaking up and loosening the compacted pomace cake between press cycles (Bird, 2010; De Serres, 1803).

Moving-head presses have various forms and adaptations throughout Mediterranean winemaking regions, commonly chosen for their effective juice extraction and suitability for medium-sized wine operations. It allows for high hourly output, depending on the scale of the operation and can be adapted for use in both small- and large-scale productions. The process can also be mechanised using water or steam power and there are many variations available. Labour requirements vary with scale (size of the equipment) but the method can be labour-intensive compared to other mechanised presses. Archaeological evidence is often minimal or absent, depending on the materials used. While it requires a significant financial investment upfront, the process has some drawbacks: a thick cake often forms, which can compact too much and hinder the flow of juice through the screen.



Photo 4.6: Example of a makeshift pneumatic press from Ararat in Armenia (photo by V. Newson).

The pneumatic press is characterised by a large, closed cylindrical drum into which grapes or other fruits are placed. A flexible internal bladder within the cylinder is inflated with either air or water, exerting uniform outward pressure against the fruit mash. This uniform distribution of pressure creates a characteristic donut-shaped pomace cake, effectively squeezing juice evenly from the entire mass. Juice escapes through perforations in the cylinder wall, providing high-quality extraction with minimal seed crushing, thereby limiting tannin extraction and improving overall juice quality (Margalit, 1996). Pneumatic presses offer precise control of pressing cycles, enabling greater consistency, reduced oxidation and higher-quality output. Numerous pneumatic press variants are widely used across Mediterranean regions, especially in larger, quality-focused wineries that prioritise controlled, gentle pressing to produce premium wines.

The grape press described offers several advantages and considerations across different aspects. In terms of quality, it provides a higher standard of pressing by ensuring even pressure throughout the process. It is also highly efficient, delivering a high hourly output. Transportability is another benefit, as the press is easy to move. From a labour perspective, it is less labour-intensive compared to other methods. Archaeologically, it may leave little to no trace depending on the materials used in its construction. However, the press does require a high financial investment upfront. Finally, while it has many strengths, one potential drawback is the possibility of high oxygen exposure to the product.

4.4.1.3 Mechanical - Continuous Presses



Photo 4.7: Example of a screw press from Spain (photo by S. Nash).

The continuous press most commonly used in the Mediterranean and Caucasus regions is the screw press. In a basic screw press, tree fruits are placed into an input container such as a wooden case, bags or wooden planks (Photo 4.7). A large screw, made of either wood or metal, then moves the fruit through a perforated cylinder, allowing the juice released by pressure to flow out while retaining solids. As the fruit moves further down the cylinder, the residual pulp or pomace is progressively subjected to increased pressure, often enhanced by additional weights. The extracted juice then flows into a collection receptacle (Frankell, 1999). This method of production ensures even pressure is applied throughout the process, contributing to high hourly output and efficient performance. It allows for many product variations depending on the intended use and is adaptable to different scales of production. There is also control over the amount of pressure used and the process can be mechanised for greater efficiency. However, the labour requirements can vary, with some setups being quite labour-intensive depending on the scale of operation. Archaeologically, this method often leaves little to no trace, especially

depending on the material used and typically requires only non-specialised equipment. In terms of cost, it may demand a high initial financial investment, particularly at larger scales. Additionally, the product may be exposed to high levels of oxygen and the harsh pressing combined with significant movement can result in excessive tearing and grinding of the fruit.

Various types of screw presses differ primarily in their design and operational mechanics, influencing production efficiency, the ability to maximise output while minimising time, labour (physical exertions and number of people) and material input and processing ease (Hamilton, 1934-35; Drachman, 1932; Aneglini, 1967; Vincse, 1959; Latour, 1901, Avitsur, 1976; Avitsur, 1986; Irmie, 1974). The single rotating screw press with a lower handle requires significant effort, making it ideal for small-scale use with close quality control. The fixed double-screw press improves stability and pressure, boosting juice yield and quality for larger batches. A variation with upper handles enhances ergonomics for moderate-scale use. More advanced types include the Grant Point lever and screw press, which uses a central pier for better mechanical advantage, suited to medium-scale operations. The box press version lifts weighted boxes via a screw, delivering high pressure and efficient extraction for larger volumes while protecting seed integrity. The taison press, anchored between fixed posts, offers stable, consistent pressing for large-scale processing. Lastly, the modified screw press reduces fruit movement to minimise bruising and seed damage, making it ideal for high-value or delicate fruits where juice quality is critical.

4.4.1.4 Brief Conclusions

Various techniques and equipment are available for extracting fruit juice and other value-added products, all serving the same fundamental purpose: to separate juice from skins, seeds and pulp. Each type can apply controlled pressure to extract juice effectively without crushing seeds, which would release undesirable tannins, with different amounts of ease. Despite the variety of fruit-pressing methods in winemaking, a clear distinction exists between non-mechanised techniques, requiring low capital but high labour and mechanised presses, which are more costly but significantly more time-efficient (see [Appendix 3](#)).

4.4.2 Equipment Used for Fermentation and Storing

The selection of fermentation and storage containers used by winemakers depends on the type of wine produced, the specific fermentation process, ageing requirements and considerations for storage and transportation, including destination and transit duration (see section 4.7). Consequently, winemakers may either utilise the same container type throughout the entire process or employ different containers for fermentation and storage, as seen in Palestinian, Armenian and Syrian traditions. Typically, wine is fermented and stored in one or more of the following containers: (1) glass jugs; (2) ceramic *pithoi*; (3) stoneware; (4) wooden barrels, traditionally made of oak or other local, less porous woods; or (5) collection vat. Barrels and large ceramic vessels, however, appear to be the most suitable choices for fermentation. Wine aged in barrels or occasionally in ceramic *pithoi* or stoneware vats, is generally later transferred to glass bottles, where it continues to improve in quality (Rytönen, 2024; Tumanyan, 2008; Limbergen and Komar, 2024; Squitieri and Eitam, 2019). For optimal preservation, wine bottles should be stored horizontally in dark, cool and stable environments. Horizontal positioning prevents the cork from drying out, ensuring an airtight seal (Saleh, 2014; Lopes et al., 2006).

One of the most significant factors in the production of wine is the place in which the wine is fermented and stored, as wine is highly susceptible to spoilage under unsuitable conditions (Danielyan et al., 1973). Ideally, wine should be kept in a subterranean cellar characterised by thick walls, a robust roof and conditions that are consistently cold, dry and dark. The best type of cellar is one that has been dug into solid rock because it keeps the wine very cool in summer but is warm in winter (Echave et al., 2021; Butzke et al., 2012).

4.5 Process and Equipment for Vinegar Production

The process and equipment used for producing tree-fruit vinegar closely resemble those employed in making tree-fruit wine, with the addition of a second fermentation stage. This secondary stage, known as the acetic acid phase, involves natural airborne bacteria interacting with alcohol, produced during the initial fermentation and fermenting it further (Pasteur, 1868; Barja and Bourgeois, 2009). Vinegar can be produced from nearly any alcoholic base, including beers, wines and spirits, provided there is sufficient oxygen and the presence of acetobacter

(Giudici et al., 2009). Traditionally, vinegar production has been closely linked with alcoholic beverage industries and local vinegar varieties frequently reflect the traditional alcoholic beverages of their respective regions. For example, in the Eastern Mediterranean and Caucasus areas, vinegar is typically derived from grape, pomegranate, fig and date-palm wines (Das and Sarin, 1936; Forbes, 1971; Tan, 2005; Giudici et al., 2017).

There are three main approaches to vinegar production: (1) beginning with raw tree fruit, typically involving glass jugs and small-scale operations; (2) starting from pre-made juice, traditionally associated with glass or ceramic jugs and small- to medium-scale operations; and (3) using previously produced wine, generally associated with barrels and larger-scale operations. For further details on vinegar development, processing methods and the required equipment, see Figure 4.2.

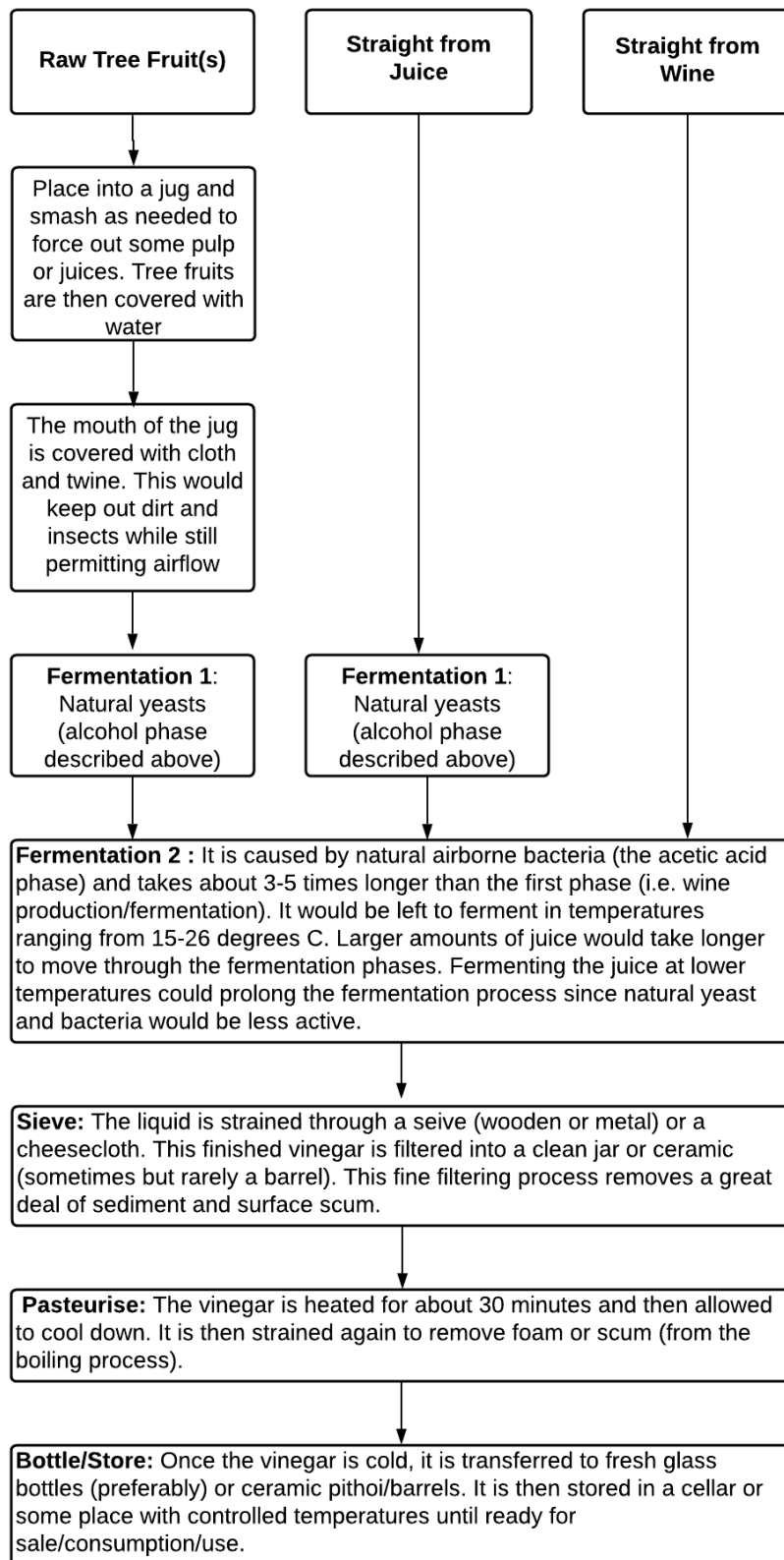


Figure 4.2: The development and processing of vinegar and the equipment used as discussed above. Note the equipment used at each stage (created by V. Newson).

There are numerous methods for producing vinegar, with the most common ones discussed here. The traditional "slow method" was particularly prevalent in France, Germany, Switzerland, Armenia and Georgia, both recently and historically. This method involves a lengthy fermentation process where wine is poured into wooden barrels through long-necked funnels. The barrels are filled just below holes located at their ends, which are covered with cloth or mesh to allow the mixture to 'breathe' (Barja and Bourgeois, 2009). These barrels are stored in warm environments, contrasting the cooler conditions required for wine fermentation and sometimes heated artificially, for instance, using stoves placed beneath the barrels. The fermentation duration varies based on several factors, including the original fruit ingredient (e.g., raw fruit, grape juice or wine), the quantity being produced per vessel (e.g., a 2-liter glass bottle versus a 600-liter wooden barrel) and the workspace temperature (warm or cold fermentation) (Bhat et al., 2014; Hutchinson et al., 2019; Hutkins, 2006). Typically, fermentation exceeds 12 months. Once completed, the vinegar is sieved to remove unwanted residues, pasteurised or filtered and finally bottled for storage (Bekatorou, 2019; Mazza and Murooka, 2009). Table 4.4 below illustrates the significant differences observed in vinegar processing techniques and equipment across Mediterranean and Transcaucasus regions, as documented in ethnographic studies.

Manufacturing Method	Process/Equipment
Jar	Crushed fruit in jars with water, covered for airflow; two-stage fermentation, then sieved, pasteurised and stored. Small-scale Mediterranean and Caucasus use (Bellochi 1991; Fritsch 1923).
Continuous	Fruit juice added to vinegar in wooden barrels; top layer removed during fermentation; matured for months. Used in France, Algeria, Morocco, Tunisia (Pasteur, 1868; Contassot 1942).
German acetifier system	Fruit mash on wood shavings via pump/sprinkler; wood supports bacterial oxidation. Central Europe use (Pasteur Vallery-Radot, 1924; Bourgeois and Barja, 2009; Dobereiner, 1819).
Juice Vinegar	Heated juice aged ~5 years in barrels, mixed annually, transferred to smaller barrels. Traditional Modena method (Belocchi, 1991; Bourgeois and Barja, 2009; Lambert, 2012).
Rotation acetifier system	Rotating 600 L vats with wood shavings and air ducts; turned 6×/day; motorised in later use. Formerly used in France, Switzerland, Spain (Bourgeois and Barja, 2009; Bellochi, 1991).

Swiss acetifier system	Two alternating rotating vats; improved efficiency, reduced evaporation; produced ~5000 L/day of 10% vinegar. Used in France, Austria, Switzerland, Germany (Rojat, 1895; Franche, 1914; Bourgeois and Barja, 2009).
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Table 4.4: Different types of vinegar processing and equipment from the Mediterranean and Caucasus.

Vinegar produced directly from wine is typically associated with medium- or large-scale operations, where lower-quality wine or wine lees were either purchased by traditional vinegar breweries from wineries or transformed into vinegar by wineries themselves as a secondary product. For instance, in Orléans, wines from various French regions that became sour during transport to Paris were commonly sold to the nearly 70 vinegar brewers in the area (Bourgeois and Barja, 2009).

In contrast, vinegar made at a local or household level traditionally involved raw or dried tree fruits or grape juice (Lambert, 2012). This practice appears widespread across Mediterranean regions (e.g., Spain, France, Italy and Palestine) and the Caucasus (e.g., Armenia and Georgia) (Bourgeois and Barja, 2009; Pasteur Vallery-Radot, 1924; Dobereiner, 1819). For example, in the Armenian village of Vayk in Vayots Dzor Province, apricot vinegar is produced from dried apricots using the jar method. Similarly, in Dvin, Ararat Province, villagers make pomegranate vinegar from unpasteurised juice (Galebedian, 2020, personal communication; Melik-Shahnasareants, 1885).

Due to vinegar's high acidity, it should not be stored in containers made from corrosion-prone materials such as brass, copper, iron or tin (Fritsch, 1923). Historically, glass or glazed ceramic containers with lids were commonly used for small-scale vinegar fermentation and storage in countries like France, Spain, Germany and Italy (Bellocchi, 1991). In Armenia, vinegar was traditionally stored in ceramic pots before being transferred to larger wooden barrels, where it aged and developed distinct flavours, similar to wine production (Hovhannisyan et al., 2015). Barrels are typical in large-scale vinegar production, often placed horizontally with bungholes drilled into the top, sealed with stoppers or cloths and smaller ventilation holes on the ends (Behrend, 1908). In certain production processes, vinegar was transferred from larger barrels into progressively smaller ones until it was ready to be bottled or stored in glass containers (Bellocchi, 1991).

Glass is widely considered the safest material for vinegar storage and has historically been the preferred container for both large-scale final-product storage and small-scale household fermentation (Johnston and Gaas, 2006). While the equipment used in vinegar production is largely non-specialised and similar to equipment for juice, wine and other liquids (see section 4.4.2 for a detailed discussion of advantages and disadvantages of alternative equipment), its complexity often reflects the scale of production. Complex equipment generally signifies substantial investment in both labour and capital associated with large-scale market-oriented production. Simplified equipment, such as basic glass jugs or barrels with minimal modifications, typically indicates limited financial investment and small-scale production serving household or local economies.

4.6 Processes and Equipment for Brandy Production

The processes and equipment for brandy production are the same as for wine, except for the double distillation (Tsakiris et al., 2014; Epstein, 2014). *Eau de Vie* is a category of fruit brandy, produced from mash, juice, wine and tree-fruit residues that is distilled and traditionally not aged. The most commonly used fruits, besides grapes, are pomegranates, apples, pears, apricots, plums and cherries. Depending on the fruit, there are two methods of production (Mandelblatt, 2011). The first is for stone fruit, with or without the stones, to be crushed and fermented into cider/wine before going through distillation (Legin et al., 2005; Gadrat et al., 2022; Brouant, 1646). The second method omits fermentation and instead macerates soft fruit (with lower sugar levels) in neutral alcohol for flavour extraction, through two rounds of distillation (Fournier, 2006; Jarvis, 1996; Reddy and Reddy, 2009, pp. 37-41). The name has come to be used more broadly, however, for a cheap, distilled spirit made from poorer quality fruit (Tadevosyan, 2019, personal communication).

There are two types of brandy: (1) plain brandy; and (2) pomace brandy. Plain brandy is liquor distilled from wine (Epstein, 2014). The fermented liquid is heated in a simple large pot with a bulbous top, usually made out of copper, until it reaches boiling point (Rice, 1996). The alcohol vapours, which include a significant amount of water vapour, are directed from the pot through a curved glass tube into a glass condenser where they are cooled, resulting in a higher concentration of alcohol. The bulbous top and curved tube are designed so that unwanted

compounds drop back into the still instead of contaminating the final product. This usually takes up to eight to nine hours (Joshi et al., 2012). This double distillation means that the alcohol is concentrated twice. The product of the second distillation will have a higher alcohol content but less taste.

Another method of distilling plain brandy involves pouring hot wine into the top of a column made out of brick or glass (Fairley, 1905). The alcohol and other low boiling-point liquids in the wine evaporate. The vapour rises while the non-alcoholic liquid falls (Cullen and Cullen, 2002). The rising vapour eventually arrives at the still to be condensed. Then the alcohol particles boil as they fall again. This happens over and over again until the liquid is collected and the process is complete (Cullen and Cullen, 2002, pp. 66-102).

Pomace brandy is a spirit made by distilling the pomace, the leftover residue from winemaking or other intensive processing of tree fruits. This pomace can be fully fermented, partially fermented or not fermented at all (Valaer, 1939). In red wine production, the pomace remains in the must for the entire fermentation process, which makes it ideal for producing brandy, whereas in rosé wine production the pomace is removed before fermentation is complete, necessitating an additional brief fermentation period (Petrovic, 2005). Finally, the pomace originating from white-wine production undergoes no initial fermentation, so it must be fully fermented before the process begins. Afterward, the alcohol is distilled off to yield the brandy (Jakobović and Jakobović, 2015).

Most brandies, much like wine, undergo maturation in wooden barrels. Once the required ageing period, determined by the specific type, has passed, the mature spirit is combined with distilled water to lower its alcohol content and then bottled. This usually takes more than 5 years (Shonkwiler, 1953; Perold, 1911). This type of brandy could be added to wine to create a fortified wine (e.g., port and sherry) (Hovhannisyan et al., 2015). Once pomace brandy and ‘eau de vie’ are distilled, they are quickly bottled to preserve the freshness and aroma of the fruit. They are not typically aged in wooden barrels, like wine or vinegar but in glass bottles (Mandelblatt, 2011).

4.7 Fermentation and Storage

Once the processes for producing juice, wine, vinegar, spirits and oil were complete, these value-added products were transferred into various containers, including glass jars or jugs, ceramic vessels and wooden barrels (Table 4.5). Similar fermentation and storage equipment were employed for all these value-added products, indicating a general lack of specialisation in storage containers. Because the containers used for storage did not differ significantly based on content, it becomes challenging to identify the specific product within a container by appearance alone. Consequently, chemical testing is required to possibly determine the contents of these vessels (see Chapter 7 for further details).

Equipment	Advantages	Disadvantages	Source
Glass Jug	- Survives archaeologically - May retain residue - Ages wine 30+ years - Good for acidic liquids	- High cost - Fragile and hard to transport - Not functionally interpretable without residue - Inconsistent volumes	Sevak, 1982; Melik-Shahnasarants, 1885
Ceramic Pithoi	- Survives archaeologically - May retain residue - Low cost - Can last ~20 years - Can be buried to keep cool	- Breakable (less so than glass) - Sometimes porous - Not functionally interpretable without residue - Inconsistent volumes	Brun, 1986; Frankel, 1999; Hadjisavvas, 1992; Demesticha & Knapp, 2016; Foxhall, 2007
Stoneware Crock	- Survives archaeologically - May retain residue - Low cost - Slightly less breakable than ceramics	- Very hard to transport - Poor storage (oxygen/bacteria) - Not functionally interpretable without residue	Hovhannisyan et al., 2015; Squitieri & Eitam, 2019
Wooden	- Higher cost - Easy to make - Easy to transport - Enhances wine aroma	- Rarely survives (except metal hoops) - Poor long-term storage - May be porous - Not functionally interpretable without residue	Hovhannisyan et al., 2015; MacNeil, 2001; Stevenson, 2005; Bird, 2011

Collection Vat	- Survives archaeologically - May retain residue - Suitable for large-scale collection	- Not portable - Poor for fermentation - Not functionally interpretable without residue	Frankel, 1999; Foxhall, 2007; Prive, 2003
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Table 4.5: List of advantages and disadvantages of different fermentation and storage vessels used for any tree fruit liquid.

In conclusion, no single vessel type was universally superior. Glass jugs were ideal for precise aging and chemical stability but costly and fragile. Ceramic pithoi balanced cost and storage longevity, while stoneware crocks offered durability but poor fermentation conditions. Wooden barrels were unmatched in transportability and flavor enhancement, though poorly preserved archaeologically. Collection vats served well for high-volume storage but lacked mobility and were unsuitable for fermentation. Users likely selected containers based on practical needs, whether for transport, aging, bulk storage or everyday use, while balancing considerations of cost, durability and function.

4.8 Processes and Equipment for Olive Oil Production

Olive oil extraction is the process of separating the oil from other components of the olive fruit, such as vegetable extract liquids and solid materials. Because oil and water naturally do not mix, extraction can be accomplished through physical means alone. However, the method employed depends significantly on the duration between harvesting and processing the olives (Blázquez, 1992). In some regions, olives are taken directly from the tree to the press, as is common practice in Palestine (Simaan, 2017). While, in Greece and other areas where traditional presses were relatively less efficient, olives were historically allowed to ripen and soften before pressing. Although this method facilitated easier extraction, it also resulted in higher acidity levels in the oil (Foxhall, 2007). For instance, in Cyprus, olives were sometimes left exposed to sunlight, occasionally for several days, including being placed on rooftops to enhance softening (Hadjisavvas, 1992).

Olive oil comes in six primary varieties: virgin oil, first oil, oils of the first, second and third pressings and lees oil. The quality is mainly influenced by four factors: (1) the health and quality of the trees and olive groves; (2) the ripeness of the olives at harvest; (3) the handling and

storage of olives between harvesting and processing; and (4) the extraction method itself (Kapellakis et al., 2008).

Different types of olive oil are often consumed by distinct socio-economic groups within a population and perceptions of quality can be analysed by examining the distribution of different oil types among these groups. For instance, in the 19th-century village of el-Kerje, olives underwent multiple stages of processing, they were initially pressed, then crushed and pressed a second time and finally warmed and pressed a third time. The first oil went to the owner of the olives, the second to the owner of the press and the third to make soap (Dalman, 1928-42; Hamilakis, 1996).

Once the harvested olives have been sorted, the next step is cleaning to remove stems, leaves, twigs and other debris such as dirt and insects. This process is especially important because gritty particles can damage or accelerate wear on processing equipment, potentially reducing its lifespan dramatically, from an expected 25 years down to as few as five (Komonas, 2019, personal communication). Komonas, an olive oil producer, further notes that apart from gritty particles, harvested olives sometimes contain unexpected objects such as broken glass, jewelry, metal fragments and ceramic sherds.

4.8.1 Crushing

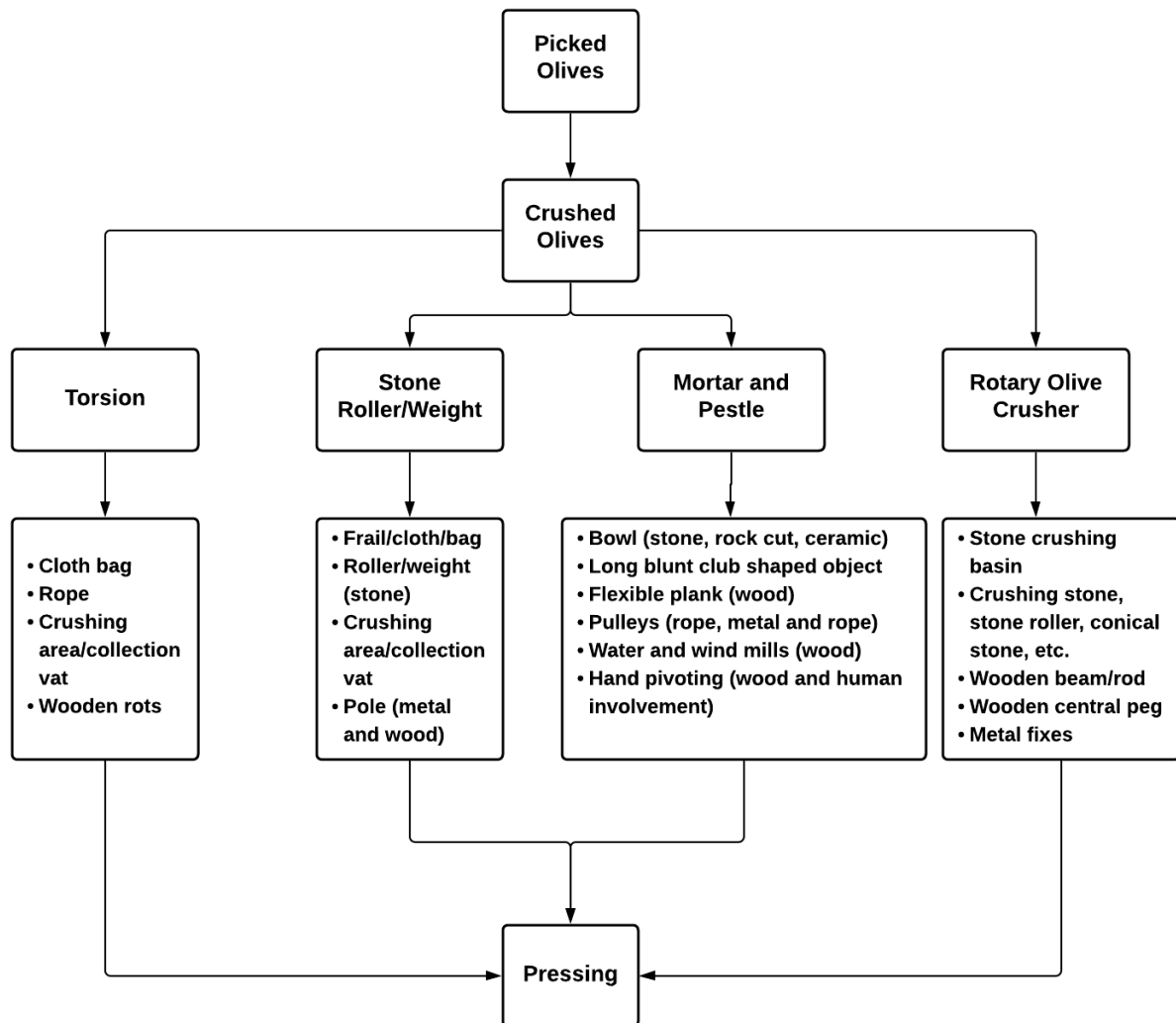


Figure 4.3: Variation in the processing /equipment of crushing olives (created by V. Newson).

Once the olives are ready to be crushed, ideally within three days of harvest, four main types of crushing equipment can be utilised, each with various subtle or complex variations: (1) organic sacks; (2) stone rollers; (3) mortar and pestle; and (4) olive crushers (Figure 4.3). Several of these methods overlap with those previously, given the historical similarities between wine and olive oil production equipment. One of the most popular methods to obtain olive oil using non-specialised, small-to-medium-scale equipment involves the addition of hot water to crushed olives or boiling the olives in water. The oil that floats up during this process is then skimmed off using a ladle or another type of non-specialised kitchen utensil. Traditionally this usually

occupied only one person but labour requirements could change depending on the quantity of olives used and the amount of oil to be extracted (Kislev, 1994-1995; Deckers et al., 2021).

Type 1 crushing involves placing very ripe olives into large sacks, typically woven from goat hair. Crushing occurs through torsion, with wooden poles twisting the sack's contents over a wooden trough designed to capture the extracted liquid (Amouretti, 1982, 1986, 1991). This approach, analogous to traditional wine-production techniques (details provided in section 4.4.1.1), is relatively simple and suitable for smaller-scale operations. However, this method often yields limited quantities of oil because the extraction process is less thorough. Additionally, the crushing is uneven, affecting the oil's quality and consistency, potentially allowing oxidation enzymes to remain active, diminishing overall quality. This traditional approach persists today, particularly in the Levant and Greece. In Greece, a metal pole inserted horizontally through the cylinder provides controlled rolling via two holes acting as handles (Oeconomou, 1996). Historically in the Levant, stone rollers were replaced after significant wear, requiring well-crafted metal poles for durability (Tepper, 1987; Bliss and Macalister, 1902). Traditionally, this manual method was operated by one or two women per roller (Boardman, 1958–1959). Mechanised versions also exist, featuring circular basins with horizontal handles moved by animal or human force (Oeconomou, 1996). Additionally, stone rollers have historically been and still are, used in wine production (Frankel, 1999).



Image 4.4: Stone rollers based on examples from Palestine and Greece that were used in olive crushing (created by V.Newson).

Type 2 crushing employs cylindrical stone rollers rolled repeatedly over olives placed in a frail or cloth bag on a crushing surface (Image 4.4). The reciprocal (back-and-forth) motion ensures a more consistent and even crushing, especially compared to torsion (Dawkins, 1902), predominantly targeting the olive pulp while minimally affecting the pit and skin. This selective

action reduces the release of oil-oxidation enzymes, preserves oil quality and results in a higher-quality oil with better preservation characteristics. Minimal water addition is needed, further enhancing the oil's flavour profile (Omar, 2010), while the low water content in the pomace simplifies residue management and facilitates production.

This traditional approach persists today, particularly in the Levant and Greece. In Greece, a metal pole inserted horizontally through the cylinder provides controlled rolling via two holes acting as handles (Oeconomou, 1996). Historically in the Levant, stone rollers were replaced after significant wear, requiring well-crafted metal poles for durability (Tepper, 1987; Bliss and Macalister, 1902). Traditionally, one or two women operated each roller (Boardman, 1958–1959). Mechanised versions also exist, featuring circular basins with horizontal handles moved by animal or human force (Oeconomou, 1996). Additionally, stone rollers have historically been and continue to be used in wine production (Frankel, 1999).

This olive oil production method involves crushing olives with low energy, preventing the paste from heating and thereby reducing the release of oil oxidation enzymes. It requires little financial investment, particularly upfront, as household materials can often be used and demands more or equal manual labour than large-scale production, making it accessible for small producers. However, the process is time-consuming compared to mechanised methods and yields only small volumes of oil. The method tends to apply irregular pressure and uses a discontinuous process with intermittent pauses, which exposes the olive paste to oxygen and light, potentially affecting oil quality. Additionally, the equipment is difficult to clean thoroughly and the process is not functionally interpretable in the archaeological record, limiting historical understanding (non specialised tool) (Kloner and Sagiv 1989-1990; Dawkins, 1902-1903; Omar, 2010; Tepper, 1987; Oeconomou, 1996; Frankel and Ayalon, 1988).

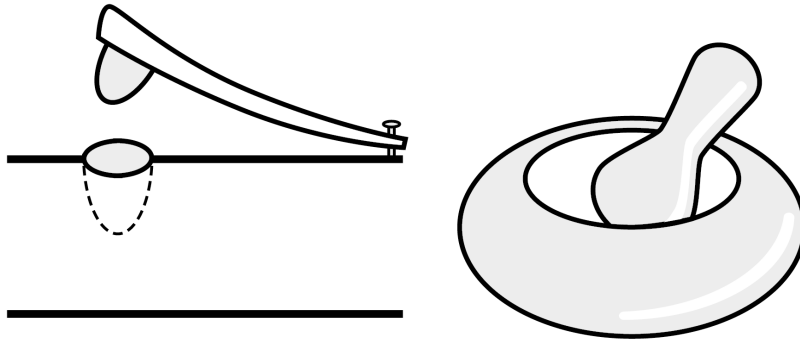


Image 4.5: Mortar and pestles examples from Romania (created by V. Newson).

Type 3 crushing utilises a mortar and pestle, operated through a partially rotary pressing and rotating motion. Traditionally crafted from durable stone, the mortar's rounded bowl shape accommodates thorough, uniform crushing when combined with the pestle's heavy, elongated form (Rivals, 1975). While traditionally employed for grain processing tasks, the versatility of mortar and pestle systems accommodates small-scale olive oil production, especially in domestic contexts. The process typically results in small quantities of oil, suitable for household use but its labour-intensive nature limits large-scale applicability. Mechanised adaptations utilising pulleys, flexible planks, water-driven or wind-powered devices and hand-operated pivots (Achaya, 1993; Casanova, 1966, 1968; D'Alembert and Diderot, 1762; Baroja, 1956; Frankel, 1999; Amouretti and Comet, 1991) have enhanced ease of production, although quality control remains variable due to differences in manual effort and equipment precision.

This method of olive crushing preserves quality by using low-energy processing, which prevents the paste from heating and reduces the release of oil oxidation enzymes. It requires little financial investment, particularly upfront, as household materials can often be used. Labour demands are lower than those of large-scale production, making it accessible for small producers. However, the process is time-consuming compared to mechanised methods and yields only small volumes of oil. The method tends to apply irregular pressure and follows a discontinuous process with intermittent pauses, exposing the olive paste to oxygen and light, which can affect oil quality. Hygiene presents a challenge, as the equipment is difficult to clean thoroughly. From an archaeological perspective, the technique is not functionally interpretable, limiting historical

understanding (Elgavish, 1969; Avitsur, 1976; Rivals, 1975; Achaya, 1993; D'Alembert and Diderot, 1762; Baroja, 1956).

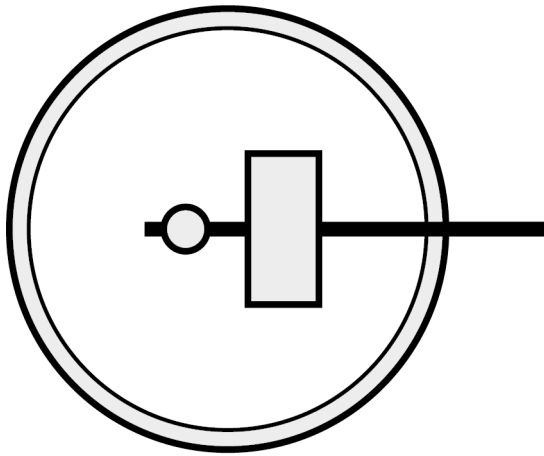


Image 4.6: Rotary olive crusher based on examples from Morocco, Algeria, Lebanon, Syria, France and Cyprus (created by V. Newson).

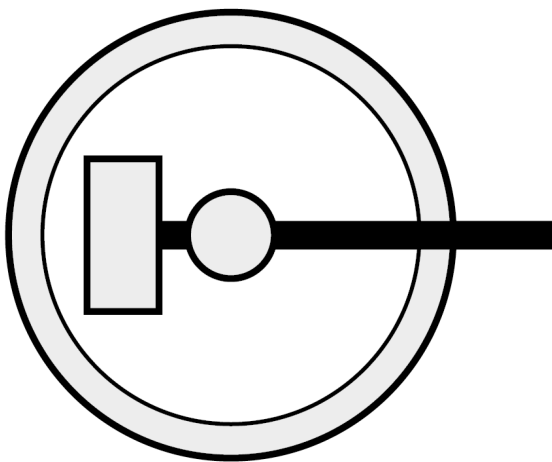


Image 4.7: Rotary olive crusher based on examples from Palestine, Egypt, Corfu and Iran (created by V. Newson).

Type 4 crushing involves pre-industrial olive crushers featuring a circular stone basin with a centrally pivoted rotating stone. The crushing stone, attached via a horizontal shaft to a vertical pivot, simultaneously rotates on its own axis and around the basin, ensuring thorough and uniform crushing of olives (Major, 1985; Sordinas, 1971) (Images 4.6 and 4.7). This method produces oil rapidly, releasing it effectively from the crushed skins and improving extraction efficiency. Typically, olives remain under the crushing stone for 30–40 minutes, facilitating complete grinding and aggregation of oil droplets into larger, more easily collected drops

(Dawkins, 1902–1903). This controlled duration activates beneficial enzymes, enriching the oil's aroma, flavour and overall sensory quality (Omar, 2010). Although the addition of heat or water during crushing can further increase oil yield, these modifications typically result in oil of lower quality due to the risk of oxidation and flavour degradation. Pre-industrial crushers with multiple stones (common in France, Portugal and Greece) increase throughput but can complicate equipment maintenance. Single-stone crushers remain prevalent for ease of maintenance and simplicity (Frankel, 1999; Sordinas, 1971; Amouretti, 1996; Mazzotti, 2004).

Historically, crushers were commonly powered by animals, water, wind or machinery. Variations of these crushing devices included differences in the positioning of the crushing stone along the shaft. In some regions such as Morocco, Algeria, the Northern Levant, Cyprus and France, the crushing stone was placed on the shaft between the handle and the central pivot. In the Southern Levant, Egypt, Italy and Greece, the crushing stone was located on the far side of the pivot. A rare alternative involved the use of concave crushers, as observed in Portugal, where the shaft did not serve as a handle; instead, a separate handle was positioned at an angle to it, a design also found in Corsica, mainland France and Spain (Mazzotti, 2004; Ohnefasch-Richter, 1913; Morato-Moreno et al., 2024; Petrakis, 2006).

Besides the rotary crusher with vertical crushing stones, several other crushing methods were known across the Mediterranean region. In the Levant, horizontal oil mills remained in use until recently. Similarly, Egypt utilised a horizontal treadmill and Tunisia employed a rotary hand-mill specifically for crushing olives (Katsarakis, 2020; Frankel, 1999). Despite these variations, most crushing devices found throughout the Mediterranean are derived from the same overarching technological tradition previously discussed concerning the round rotary olive crushers common in the Levant (Preziuso et al., 2010; Humble, 1976; Frankel, 1999). Another distinctive variant, found primarily in western North Africa, utilised an elongated, striated roller as the crushing stone (Frankel, 1999). Additionally, to facilitate easier maintenance and replacement, crushing equipment was sometimes constructed using segmented designs or consisted of multiple interchangeable parts (Armani, 1962; Migueles Ramos, 1989; Katsarakis, 2020).

Quality olive oil production using mechanised or semi-mechanised crushing benefits from continuous movement, which allows sufficient time for oil droplets to coalesce into larger drops.

Even and well-grounded pressure, combined with reduced exposure to oxygen and light, enhances oil quality. The machinery used is often compact and allows stronger control over crushing, resulting in the highest percentage of oil extraction. However, production may require more labour input, including the use of animals, wind or water and greater upfront financial investment. While mechanised methods are functionally interpretable in the archaeological record, they are less time-efficient than simpler manual methods. The pomace produced may remain moist or wet, reducing antioxidant levels due to added water and the machinery is subject to wear and tear. Despite these challenges, mechanised crushing offers superior efficiency, quality and control over the olive oil extraction process (Katsarakis, 2020; Major, 1985; Sordinas, 1971; Dawkins, 1902–1903; Mazzotti, 2004; Ohnefasch-Richter, 1913; Armani, 1962; Migueles Ramos, 1989; Avitsur, 1976; Hamilton, 1934–35).

4.8.2 Pressing

At this stage of olive oil production, pressure is applied to crushed olive paste to separate the liquid components from the solid materials. Traditionally, the olive paste was spread onto disks or placed inside bags, frails made from vegetable fibers or cheesecloth. These disks or frails were then stacked on top of one another before being placed into a press. By applying pressure, using methods such as weights or screws, the solid olive paste became compacted, forcing the liquid phases to percolate out of the paste (Frankel, 2016; Rowan, 2015; Warnock, 2007; Amouretti et al., 1984).

The specific pressure applied and the speed at which it was administered significantly depended on the type of pressing equipment and the quantity and quality of the olive paste. Higher quality pastes, typically richer in oil content, often required gentler, more controlled pressure to prevent the extraction of bitter or unwanted compounds. Greater quantities of paste or lower quality batches might be pressed more aggressively to maximise yield, though at the risk of diminishing the final oil quality. To facilitate more efficient liquid separation, water was frequently applied along the sides of the stacked disks or frails, accelerating percolation and improving the speed and ease of production. After extraction, careful separation of the liquids was crucial to ensure purity and high-quality oil.

The cleanliness of equipment played a critical role in maintaining oil quality and consistency. Disks, bags or frails needed thorough cleaning after each pressing to remove residual olive paste. Failure to adequately clean equipment could result in fermentation of leftover paste, contaminating subsequent batches and causing flavour inconsistencies. This necessity for meticulous cleaning extended to all pressing tools, including grindstones and other equipment, to avoid potential spoilage and preserve the oil's organoleptic properties.

Regional variations existed in olive oil extraction practices, influenced by the specific types of equipment used, processing times, labour availability and the desired quantity and quality of oil. Equipment that facilitated gentle, slow pressing typically produced higher-quality oils but was labour-intensive and yielded smaller quantities. Quicker, high-pressure methods increased production efficiency, they produced larger quantities of oil in less time and with less labour but could negatively impact the flavour profile and overall quality. Such trade-offs in production methods across regions resulted in distinctive variations in olive oil, which are detailed in Table 4.6.

Area	Process	Source
El-Kerje, Palestine	The olives were pressed three times: the first oil went to the olive owner, the second to the press owner and the third (after reheating and re-crushing), was used for soap in a nearby village.	Dalman, 1908
Nablus, Palestine	The olives were pressed only twice, the second pressing being after soaking the mash in water and after a second crushing.	Avitsur, 1986
El-Talife, Palestine	Hot water was poured over the first and only pressing.	Dalman, 1928-1942
Mi'ilya, Palestine	The olives were pressed only once without addition of any water.	Dalman, 1928-1942
Huévar-Huelva, Spain	The olives were pressed twice, with the olive cake broken up before the second pressing and hot water poured over the pulp during pressing.	Brun, 1986; Lauffer, 1971; Frankel, 1999

Table 4.6: Variations in olive oil pressing processes in the Mediterranean.

Four main types of equipment were historically used to press olives: (1) simple lever presses utilising drums and weights; (2) lever-and-screw presses; (3) single rotating-screw presses; and (4) double fixed-screw presses. Drums are windlass, a type of winch consisting of a horizontal, rotating cylinder or barrel. It is the power-multiplying mechanism that allows a small amount of

human effort to apply immense pressure to the pressing beam. Most press components historically were made from organic materials such as wood, rope or cloth, which typically decay over time, rarely surviving in the archaeological record. For example, direct-framed wooden presses found at Managri in the Troodos Massif and Mamonai in Paphos District, Cyprus, demonstrate complete reliance on wooden construction (Hadjisavvas, 1992). Similarly, screw presses made entirely of wood, including the screw itself, have been documented in olive oil production in France (Burton and Lewitt, 2019; Amouretti, 1993; Amouretti et al., 1984). Such presses are perhaps characteristic of small-large-scale production since poor quality oil could result from the continuous use of a wooden press and press bed (if it was impregnated with old rancid oil which contaminated the new oil) but they were at least cheaper to replace.

Wooden presses were economically practical due to the relatively low cost of replacement, making them suitable for both small and medium-scale producers. However, continuous use of wooden presses could compromise oil quality. Wood, absorbing oil during pressing, could become impregnated with old, rancid residues, contaminating newly produced oil and diminishing its quality. Components constructed from durable materials such as stone or metal, like weights, screws and drums, were more expensive but provided a lasting investment and often survive archaeologically, offering insights into historical production methods.

Type 1 comprises lever-and-weight and lever-and-drum presses. Such presses consisted of a lever (beam), usually made of wood, inserted into the fixed end of the beam press at the anchoring point (i.e., the beam niche), while the other end of the beam was the point of applied force (i.e., simple weights). In this case, humans were needed to lift the weights (Hamilton, 1934-35; Avitsur, 1976). The olives to be pressed were placed below the pressing point. The weights were brought to bear (due to gravity or human physical force) on the pressing point, resulting in the pressing (usually multiple times) of the olives. The juice flowed into the collection receptacles placed either below or to the side. The use of the beams as a lever multiplied the applied force, compared to previous methods like rollers and treading (see Chapter 7 for more detail). They were relatively easy to construct and operate. They required fewer specialised parts, facilitating straightforward assembly and maintenance. However, due to their basic design, these presses typically produced lower quantities of oil and the quality could vary depending on how thoroughly olives were pressed, at least compared to the other types. This

type of equipment usually involved three people, two to deal with the weights and drums and the other to place the olive paste (Mód and Simon, 2023; Frankel, 2016). Lever and weight presses throughout the Mediterranean exhibit numerous variants, particularly in the attachment and operation of the weights (e.g., weights being tied/hung from a beam in Italy and the Levant) and drums (drums and weights used together)(Vincze,1959; Frankel, 1999; Archives of Musée National des Arts et Traditions Populaires, Paris; Casanova,1966, 1968; Dalman,1928-42; Avitsur,1976; Hamilton, 1934-35; Cresswell, 1965; Camps Fabrèr, 1953; Wulff, 1966, Migueles Ramos, 1989; Mau, 1907; Mattingly, 1990; Billiard, 1913; Humbel, 1976; Latou, 1901).

Type 2, the lever-and-screw press, operated similarly to lever-and-weight/drum presses but provided a greater mechanical advantage compared to Type 1 due to the method used to lower the beam. In this press, the screw was securely fixed within a wooden frame or beam. The beam's free end was raised or lowered by turning the screw, typically using a wooden handle, which then pressed a crushing stone down onto the olives. The screw weight was connected to the screw via mortices (Gur and Spiegel, 1963; Amouretti et al., 1984), enhancing control and improving efficiency, allowing the operator to extract a greater quantity of olive oil with less effort while maintaining consistent quality. This design allowed for more effective extraction, significantly increasing both the quantity and consistency of the resulting olive oil. However, the complexity of this construction necessitated regular maintenance of the screw mechanism. Proper maintenance was essential for preserving oil quality, as worn or inadequately cleaned equipment could contaminate the oil, causing rancidity.

The Arginunta press is the most common example of a Type 2 press found across the Mediterranean, as indicated by its widespread presence in the Levant, Cyprus, Greece, Turkey, Italy, France, Spain and Portugal (Amouretti et al., 1984). In this type of press, the nut or screw mechanism is fixed above the end of the pressing beam, while the lower end of the screw is attached to a weight. The screw end is secured by two boards with semicircular indentations, held together by long, rounded pins. These boards are then joined to mortices in the weights using additional tenons (D'Alembert and Diderot, 1762; Paton and Myers, 1898). When operating the press, turning the screw within the nut above the beam lowers the beam. Once the beam reaches its lowest position and can no longer descend, further turning of the screw lifts the weight off the ground (Avitsur, 1976, 1986). This design ensures safety for labourers, promotes

uniform pressing and prevents equipment damage by eliminating the risk of parts breaking loose during operation. Additional examples of simple screw presses are available in: Rozier, 1776; D'Alembert and Diderot, 1762; Figurier, 1877; Hogarth, 1889; Paton and Myres, 1898; Bel, 1917; Anderson, 1903; Coon, 1931; Drachman, 1932; Benoit, 1936; Kotzia, 1955; Vincze, 1959; Baroja, 1963; Angelini, 1967; Irimie, 1974; Humbel, 1976; Amouretti, 1981; Aguilar Criado et al., 1981; Sáez Fernández, 1987; Brun, 1986; Frankel, 1999; Model in Musée National des Arts et Traditions Populaires, Paris; and Archives of Musée National des Arts et Traditions Populaires, Paris.

Type 3, a single rotating-screw press and Type 4, a double fixed-screw press, both involve a ram driven up and down by a screw, with the screw putting weight onto the olives through the use of a handle (Amouretti et al., 1984). The screw shaft can be operated by a handle or a wheel, which helps sustain the tool's momentum and thrust, making it easier to use and delivering a continuously pressing motion. The shape of the screw weight itself enhanced worker safety, as it was less likely to shift or fall out of place.

Single rotating-screw presses, allowed for continuous pressing, significantly enhancing production efficiency. By facilitating steady, controlled pressure, they improved both the quantity and uniformity of oil extraction, often yielding higher-quality oil with fewer impurities. However, their complexity and reliance on precision-engineered components meant they were more expensive to construct and maintain, thus representing a substantial initial investment. Double fixed-screw presses provided the most consistent extraction method among these types, applying uniform and reliable pressure that optimised oil yield and quality. These presses were particularly suitable for larger-scale production due to their durability and the ability to handle higher olive volumes. Nonetheless, their significant upfront cost and complexity posed barriers to smaller-scale producers. While these presses required a larger capital investment, they were more efficient, producing higher quantities of better-quality oil from the same amount of olives in less time. There are numerous variants of these presses found in: D'Alembert and Diderot, 1762; Figurier, 1877; Billiard, 1913; Dalman, 1924–42; Brondsted, 1928; Camps Fabrer, 1953; Vincze, 1959; Honigsberg, 1962; Casanova, 1968; Sordinas, 1971; Irimie, 1974; Humbel, 1976; Avitsur, 1976, 1986; Laufner, Faas and Cuppers, 1987; and Frankel, 1999.

4.8.3 Oil Separation

The third stage in oil production involves extracting oil from the watery lees. Every oil separation method depends on centrifugal force, the principle that the lighter oil rises due to gravity, floating above the heavier lees. Four distinct methods of oil separation have been documented: (1) skimming; (2) overflow decantation; (3) underflow decantation; and 4) combined overflow and underflow decantation. Additionally, another method of extracting olive oil involves adding hot water to either crushed olives or olives that have been stored for extended periods. The oil then rises to the top and is skimmed off (Dalman, 1928-42; Avitsur, 1986; Amouretti et al., 1984).

The simplest and least sophisticated method, skimming, involves a person pouring the liquid from vessel to vessel and manually skimming the oil from the top. This was usually done with a ladle, shell or another domestic tool. Alternatively, a very large separating vat, several cubic meters in capacity, could be attached to a press, allowing the expressed liquid to settle and the oil to rise naturally. This method was widely used across the Mediterranean, with similar equipment also documented in the Caucasus (i.e., Armenia and Georgia) for wine production (Hovhannisyan et al., 2015; Frankel, 1999; Brondsted, 1928; Bel, 1917). In overflow decantation, an opening just below the rim of a vessel or vat allowed the floating oil to flow out while the heavier watery lees remained behind (Vossen, 2007; Migueles Ramos, 1989). This method was particularly prevalent in the Levant, North Africa (i.e., Egypt, Tunisia and Algeria) and southern Europe. Underflow decantation, most commonly used in the Aegean and Cyprus, involved allowing the separated liquids to flow out sequentially through an opening or spout at the bottom of the separating vessels or vats (Hadjisavvas, 1992; Bousko, 2006; Forbes and Foxhall, 1978). However, vessels with bottom spouts were not exclusively used for olive oil separation; they could also function as mobile crushing and extraction vessels for grapes and other tree fruits (Hamilakis, 1996; Hadjisavvas, 2012; Dadelinyan, 2020, personal communication). The most sophisticated method was combined overflow and underflow decantation. In this process, the expressed liquid flowed into a larger compartment, where an internal opening remained stoppered until the oil had fully separated. At that point, the lees were released into a smaller compartment. Openings near the rims of both compartments allowed the

oil to flow out of one and the lees out of the other. This type of equipment has traditionally been found throughout the western Mediterranean (Rojas-Sola et al., 2012; Vossen, 2007).

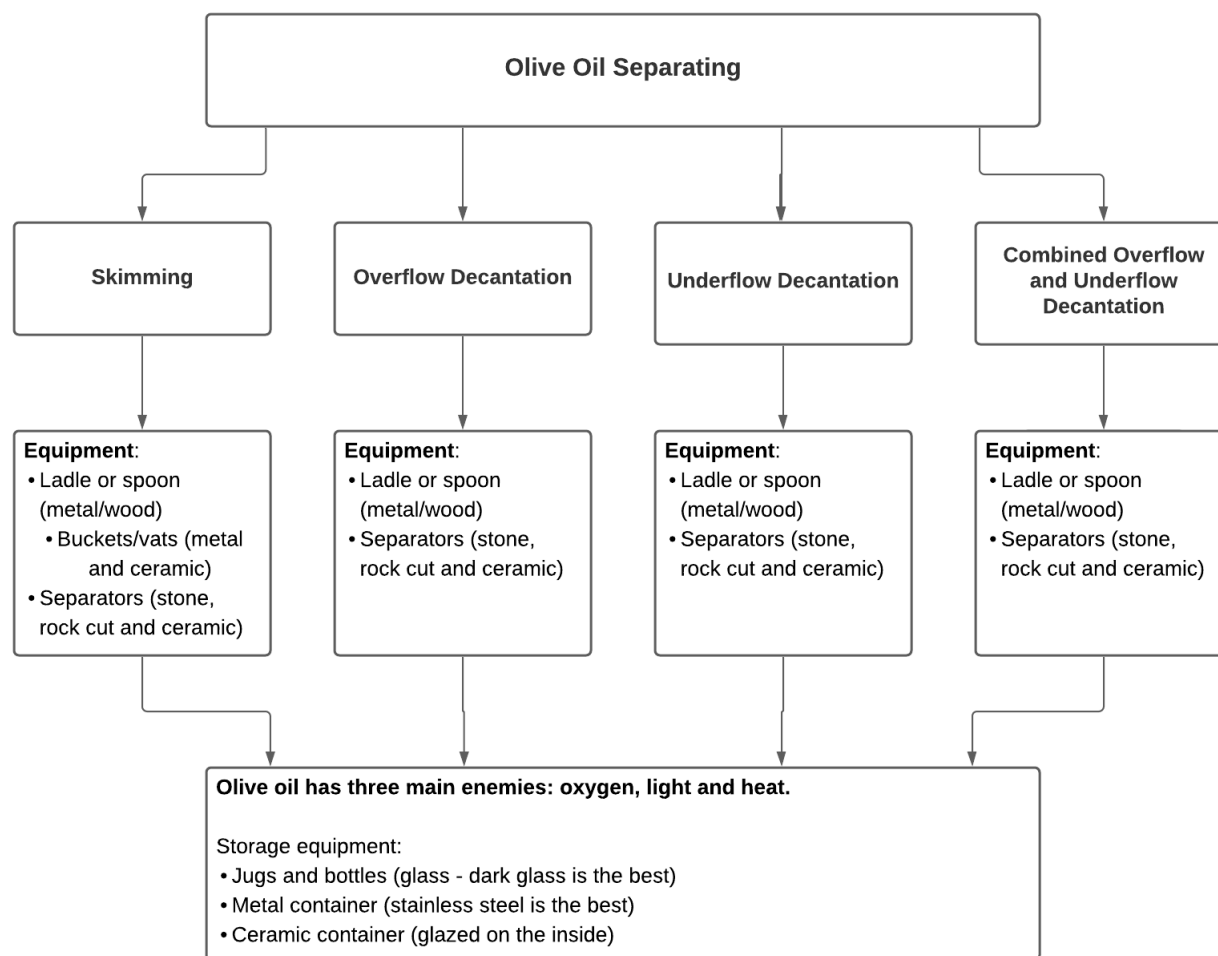


Figure 4.4: The variation in processing/equipment of separating olive oil (created by V. Newson).

The materials used to construct these separation devices varied depending on the scale and sophistication of the production (see Figure 4.4). Generally, small-scale, simple equipment was made of wood, ceramic or rock-cut material, whereas larger-scale or more advanced equipment was typically made of stone or also rock-cut. Unlike wine, which can improve with age, olive oil does not, necessitating its swift storage and transportation to market. Three main types of vessels were used for this purpose: (1) glass jugs and bottles; (2) metal containers; and (3) ceramic containers (Méndez and Elena Falqué, 2007; Kiritsakis et al., 2002; Kiritsakis and Dugan, 1984; Piscopo and Poiana, 2012).

4.9 Brief Discussion and Reflection

4.9.1 Comparison of Tree Fruits by Harvest, Storage, Processing and Liquid Production

Table 4.7 highlights key differences in the growth, longevity, storability and processing characteristics of five important fruit crops, grapes, olives, figs, pomegranates and dates. Olives stand out for their long maturation time, taking 7–15 years to bear fruit and their exceptionally long lifespan of 150–1000 years, making them the most enduring of the five. In contrast, pomegranates have the shortest lifespan (15–20 years) but begin bearing fruit relatively quickly (3–4 years).

Storability as fresh table fruit varies considerably. Pomegranates and dates have a clear advantage, lasting 4–6 months, while grapes, olives and figs have a very short shelf life of just a few days. However, all five fruits exhibit high storability when dried or processed, making them suitable for long-term storage and value-added production. In terms of liquid products, grapes (wine) and olives (oil) are particularly long-lasting; grape wine can be stored for over 30 years, while olive oil typically lasts 6–18 months. In contrast, fig-based fermented products spoil quickly, usually within two months and date-based fermentation is the shortest-lived, remaining viable for only about seven days.

Processing requirements and labour investment also differ. Grapes, olives and pomegranates require high labour and investment for wine or oil production, whereas figs and dates are more easily processed and require less input. Figs and dates are particularly efficient for fermentation because their fruit can be reused across multiple cycles, reducing the quantity needed per litre of product. Pomegranates, however, require a high volume of fruit per litre, making them less efficient for value-added production. These distinctions highlight the contrasting economic and agricultural roles of each fruit, with olives and grapes representing high-labour, long-term investments, while figs and dates offer more efficient, short-term processing potential.

	Grapes	Olives	Figs	Pomegranate	Date
Processing Months	August to October	August to December	June to October	September to October	August to December

Multiple Harvests	No	No	Yes (up to 3)	No	Yes (up to 3)
Earliest Fruit Bearing (years)	Low (2 years)	High (7-15 years)	Low (3-4 years)	Low (3-4 years)	Medium (4-8 years)
Life of the Tree (years)	Medium (50-100)	High (150-1000)	High (100-200)	Low (15-20)	Medium (50-100)
Storability (table fruit)	Low (2-4 days)	Low (3-5 days)	Low (3-7 days)	High (4-6 months)	High (4-6 months)
Storability (fruit dried/processed)	High	Medium	High	High	High
Storability (wine/oil)	High (up to 30+ years)	Medium (6-18 months)	Low (less than 2 months)	High (2-5 years)	Low (less than 7 days)
Quickest Fermentation (wine)	Medium (2 weeks)	N/A	High (4 weeks)	High (4 weeks)	Low (2+ days)
Wine/ Oil Processing (labour/investment)	High	High	Low	High	Low
Quantity (amount produced)	Medium	Medium	High	Low	High
Amount of Fruit Used/ Litre of Value-Added Product*	Medium	Medium	Low (since they can be reused for more than 1 fermentation process)	High	Low (22 dates/L but can be reused for more than 1 fermentation process)

Table 4.7: Comparison of the tree fruits under study in terms of when they first bear fruit, how long they live, their quickest fermentation process, their storability as a table fruit, dried/processed and as oil/wine, the labour costs of processing and the quantity of liquid they can produce.

4.9.2 Processing Equipment Comparison

Almost any type of equipment mentioned above can be used to extract liquid from a variety of fruits, including grapes, olives, figs, pomegranates and dates but with different success and quality (Table 4.8). However, the suitability of each type of equipment varies depending on several factors. These include the amount of pressure required, the time and cost investment, the

labour involved and the structural characteristics of the fruit itself (e.g., whether it has a hard or soft outer shell or a mushy or firm interior).

Processing Equipment	Types of Fruits*	Scale**
Treading	Grapes, Pomegranates	Small-Large (depending on people)
Stone Rollers	Grapes, Olives, Figs, Dates	Small-Medium
Weights and Wood Boards	Grapes, Olives, Figs, Pomegranates, Dates	Small-Medium
Torsion	Grapes, Olives, Figs, Pomegranates, Dates	Small-Medium
Pestle and Mortar	Pomegranates	Small
Vermentation Vessel and Hand Held Crusher	Grapes, Figs, Dates	Small-Large
Basket Press (Batch Press)	Grapes, Olives, Figs, Dates	Medium-Large
Moving Head Press (Batch Press)	Grapes, Olives, Figs, Dates	Medium-Large
Pneumatic Press (Batch Press)	Grapes, Olives, Figs, Dates	Medium-Large
Continuous Press	Grapes, Olives, Figs, Dates	Medium-Large
Rotary Olive Crusher	Grapes, Olives, Figs, Dates	Large
SLWP with Drums	Grapes, Olives, Figs, Dates	Medium-Large
Lever and Screw Press	Grapes, Olives, Figs, Dates	Medium-Large
Single-Rotating Press	Grapes, Olives, Figs, Dates	Large
Double-Fixed Screw Press	Grapes, Olives, Figs, Dates	Large

Table 4.8: Processing equipment, applicable fruit types and production scale. Note: *These are the types of fruit that can be processed using listed equipment, not necessarily a good product. ** *Production scale refers to the quantity of liquid produced relative to the time and labour required, including physical exertion and number of people involved.*

As a result, while many extraction devices are versatile, certain types of equipment are more efficient or ideal for specific fruits. Selecting the right equipment for each fruit can optimise yield, reduce processing time and minimise labour and costs (Table 4.9).

Value-Added Product	Most Effective* Piece of Equipment Based on Large-Scale Production**
Oil (Olive)	● Rotary Olive Crusher ● Double fixed-screw press
Juice/Wine/Vinegar (Grapes)	● Fixed-Double Screw Press
Juice/Wine/Vinegar (Figs)	● Basket Press
Juice/Wine/Vinegar (Pomegranates)	● Torsion ● Gentle Basket Press
Juice/Wine/Vinegar (Dates)	● Basket Press

Table 4.9: The most effective pieces of equipment for producing fruit-based valued-added products. Note: *Effective meaning the most liquid being produced in the quickest time using the least amount of physical effort, without impacting quality **

For olive oil, the most effective pieces of equipment were the rotary olive crusher with a double-fixed screw press. This is because olives are tough, oily fruits with pits, so they require thorough, uniform crushing to release oil efficiently. Rotary crushers provide consistent grinding without overheating the paste, allowing oil droplets to coalesce, preserving flavor and aroma. The double fixed-screw presses optimise extraction by applying uniform, strong pressure, yielding high-quality oil with minimal impurities. Methods like torsion sacks or mortar/pestle produce smaller volumes and uneven extraction, suitable only for domestic or very small-scale production. Pneumatic or mechanical screw presses give precise control but require higher investment.

For grapes, the fixed double-screw press is optimal because grapes are soft and juicy, yet their seeds and skins are fragile. Applying too much pressure can crush the seeds, causing bitterness and altering the flavor. This press provides consistent, even pressure across the fruit, allowing for high output and efficient processing. It is versatile, supporting different product types and scalable production, with precise control over pressure and can be mechanised to increase efficiency. The fixed double-screw press enhances stability and pressure, improving both juice yield and quality for larger batches. Basket or moving-head presses are suitable for medium-scale production, requiring moderate labour while maintaining flavor and colour, though they may be less consistent than pneumatic presses. Traditional treading or stone rollers

are best for small-scale or household use but they are labour-intensive and produce variable results.

The torsion method with cloth sacks or a gentle batch press (basket press) would be ideal for pomegranates because of the seed structure of pomegranates. They are hard and excessive pressure can rupture them, releasing tannins and bitterness. Gentle pressing with weights, torsion, minimises seed breakage, preserving flavor. More mechanised equipment, like pneumatic or screw presses may be too forceful for pomegranates unless carefully controlled. Stone rollers and treading could crush seeds inadvertently, affecting juice quality.

When figs or dates are crushed for fermentation in large water-filled vats, the priorities change. The fruit pulp must release sugars efficiently into the liquid and tough or sticky material needs to be broken down enough to mix thoroughly with the water. Gentle pressure is less important, as there is no risk of seed bitterness affecting flavor, unlike with grapes or pomegranates. In this context, efficiency (achieving effective sugar extraction and pulp breakdown rapidly and with minimum physical and monetary effort) and throughput are more critical than preserving delicate fruit structure. For both fig and date wine, a basket press is ideal because it effectively breaks down the pulp for easy mixing in the vat without requiring excessive investment or physical labour. Stone rollers could also accomplish this but they demand significantly more labour, while more sophisticated presses are unnecessary since only partial breakdown is required, unlike with olives. Torsion or manual pressing would be too slow and labour-intensive for this purpose.

4.9.3 Multiuse Theory

The comparative analysis of grapes, olives, figs, pomegranates and dates demonstrates substantial opportunities for multi-use processing systems, particularly where overlapping harvest and processing windows exist and where versatile equipment can handle multiple fruit types without compromising efficiency – that is, the optimal use of equipment and resources to produce the maximum quantity of high-quality product with minimal time, labour and waste.

The timing of fruit maturation and harvest creates clear opportunities for sequential processing on shared equipment. From summer to early autumn (June–October), figs, grapes and dates can be harvested and processed within overlapping periods, with figs and dates often producing

multiple harvests that allow equipment to be used consecutively without idle time. From late summer to winter (August–December), grapes, olives and dates share extended harvest and processing periods, making it feasible to plan sequential or overlapping production cycles using the same presses or crushers. Pomegranates, with their short and concentrated harvest window (September–October), are also compatible with multi-fruit processing schedules due to their tolerance for gentle pressing methods, eliminating the need for dedicated machinery. This temporal overlap reduces downtime for processing equipment and enables more efficient labour deployment, particularly in regions where multiple fruit crops are grown simultaneously.

Most modern and traditional extraction equipment, including basket presses, moving-head presses, rotary crushers and screw presses, can accommodate multiple fruit types with only minor adjustments. The basket press, for example, is suitable for figs, dates, grapes and olives, making it ideal for sequential processing when several fruits mature within the same season; its ability to handle both soft and moderately firm fruits allows quick transitions between products without the need for specialised machinery. Double fixed-screw presses and rotary crushers, while optimised for olives and grapes, are also capable of processing firmer fruits such as figs and dates, enabling high-volume oil or juice extraction across different crops when scheduled appropriately. Torsion and gentle pressing methods are best suited for delicate fruits like pomegranates to prevent bitterness but they can also be applied to softer fruits when careful handling is needed for premium juice or wine production. This versatility allows the same infrastructure to produce multiple value-added products, minimising capital expenditure and floor space requirements.

Each fruit's intrinsic characteristics, such as storability, fermentation potential and liquid yield, make them well-suited for multi-use processing. Highly efficient fermentable fruits like figs and dates produce more wine per unit of fruit and can undergo multiple fermentation cycles, allowing a single vat or basket press to be reused for different fruits in succession, thereby maximising overall output. Long-term storage fruits, such as grapes for wine and olives for oil, demand higher labour and investment but their extended shelf life permits careful scheduling of processing equipment to avoid overlap, making sequential use feasible. Even quick-fermenting, short-lived products like figs and dates are compatible with rapid processing schedules, enabling

presses that have recently processed grapes or pomegranates to be used immediately without significant downtime.

Sequential use of versatile equipment supports more efficient labour allocation throughout the processing season, meaning that labour, time and equipment are used optimally to achieve maximum output with minimal wasted effort or resources. Labour-intensive tasks, such as pressing or crushing, can be scheduled across different crops to maintain consistent workloads, avoiding the peaks and troughs in staffing that often occur with single-crop operations. Additionally, switching between fruits on the same equipment reduces repetitive setup costs. Minor adjustments, such as cleaning, adjusting pressure or changing baskets, allow continuous operation across multiple crops without the need for multiple dedicated machines, improving both efficiency and overall workflow by maximising productivity while minimising wasted labour and time.

Adopting a multi-use approach offers several economic advantages. Fewer specialised machines are required, which lowers capital investment, while maximising the operational time of presses and crushers increases the return on equipment. The approach also provides greater flexibility in crop planning, enabling farmers and processors to adjust harvesting and processing schedules in response to market demand, labour availability or variations in crop yield. In addition, shared equipment use enhances sustainability by reducing energy consumption and waste, as machines are utilised consistently rather than intermittently.

The convergence of harvest periods, the versatility of pressing and crushing equipment and the varying shelf lives and fermentation characteristics of grapes, olives, figs, pomegranates and dates strongly support a multi-use processing model. By strategically sequencing crops and utilising adaptable equipment, processors can optimise labour, reduce costs and maximise liquid yield across multiple value-added products, creating a resilient and efficient fruit-processing operation.

4.10 Conclusion

There are three key concepts from this chapter that are crucial when interpreting archaeological evidence related to tree fruit processing equipment: (1) small-scale processing generally involves

less durable, less functionally specific and thus less easily interpretable equipment, whereas large-scale processing equipment tends to be more durable and interpretable archaeologically; (2) both the equipment (tools and facilities) and the methods (traditional processes) used for processing juice, wine, vinegar and oil are relatively similar; and (3) the continued use of simple and non-specialised processing equipment appears continuously over space and time.

Small-scale processing typically utilises non-specialised, multi-purpose household tools, requiring minimal capital investment but often demanding greater labour relative to the output produced. Simple equipment and methods, such as torsion devices, rollers, weights, pestles and mortars and basic lever-and-weight presses, can be employed for making juice, wine, vinegar and oil. This universality makes it challenging to determine which specific method or type of value-added product was associated with any piece of equipment preserved archaeologically.

Conversely, large-scale processing is often linked to specialised equipment that is typically crafted from durable materials such as stone or fired clay. This makes large-scale processing equipment more likely to be preserved archaeologically and more easily interpretable regarding function. Such specialised equipment generally reduces the human labour required per volume of finished product, as animal, wind or water power often supplemented manual labour. The scale and sophistication of processing correlate closely with the quantity of available fruit and labour. Although olive oil, juice, wine and vinegar processing equipment share similar features, such as screws, weights and drums, variations mainly occur in the crushing techniques. For example, grape juice production often involves treading, while olive oil production uses rotary crushing.

Large-scale olive oil production, in particular, typically involves specialised, identifiable equipment because olive pits are significantly harder to crush than softer fruits such as grapes. Thus, installations designed specifically to crush olives into paste are archaeologically distinctive. However, distinguishing between equipment for oil production and that for juice, wine or vinegar still requires context-based analysis. Archaeologists must examine which fruits were processed, what fruits were stored nearby awaiting processing and which finished products were stored in the vicinity.

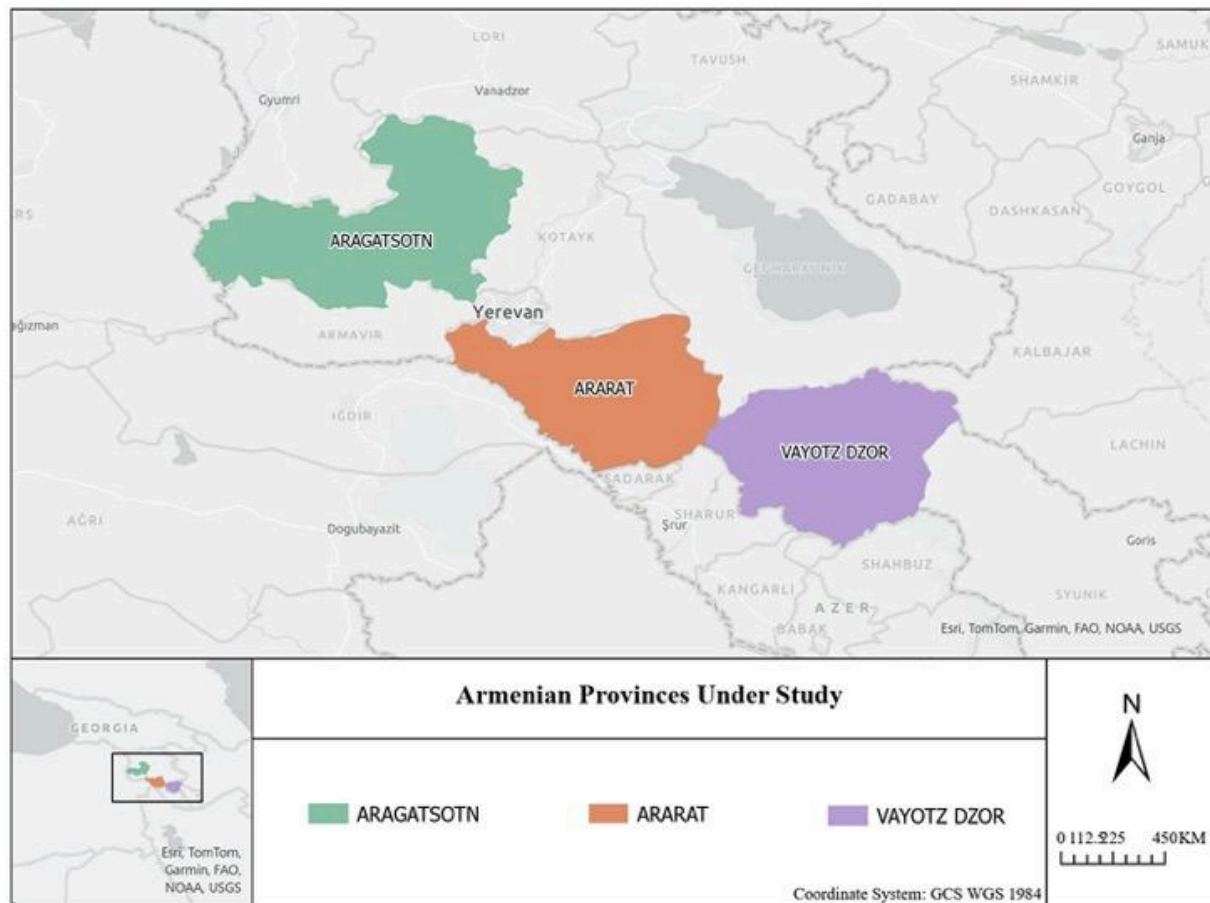
Traditionally, both oil and wine production begin with the crushing and/or pressing of fruits immediately after harvest. Subsequently, oil must be separated from watery lees, while wine and

vinegar require fermentation. Simple juice extraction generally needs minimal additional processing, typically only pasteurisation. A significant distinction between these products is that most liquid extraction occurs in the initial processing stage for juice, wine and vinegar, whereas for olive oil, the bulk of extraction takes place in a secondary pressing stage, after creating the olive paste.

The similarities among processing methods and equipment make it difficult to identify precisely which equipment was used for each product, even in large-scale processing contexts. This ambiguity encourages multipurpose use of large-scale, permanent facilities that would otherwise represent significant investments used only seasonally. Wine and other spirit productions, such as Eau de Vie and Brandy, traditionally occur between mid-July and late September, lasting at most three months. Olive oil production generally follows from October to December, also spanning about three months. Thus, if facilities were exclusively dedicated to producing a single product, they would operate just three months annually, yielding a relatively low return on substantial capital investment.

Chapter 5 - Fermenting the Future: An Ethnography Study of Wine Processing Equipment in Aragatsotn, Ararat and Vayots Dzor

This chapter presents a detailed ethnographic study of traditional wine processing equipment in three key regions of Armenia: Aragatsotn/Արագածոտն (south of the Aragats and Arteni mountains), Ararat/Արարատ (in the Ararat plain) and Vayots Dzor/Վայոց ձոր (northwest area) (Map 5.1). The research, conducted between January 2020 and September 2023 in collaboration with the Armenian Ministry of Education, Science, Culture and Sport, aimed to document and analyse the equipment, techniques and practices used in the production of wine through interviews and surveys of available processing equipment.



Map 5.1: Map of Armenia and the three regions under study: Aragatsotn, Ararat and Vayots Dzor.

The primary goal of this ethnographic study is to examine how the location, layout, equipment types and materials of modern wineries influence the scale of operations, specifically in terms of

output and workforce requirements. This will provide a deeper understanding of the labour force involved. This analysis is intended to enhance the interpretation of archaeological equipment discussed in Chapters 7 and 8. Additionally, the project aimed to develop a heuristic tool to investigate the causes and contexts of variability in contemporary production methods and equipment, which will inform the interpretation of historical production equipment and tools. This builds on Chapter 4, which focused on the ethnography of processing equipment in the eastern Mediterranean and Armenia regions. This study focuses on understanding the variability in winemaking methods and equipment used in these regions, by drawing on interviews with 72 local winemakers (with 43% of participants situated in Aragatsotn, 24% in Ararat and 33% in Vayots Dzor) and surveys of historic wineries. However, the inability to share interview transcripts or images of the land and equipment associated with these testimonies, due to restrictions imposed by the Armenian government and the ongoing physical and cultural genocide, somewhat limits the study's transparency, verifiability and interpretive depth. Most significantly, it obscures the human decision-making component of the *chaînes opératoires*, from fruit cultivation and processing techniques to equipment use (e.g., layout, materials), fermentation, storage and trade, all of which are essential for understanding labour organisation and production practices. It also slightly limits the comparative framework intended to link modern practices with archaeological interpretations.

Another aim was to preserve the viticultural and vinicultural heritage of these regions, which is increasingly threatened by the rise of industrialised wineries that rely on modernised mechanised equipment and the decline of small, family-owned operations that use small-scale traditional non-mechanised methods. The threat to viticultural and vinicultural heritage is a problem for several reasons: loss of cultural heritage, reduced wine diversity, impact on local economies and environmental concerns. Traditional winemaking methods are often deeply rooted in the history and identity of regions. When small, family-owned wineries that preserve these techniques disappear, a significant part of the region's cultural and historical legacy is lost. Industrialised production tends to lack the unique connection to tradition and terroir, even though many wineries in Armenia are trying to stay connected to their heritage by using *karases* and other traditional methods. *Karases* are large ceramic fermentation vessels that have been used within the region since at least the 9th century BCE, with smaller ones having been found as early as the

5th millennium BCE (see below for more information).

Small-scale, traditional operations often produce wines with unique characteristics that reflect local grape varieties, climates and techniques. The rise of industrialised wineries tends to standardise production, leading to fewer distinct wine styles and a more homogeneous market. Family-owned wineries frequently support local economies by providing employment and preserving agricultural practices passed down through generations. As they decline, jobs are lost and communities that rely on wine production may face economic hardship. Traditional methods of wine production often focus on sustainability, using fewer chemicals and less mechanised equipment. Industrial wineries, by contrast, tend to rely on heavy machinery and intensive agricultural practices, which can lead to environmental degradation, including soil depletion, increased water usage and a higher carbon footprint. Many small wineries are family-run, with knowledge and skills passed from one generation to the next. As ageing owners stop producing wine and younger generations lose interest or are unable to sustain traditional methods, due to economic viability and constraints, competition with industrial wineries or lifestyle and labour demands or are unable to sustain traditional methods, the continuity of centuries-old practices is broken and this knowledge may be lost forever.

Through this ethnographic approach, the chapter explores key themes such as the types and functionality of equipment (including its role in shaping scale of operation), the influence of regional geography and history on winemaking practices, the impact of modernisation on traditional techniques and labour practices. The chapter is structured into several subsections, each addressing different aspects of winemaking equipment and practices. First, it outlines the typologies and functionality of the core pieces of equipment. Then, it explores regional observations and trends, highlighting how wine production evolved over time in each of the three regions. The chapter examines both the scale of production, that is, the overall quantity of wine produced and the size of the operation and the associated labour requirements. It details how different equipment setups influenced not only the number of workers needed to manage production at a given scale but also the efficiency of the winemaking process. Here, efficiency refers to the ease and speed of processing, the amount of wine produced per worker and the effectiveness of the equipment in maximising yield while minimising effort. In other words,

while scale relates to the total volume of production or size of production (e.g., small-scale vs. large-scale), efficiency concerns how well resources, particularly labour, are used within that scale. Small-scale operations tend to have lower efficiency, particularly in terms of speed and yield per worker. Medium-scale operations balance efficiency, such as throughput and output, while beginning to optimise labour use and equipment. Large-scale operations prioritise high efficiency, maximising throughput and cost-effectiveness through mechanisation and labour specialisation.

Additionally, it also delves into the material composition of winemaking equipment, comparing the use of stone, wood and brick presses and analysing their impact on both the production process and the final wine product. The study also considers the balance between modernisation and tradition, exploring how winemakers have navigated technological advancements while preserving their cultural heritage. Lastly, the chapter discusses the significant cultural and economic losses caused by the destruction of wineries in Artsakh, emphasising the importance of documenting these traditions to prevent further erosion of Armenian winemaking heritage.

5.1 Variables and Functionality

The wine processing facilities surveyed reported a high degree of uniformity, with some variations primarily related to the internal arrangement of equipment within the structures. The addition or absence of certain pieces of equipment, however, could potentially impact the winemaking process or the final product. For example, producing red wine within storage vessels, rather than allowing maceration to occur in a separate vessel, could affect the final value-added product, as oxygen would have greater access to the liquid during fermentation. This increased exposure to oxygen could accelerate the fermentation process, influence the development of tannins and alter the wine's flavour profile, potentially resulting in a more oxidised or differently textured product. Wineries were constructed from stone and typically consisted of a rectangular building that usually but not always, included the following pieces of equipment:

(1) *Aragast/արագաստ*: a specific section for grape treading and/or pressing, generally plastered with lime and made out of stone.

(2) *Gub*/*գութ*: a small stone pit used for collecting the must and allowing sediments to form and settle.

(3) *Takar*/*տակար*: a stone collection vat into which the juices flowed.

(4) *Tarapan*/*տարապան*: a traditional separate stone structure used to extract the must from pressed grapes. It is placed either to the side or on top of the *aragast*. For a more detailed explanation see Chapter 8.

(5) *Karases*/*կարասես*: large ceramic fermentation vessels (see Photo 5.1)

(6) Other storage vessels used for fermentation, including oak barrels.

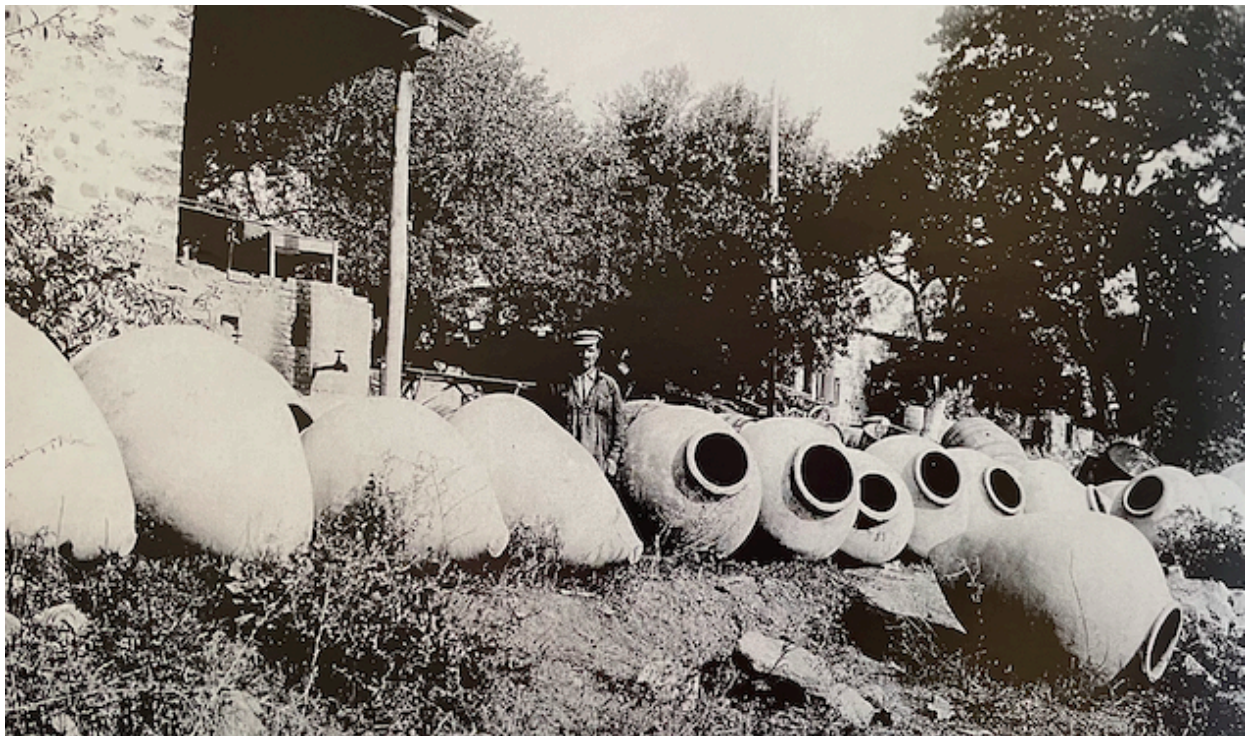


Photo 5.1: Karases, large ceramic fermentation vessels, being used in the fermentation of wine in the vineyards of Sardar (Yerevan History Museum, Gm.1417).

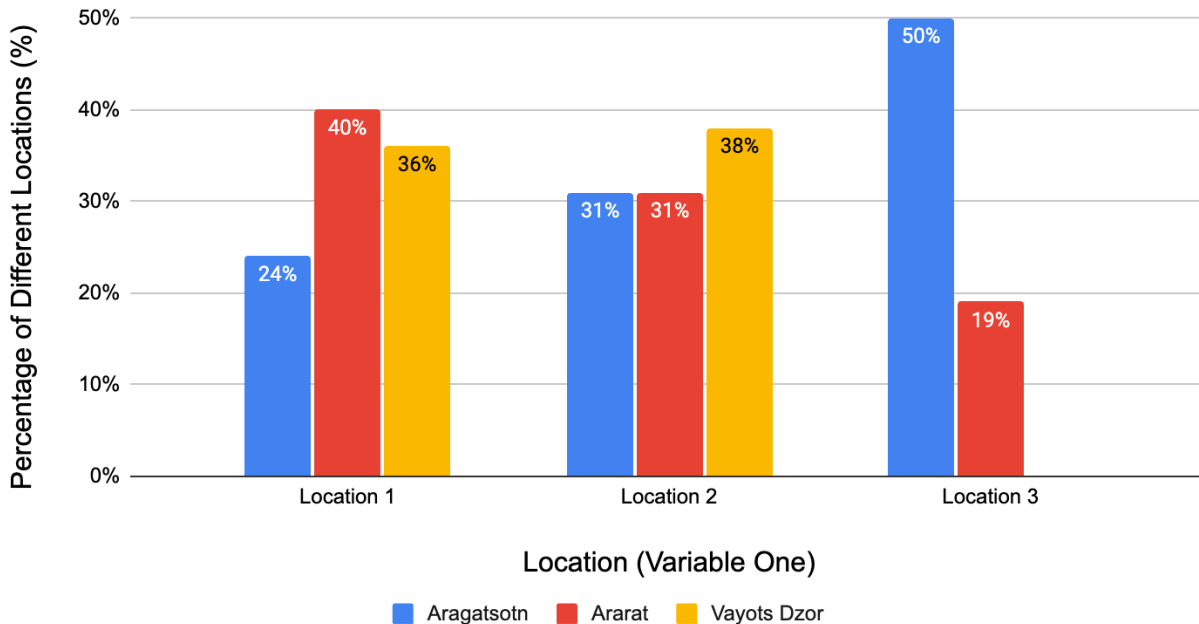
In addition to these fundamentally simple installations (see Chapter 7.2), wine processing installations also included wine cellars. A detailed categorisation of variables of traditional

wineries has been developed in this chapter as a framework for both the upcoming analysis and future research. For an extensive breakdown of all the variables and additional information, such as participants, marz (provinces), dates (CE), variables one to four, knowledge of distinct winery facility and/or the physical presence of a separate wine facility located either within the vineyard or on land owned by the winery and evidence of small huts, see [Appendix 2](#). These facilities were dated based on oral traditions and old photographs provided by participants and their families, comparisons of construction materials and building degradation with locally dateable structures and the analysis of previously dated presses in Armenia from the same or slightly earlier periods.

5.1.1 Variable One: Location

The first variable for categorisation was the location of the wineries, as this chapter aims to serve as a tool for hypothesising where to find Urartian processing equipment in Chapter 8. Just over 96% of participants reported that the location of wine presses was influenced by the desire to preserve more fertile land for vines and by the need to process the wine securely within their owned land while remaining close to the vineyard. The three variables are as follows: (1) stone buildings with installations inside, which were either purposefully constructed or incorporated into existing residential stone structures; (2) standalone, non-permanent buildings made of wood, with installations inside, located within the vineyard or on poor-quality land; and (3) repurposed or standalone permanent buildings made of stone, with installations inside, also situated within the vineyard or on poor-quality land (Graph 5.1).

Percentage Distribution of Variable One by Location Across Aragatsotn, Ararat, and Vayots Dzor



Graph 5.1: Regional distribution of location types (variable one) in Aragatsotn, Ararat and Vayots Dzor.

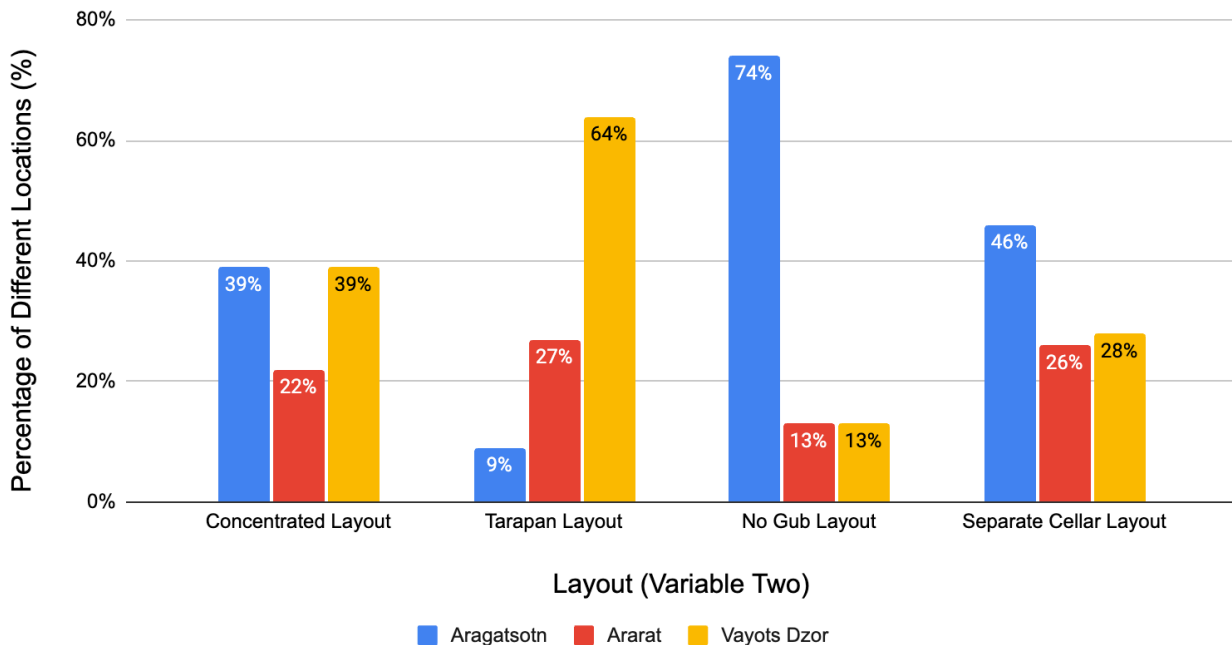
All these structures are still found on land owned by the winemakers but their degree of structural permanence varies, primarily based on the quality of the building materials used (stone versus wood) and their location. Location one is typically the smallest, as it was constructed within an already existing building, allowing no adaptability in terms of size. This is followed by location two (similar in size to location one) and location three. This affects the number of people who can work in these spaces and the equipment they can accommodate, which in turn influences production volume (larger presses yield more liquid), labour requirements (number of workers) and potentially the quality and types of wine produced (e.g., no *gub* or *tarapan*). Additionally, 47 out of 72 participants reported having either historical knowledge of a distinct winery facility and/or the physical presence of a separate wine facility located either within the vineyard or on land owned by the winery.

5.1.2 Variable Two: Equipment Layout

The second variable concerned the arrangement of winemaking equipment within the winery, including the spatial organisation of essential tools such as the *aragast*, *gub*, *tarapan* and of storage facilities. They were subdivided into four main layouts: (1) Concentrated Layout ; (2)

Tarapan Layout ; (3) No Gub Layout ; and (4) Separate Cellar Layout (Graph 5.2).

Percentage Distribution of Variable Two by Layout Across Aragatsotn, Ararat, and Vayots Dzor



Graph 5.2: Regional distribution of layout types (variable two) in Aragatsotn, Ararat and Vayots Dzor.

The Concentrated Layout involves the concentration of all winemaking equipment (*aragast*, *gub*, *takar* and wine cellar) within a single room, indicating an operation tailored for small to medium-scale production (Figure 5.1). This arrangement facilitates easier management and oversight of the entire winemaking process within a single space. It is suitable for producing a range of wines but is particularly well-suited for small batches of high-quality wine. They were present in all three areas from the 16th to the 20th centuries but became most popular during the 19th to 20th centuries.

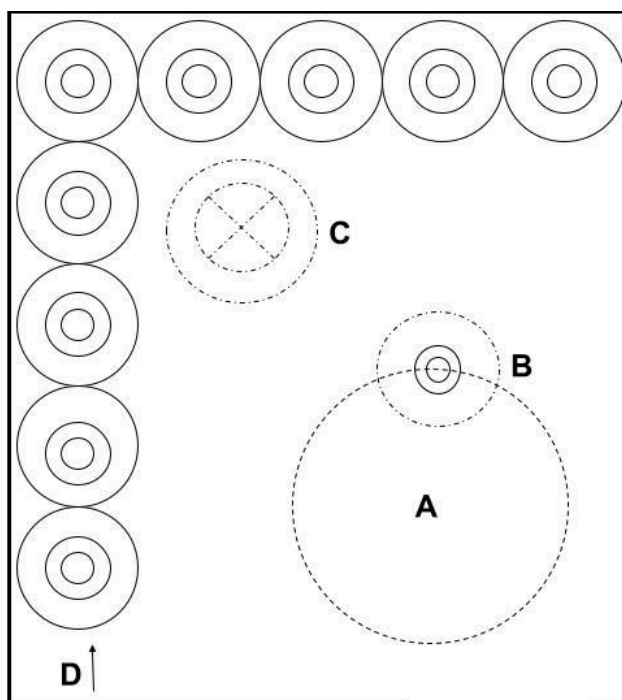


Figure 5.1: An example of a Concentrated Layout. Legend: A= aragast (արագաստ) B= takar (տափար), C= gub (գութ) and D = karases (կարասներ).

The Tarapan Layout differs from the Concentrated Layout by omitting the *gub* and incorporating a *tarapan* (Figure 5.2). This difference aims to achieve a higher quality of wine with distinct flavours. The exclusion of the *gub* indicates a different approach to fermentation and processing, focusing instead on optimising the extraction of juice from the grapes. It could be used to produce both red and white wines but the emphasis was usually on achieving a more premium wine according to participants 5,19, 34 and 56. They were present from the 17th century through to the 20th century in Ararat and Vayots Dzor but only from the 19th to 20th centuries in Aragatsotn.

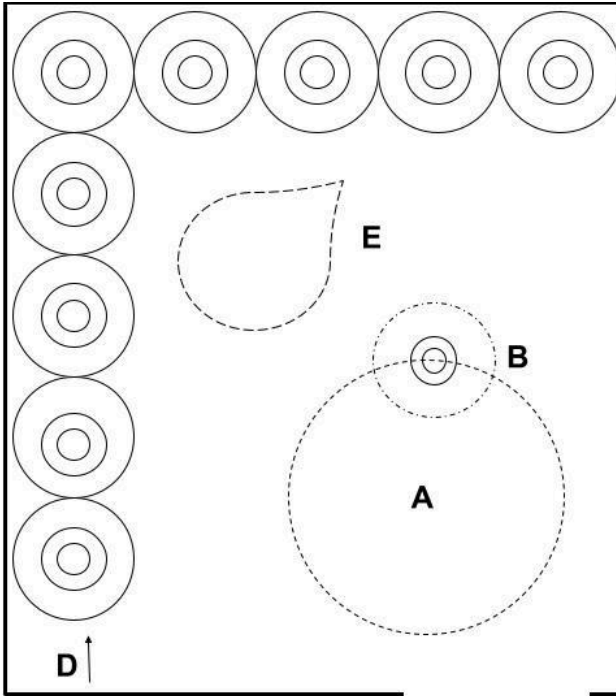


Figure 5.2: An example of a Tarapan Layout. Legend: A= aragast (արագաստ) B= takar (տակար), D = karases (կարասներ) and E= tarapan (Տարապան).

The No Gub Layout resembles the Concentrated Layout but excludes both the *gub* and the *tarapan* (Figure 5.3). This exclusion indicates a simpler setup where grape processing may be less refined and winemaking perhaps relies on natural fermentation techniques. It suggests a smaller-scale of production compared to all the other layouts. This layout is indicative of a focus on white wine production and/or in-vessel maceration for red wine, as supported by participants 1, 10 and 71. They are present in Aragatsotn from the 17th to 20th centuries but only appear in Ararat during the 18th and in Vayots Dzor in the 17th/18th centuries.

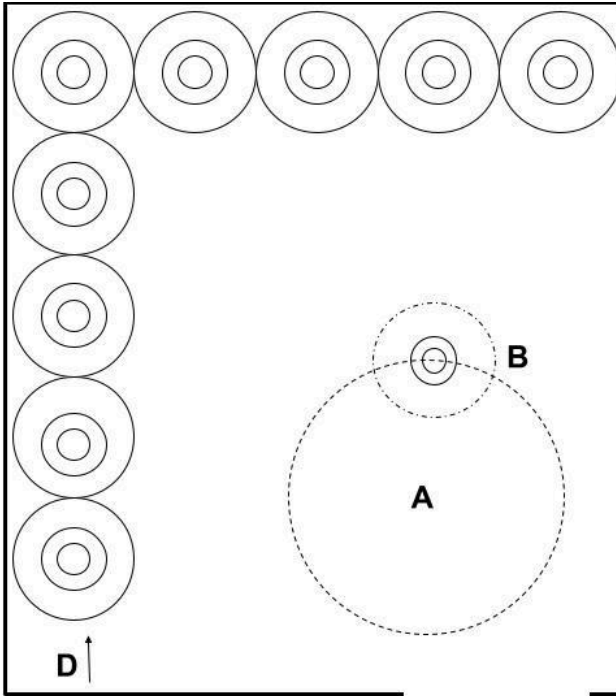


Figure 5.3: An example of a No Gub Layout. Legend: A= aragast (արագաստ) B= takar (տակար) and D = karases (կարասներ).

The Separate Cellar Layout features a design that separates core winemaking functions, dedicating one room to the wine processing installation (*aragast, gub, takar and tarapan*) and another to the wine cellar/storage (Figure 5.4). The separation of production and storage reflects a structured and organised approach to winemaking characteristic of larger-scale operations with more space for processing equipment, labour and wine storage. This design enhances operational efficiency by streamlining production in one room and managing ageing and storage in another, enabling greater output and better results with fewer wasted resources such as time, space, labour and materials. The dedicated storage space suggests a commitment to quality control, allowing winemakers to monitor and regulate environmental factors such as light and temperature, ensuring consistent maturation and adherence to desired standards. The widespread adoption of this layout underscores its effectiveness and benefits for both production and maturation processes. They appear in all three areas from the 16th to late 19th centuries but completely disappear by the 20th century.

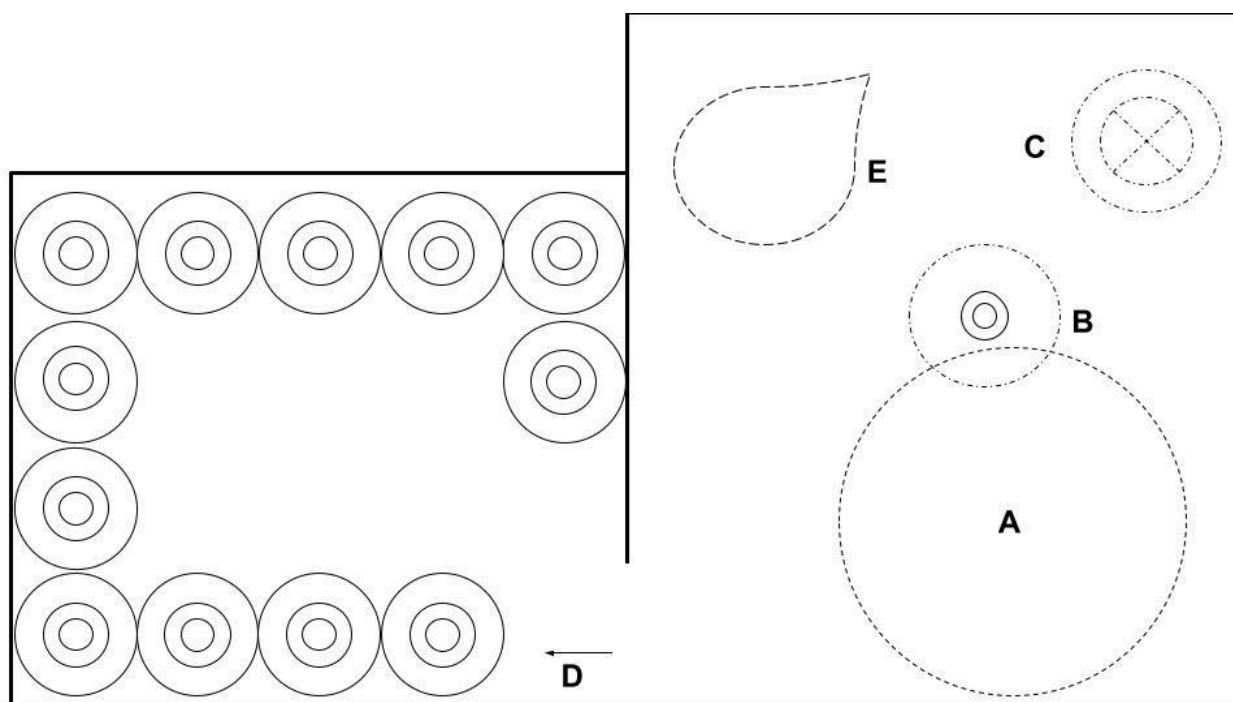


Figure 5.4: An example of a Separate Cellar Layout. Note that this is the only layout with a separate cellar. Legend: A= aragast (արագաստ) B= takar (տակար), C= gub (գոբ), D = karases (կարասներ) and E= tarapan (Տարապան).

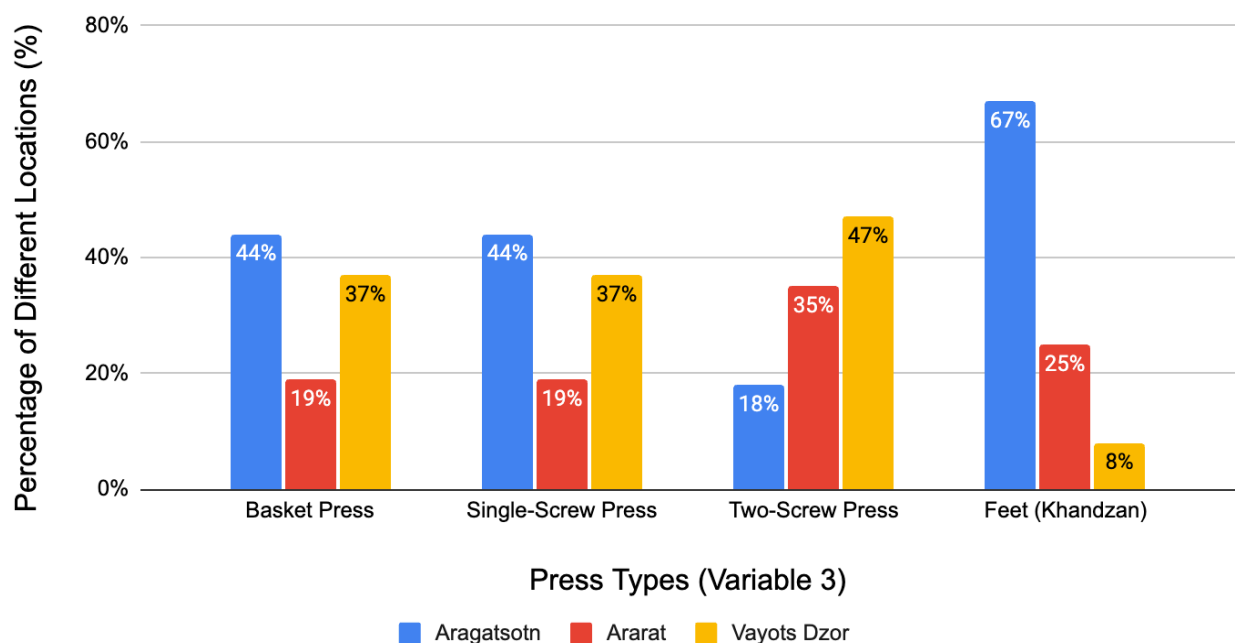
The layout of equipment influences how winemaking processes are managed and is therefore a strong indicator of the winery's operational scale , that is, whether it is structured for small-scale, limited production or large-scale, high-volume production , and how efficiently it uses time, labour, energy and resources to produce wine. For example, a Concentrated Layout , where all equipment, including the cellar, is in one room, optimises space and streamlines workflows, making it ideal for smaller-scale operations or limited labour. In contrast, a Separate Cellar Layout , with the cellar in a different room, allows for larger spaces, more extensive equipment, higher production capacity and greater labour specialisation. These layout differences reflect the scale of operations, labour organisation and production goals of the winery.

5.1.3 Variable Three: Specific Pressing Mechanisms

The third variable focused on the specific pressing mechanisms employed on the *aragast*, such as: (1) a basket press; (2) a single rotating-screw press; (3) a fixed two-screw press; and (4) simply treading with feet. While both basket presses and screw presses share the principle of applying pressure to extract juice, the screw press, especially the two-screw variant, offers greater efficiency, control and scalability. In this context, scalability refers to the ability of the

press to handle increasing volumes of grapes without loss of efficiency (output totals, ease of output and timeliness) or quality, allowing winemakers to adapt to larger production demands as needed. Rather than lowering a single plate to press the grapes, plates on opposite sides of an enclosed cylinder come together to compress them. Typically, this method handles a much larger volume of grapes than a basket press. Generally the volume of grapes handled is significantly greater than that of a basket press. The ability of the two-screw press to apply a wider and more consistent range of pressures makes it a more valuable tool for handling large grape volumes while preserving juice quality. Variations in how grapes are pressed are impacted by force (crushing, changeable and actuation), mechanical advantage and control over pressing. For a more detailed explanation of such variations see [Appendix 3](#).

Percentage Distribution of Press Types Across Aragatsotn, Ararat, and Vayots Dzor



Graph 5.3: Regional distribution of press types (variable three) in Aragatsotn, Ararat and Vayots Dzor.

Khandzan/խանձանի differs from all the other types observed or discussed with participants. These types featured elongated, trough-shaped presses (nav/նավ in Armenian) with large walls in which grapes were crushed by the worker's feet. The press included a long reservoir typically coated with thick lime mortar, featuring a slightly sloped bottom and a hole leading to a stone jar buried in the ground. According to participants 16 and 21, the grapes were first slowly crushed by the

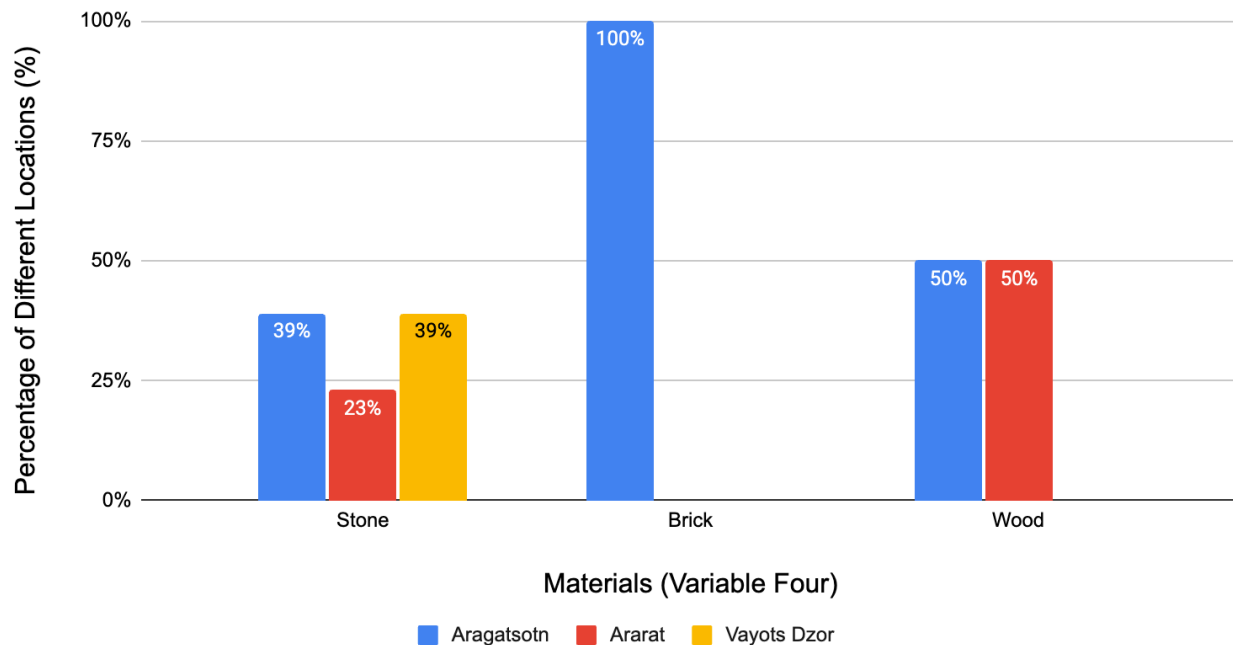
treaders' bare feet. Once most of the juice was released, the treaders would diligently press the grape skins with their heels. They would then stir the grapes and must with an oar, allowing the juice to drain and repeat the process. The juice flowed through the reservoir and was transferred from the first jar into a second one before being ladled with large, long-handled spoons into the *karases* (Participant 72, personal communications, 2020, 2021).

This design is similar to the Georgian Satsnakheli/ საწნახელი, which is constructed from masonry, hollowed-out rock or hollowed-out logs. It also resembles the 12th/13th century CE press found in the Lori province (Hobosyan, 2011, 2014), suggesting the possibility of continuous use of such presses for over 700 years. Examples located in wooden, non permanent structures were found in Ararat and Vayots Dzor dating from the 18th to 19th centuries, while ones located in stand-alone stone structures with stone installations were found in vineyards or on poor-quality land in Aragatsotn and Ararat from the 19th century onwards (latest dates).

5.1.4 Variable Four: Materials

The fourth variable considered the materials from which the equipment (*aragast, gub, takar, tarapan*, etc.), not including the basket or screw presses, was made. The choices of materials (including brick, stone and wood) influenced not only the durability and functionality of the equipment but also the flavour and quality of the wine. The *aragast, gub, takar, tarapan* were all made of stone when basket presses, a single rotating-screw press and a fixed two-screw were used. While, the Khandzan were subdivided on the basis of materials, with the nav being made of stone, brick and wood, used because these could have an impact on the winemaking process (e.g., by affecting temperature regulation, moisture, durability and cleaning) and the final wine product (e.g., flavours and texture and tannins) (Participants 12,17 and 21, personal communications, 2020, 2021).

Percentage Distribution of Materials by Location Across Aragatsotn, Ararat, and Vayots Dzor



Graph 5.4: Counts of the different materials (variable four) across all three regions.

5.1.5 Tsaravaz

Of 72 participants, 21 reported family members building small traditional huts known as tsaravaz (ցարավազ) based on either childhood memories or stories passed down through generations.

These small huts were constructed at the end of the vineyards, on the poorer quality of land, for people to sleep in during the day and night to protect the vines from frosts, animals and robbers over a two month period during the ripening of the grapes. Men would typically guard at night and women and children during the day time (Participants 16 and 44, personal communication, 2020; Hovhannisyan et al., 2015, pg 165-167).

5.2 Regional Observations and Trends

5.2.1 Observations by Province

To analyse regional trends in the dataset, attention was given to key variables (e.g., layout, pressing mechanisms and equipment, materials and the presence of specific features) and how

they vary across the provinces: Aragatsotn, Ararat and Vayots Dzor. The data reveals clear chronological and regional trends in winemaking practices.

Aragatsotn

In Aragatsotn, Separate Cellar Layouts were predominant from the 16th to the 19th centuries, while Concentrated Layouts emerged during the 19th and 20th centuries. No Gub Layouts appeared sporadically across various periods. The dominance of Separate Cellar Layouts highlights a traditional focus on both quantity and quality, whereas later shifts to Concentrated and No Gub Layouts reflect economic or practical adaptations. No Gub Layouts emerged almost exclusively in Aragatsotn, hinting at a potential preference for white wine production or red wine production directly in the fermentation/storage vessels. In terms of equipment, basket presses were widely used in earlier periods but were gradually replaced by single-screw presses in the 19th and 20th centuries, with two-screw presses occasionally employed. The winemaking practices in Aragatsotn demonstrate a clear technological progression, transitioning from manual to mechanical methods over time. Stone was consistently utilised throughout all periods. The region features 8 of the 12 documented Khandzan, most of which date to the 19th-20th centuries; three are constructed from brick (earliest evidence), three from stone and two from wood. Additionally, 21 out of 30 participants reported historical knowledge of distinct winery facilities or the physical presence of separate wine facilities, typically located within the vineyard or on winery-owned land. Aragatsotn also contains nearly half (10 out of 21) of the documented tsaravaz.

Ararat

Similar to Aragatsotn, Separate Cellar Layouts were predominant during earlier periods (from the 16th to the 19th centuries), while Concentrated Layouts are more common in later periods (19th and 20th centuries) in Ararat. Some instances of Tarapan Layouts emerged in the 19th century. The dominance of Separate Cellar Layouts highlights a traditional focus on both quantity and quality, whereas later shifts to Concentrated and Tarapan Layouts reflect economic or practical adaptations. Compared to Aragatsotn, the pressing mechanisms are more diverse, including the use of basket, single-screw and two-screw presses across all periods indicating no clear technological progressing or transition until the 19th century when single-screw presses

became more predominant. Stone remained a consistently utilised material throughout all periods. The region features only 3 of the 12 documented Khandzan, which date from the 18th-20th centuries. Two were constructed from wood and one from stone. Numerous participants (11 of 17) reported historical knowledge of distinct winery facilities or the physical presence of separate wine facilities, typically located within the vineyard or on winery-owned land. However, documented tsaravaz (4 of 17) are sparsely mentioned.

Vayots Dzor

Similar to Aragatsotn and Ararat, Separate Cellar Layouts were predominant during earlier periods (from the 16th to the 19th centuries), while Concentrated Layouts are more common in later periods (19th and 20th centuries) in Vayots Dzor. Some instances of Tarapan Layouts emerged in the 19th and 20th centuries. There was a predominant use of two-screw presses in earlier centuries, with an increasing use of single-screw presses in later periods. Basket presses were less frequently used compared to Aragatsotn and Ararat. Stone was a consistently utilised material throughout all periods. Vayots Dzor only has a stone Khandzan, which dates from the 18th to 19th centuries. More than half participants (15 of 25) reported historical knowledge of distinct winery facilities or the physical presence of separate wine facilities, typically located within the vineyard or on winery-owned land. Compared to other regions, there is a higher occurrence of documented tsaravaz (10 of 25).

5.2.2 General Trends and Patterns

Across all regions, Separate Cellar Layouts dominate older periods (16th to 19th centuries). However, there was a clear shift towards Concentrated Layouts in the 19th to 20th centuries. The exclusive presence of only Concentrated Layout, Tarapan Layout and No Gub Layout, along with the absence of Separate Cellar Layout wine making facilities from the mid -19th century CE onwards, likely reflects the historical context of the Müskirat resmi. This was an Ottoman tax on alcoholic beverages that increased significantly by 15-20% in the 1860s. Notably, Christian priests and monks were generally exempt from this tax for personal consumption and mass-related uses (Shaw, 1975).

In response, many producers likely shifted to smaller-scale operations in terms of spatial layout, pressing mechanisms and equipment. This shift aimed to reduce costs and risks, resulting in

facilities that were smaller compared to those of the Early Modern Period (15th–18th centuries CE)(see Chapter 8). Earlier facilities were often larger and more extensive, employing Separate Cellar Layouts and pressing mechanisms such as single-screw and two-screw presses, reflecting a production scale designed to meet broader market demands.

In contrast, later facilities were compact and cost-efficient, requiring less capital investment and fewer resources, particularly for pressing mechanisms and equipment such as basket presses and foot treading. These adjustments made the facilities ideal for reducing operational costs but demanded greater labour investment. Additionally, their compact nature allowed for easier concealment, enabling producers to evade strict tax enforcement and regulations, especially in areas like Location One. Higher taxes also made wine more expensive for consumers, likely shifting demand toward locally produced, more affordable options, which these smaller-scale facilities were well-suited to provide. Maintaining smaller, traditional setups allowed winemakers to preserve local practices.

This shift in production scale, that is, a change in the quantity of wine being produced and the level of labour required per unit of output, is further supported by the peak of Khandzans during the 19th and 20th centuries, primarily in Aragatsoth and, to a lesser extent, in Ararat. It represents a transition toward smaller-scale, lower-volume production that relied more heavily on manual labour, particularly through traditional methods such as treading (a practice of historical significance in Armenia, as discussed in Chapter 8). This trend persisted even as technological advancements elsewhere enabled increased production capacity and throughput (see below).

5.3 Scale of Production and Labour Force Distribution in Winery Layouts

For current and recent wineries run by the participants, the scale of production and the scale of labour required is known but for earlier wineries this must be estimated from a consideration of the surviving equipment, specifically the physical layout (variable two: concentrated, separate cellar or standalone structures), the complexity and type of the equipment (variable three: basket press, rotating-screw press, fixed two-screw press or foot treading) and how many people would ideally be used today to do the same job. When discussing production scale, it is assumed that

using different pressing mechanisms for the same amount of time, with the same amount of grapes and labour, would yield different quantities. This variation serves as the basis for categorising output into small, medium or large-scale, providing a general framework for comparability.

In terms of how many workers were required, this refers to the labour input needed to run a smooth, efficient and sustainable operation with relative ease. The size of the location (variable one) makes very little difference in terms of the number of workers. The labour requirement depends primarily on the layout, the equipment inside and the pressing mechanism rather than the size of the building. For example, if Location 1 has a Concentrated Layout with one basket press and so does Location 3, they would produce the same quantity and quality of wine using the same labour force. No additional workers would be required. The No Gub Layout would possibly require less workers due to the absence of a *gub* and *tarapan*, which are essential for creating different quantities, types and qualities of wine. In contrast, the Separate Cellar Layout (*aragast*, *takar*, *gub*, *tarapan* and cellar) would likely require more workers given the need to manage the separate wine storage area and the *tarapan* workers. In terms of the impacts on labour requirements of press technology, basket presses require the most manual labour due to their semi-manual operation, involving both physical pressing and managing juice flow. The single-screw press is the most labour-efficient mechanism, due to its mechanised design and moderate throughput capacity. Two-screw presses, though more mechanised, require more labour due to increased production scale and the need for oversight of the complex operation.

5.3.1 Concentrated Layout

The Concentrated Layout is one of the most efficient designs for small to medium-scale wine production (Table 5.1). The layout reduces the need for a large labour force, as workers can easily manage all stages of production and do not have the room to move as easily as in other layouts. Typically, two to five workers would be sufficient to oversee grape pressing and initial fermentation processes. The inclusion of a basket press indicates a semi-manual process where labour is required for operating the press and managing the flow of juice. The efficiency (e.g., optimising labour and workflow to maximise output with minimal wasted time, effort and space) of production in this setup would be enhanced by the compact layout, allowing workers to

quickly transition between tasks, keeping a steady pace of around 100-120 kg/hr/worker, depending on grape variety and condition. This is somewhat comparable to feet treading (Participant 36, personal communication, 2020, 2021). The use of a rotating-screw press suggests a more mechanised process compared to the basket press. This type of press requires less manual labour for juice extraction, increasing the overall productivity. A facility using this setup could expect a higher throughput, with an estimated labour requirement of two to four workers operating at 120-150 kg/hr/worker (Participants 20 and 54, personal communication, 2020).

Press Technology	Production Scale	Labour Force
Basket	Small - Medium	3-5 workers
Single-screw	Medium - Large	2-4 workers

Table 5.1: Winemaking press types by technology, production scale and labour force for Concentrated Layout wineries.

5.3.2 Tarapan Layout

The Tarapan Layout (Table 5.2) may suggest the need for an additional worker compared to the Concentrated Layout. This is because pressing and extracting the must involves both the *aragast* and the *tarapan*, typically using a smaller press or rollers on the *tarapan* (see Chapter 4) for producing different types of wines with different flavour profiles and/or quality levels. A manual basket press would require a labour force of three to five workers, while a single-screw press, being more mechanised, allows for greater scalability with a workforce of two to four workers. The two-screw press, however, would require a labour force comparable to that of the manual basket press, albeit with higher output.

Press Technology	Production Scale	Labour Force
Basket	Small - Medium	4-5 workers
Single-screw	Medium - Large	3-4 workers
Two-screw	Large	4-5 workers

Table 5.2: Winemaking press types by technology, production scale and labour force for Tarapan Layout wineries.

5.3.3 No Gub Layout

The No Gub Layout (Table 5.3) is primarily suited for small-scale wine production. With fewer specialised tools and components, the labour requirements are reduced. Workers focus on pressing and basic fermentation, enabling the creation of diverse types and flavour profiles within fermentation vessels rather than more specialised equipment. This suggests that fermentation was likely tailored for smaller batches of wine. The reliance on basket presses limits production scale, making this layout ideal for small farms or households producing wine for local consumption. However, incorporating a single-screw press expands its potential for medium-scale production.

Press Technology	Production Scale*	Labour Force
Basket	Small - Medium	3-4 workers
Single-screw	Medium	2-3 workers

Table 5.3: Winemaking press types by technology, production scale and labour force for No Gub Layout wineries.

5.3.4 Separate Cellar Layout

The Separate Cellar Layout (Table 5.4) is indicative of medium-to-larger-scale wine production operations. The separation of functions suggests it could accommodate a larger team than any of the other layout types. The labour force could be divided between operating the presses and overseeing storage and fermentation. The use of advanced pressing technology, such as rotating-screw presses and fixed two-screw presses, indicates a capacity for large-scale production. These presses generally require fewer workers to operate since they are more mechanised and can process large volumes of grapes. However, the separate storage space also might suggest the need for more workers to move and transfer the value-added products. This layout is particularly well-suited for large-scale commercial operations aiming for both volume and quality control.

Press Technology	Production Scale*	Labour Force
Basket	Small - Medium	4-6 workers
Single-screw	Medium - Large	3-5 workers

Two-screw	Large	4-6 workers
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Table 5.4: Winemaking press types by technology, production scale and labour force for Separated Cellar Layout.

5.4 Pressing Efficiency and Labour Force: Khandzan

The data reported by participants from Khandzan facilitates a detailed analysis of the efficiency (i.e., how effectively resources such as labour, time and equipment materials are utilised to maximise grape processing output) of grape pressing operations in Aragatsotn, Ararat and Vayots Dzor. This analysis is done through the materials used for the equipment (stone, wood, brick), then the number of workers involved, the quantity of grapes processed, the time required to press the grapes and the resulting throughput measured in kilograms per hour per worker (Table 5.5).

Materials	Location	Workers	Amount (kg)	Time (hr)	Throughput (kg/hr/worker)	Sources
Stone	Aragatsotn	2	350	1.5	117	Participant 3, personal communication, 2021
Stone	Aragatsotn	3	725	2.5	97	Participant 30, personal communication, 2021
Stone	Aragatsotn	1	120	1	120	Participant 52, personal communication, 2020, 2021
Stone	Ararat	2	375	2	94	Participant 42, personal communication, 2020
Stone	Vayots Dzor	3	650	2.5	87	Participant 72, personal communication, 2020
Wood	Aragatsotn	3	600	2	100	Participant 17, personal communication; 2021
Wood	Aragatsotn	3	550	1.5	122	Participant 12, personal communication, 2021
Wood	Ararat	5	1275	3	85	Participant 4, personal communication, 2020
Wood	Ararat	3	650	2.5	87	Participant 32, personal communication, 2020

Brick	Aragatsotn	4	800	2.5	80	Participant 21, personal communication, 2020
Brick	Aragatsotn	2	400	2.5	80	Participant 16, personal communication, 2020
Brick	Aragatsotn	2	400	2.5	80	Participant 33, personal communication, 2022

Table 5.5: The amount of juice output by workers (kg per hour per worker) in Aragatsotn, Ararat and Vayots Dzor (Armenia).

The range of throughputs for all three locations (approximately 80–125 kg/hr/worker) appears relatively consistent, which is why pressing efficiency, specifically throughput, was calculated in relation to material, as it represented the most consistent and measurable variable across cases. While other influential factors, such as human characteristics and cultural context, were recognised, they were considered too variable or qualitative to serve as a reliable basis for standardised efficiency metrics. As shown in Table 5.5, some variability does exist in individual cases but this can often be attributed more to differences in workers' stamina, age, experience or work ethic than to the technology or material used. Nevertheless, the overall consistency in throughput suggests that human elements may play an equally significant role as technological factors in influencing productivity. It also highlights the cultural context in which wine production takes place. For example, wine making is often a social and communal activity rather than being purely a production-oriented process. This perspective likely holds true in the Armenian regions studied here, where small-scale operations prioritise tradition, quality and the shared experience of winemaking over rapid processing. In addition to measurable productivity, winemaking in Armenia is often intertwined with cultural practices. For instance, specific songs and dances, such as the "Grape Picking Dance" (Խաղողի հավաքելու պար) and "Glory to Your Sacred Cross" (Փառք Քո Սուրբ Խաչին), are performed during the process (Armenian Apostolic Church, personal communication, 2022).

Although there is a general similarity in throughput across different materials, it is worth noting that the type of material used in treading, stone, wood or brick, could potentially influence the flavour and quality of the wine produced. Continuous use of specific materials may impart unique characteristics to the juice that contribute to the value-added product. For instance, all three materials, stone, wood and brick, play a role in maintaining stable temperatures during the winemaking process, with brick providing good insulation, stone having high thermal mass

(a material's ability to absorb, store and release heat) and wood offering controlled oxygen exchange (Participant 32, personal communication, 2021). Temperature control is essential for fermentation and ageing. Too much heat can lead to rapid fermentation, which might result in an imbalance in the flavours and aromas. If the fermentation is too slow due to low temperatures, it can result in undesirable characteristics like stuck fermentation. In terms of flavour impact, brick is mostly neutral but can risk introducing musty flavours if the press is not properly maintained, while stone can add subtle mineral complexity to the wine. Wood imparts the most noticeable flavours, with potential for vanilla, spice and tannins, adding significant complexity and ageing potential. Stone is the easiest to maintain due to its low porosity, while brick and wood require more careful sanitation due to the risk of harbouring bacteria or mould. Poor sanitation of brick and wood can lead to unwanted flavours. Wood and stone play the biggest roles in tannin extraction and wine structure, while brick has a lesser effect. Wood's contribution to tannins can significantly shape red wine structure, while stone provides precise control over extraction, influencing mouthfeel and body of the wine (Participant 12, personal communication, 2020, 2024).

5.5 Other Fruit Processing Equipment

5.5.1 Pomegranate

Participant 15 reported that to enhance the flavour profile of their wine, they incorporated pomegranates and wild berries to create multi-fruit wines. A small wooden basket press, operated by one person, was used to macerate pomegranates either alongside or in a separate area from the main processing equipment, occasionally in the cellar. Another participant (Participant 3) corroborated this and noted that workers rarely extracted every pomegranate seed individually. Instead, they cut pomegranates into fifths and remove as much of the membrane and rind as possible before applying the pressing plate. This method significantly expedited the extraction process.

A traditional method involved placing fruits in cheesecloth strainers, with wooden boards positioned above and below the cheesecloth and applying stone weights on top of boards for pressing (Participant 54, personal communication, 2020). Additionally, it was reported that in their youth, they used the cheesecloth strainers to hold the fruit while employing a torsion

movement to crush the grapes (see Chapter 4). Participant 26 described another traditional technique involving manually squeezing pomegranate seeds using a mortar and pestle. This method is labour-intensive and requires careful handling to maximise juice extraction. The mortar used in this process was more conical than typical mortars, with a higher rim to catch the juice and splatter, while the pestle was notably wider.

5.5.2 Figs

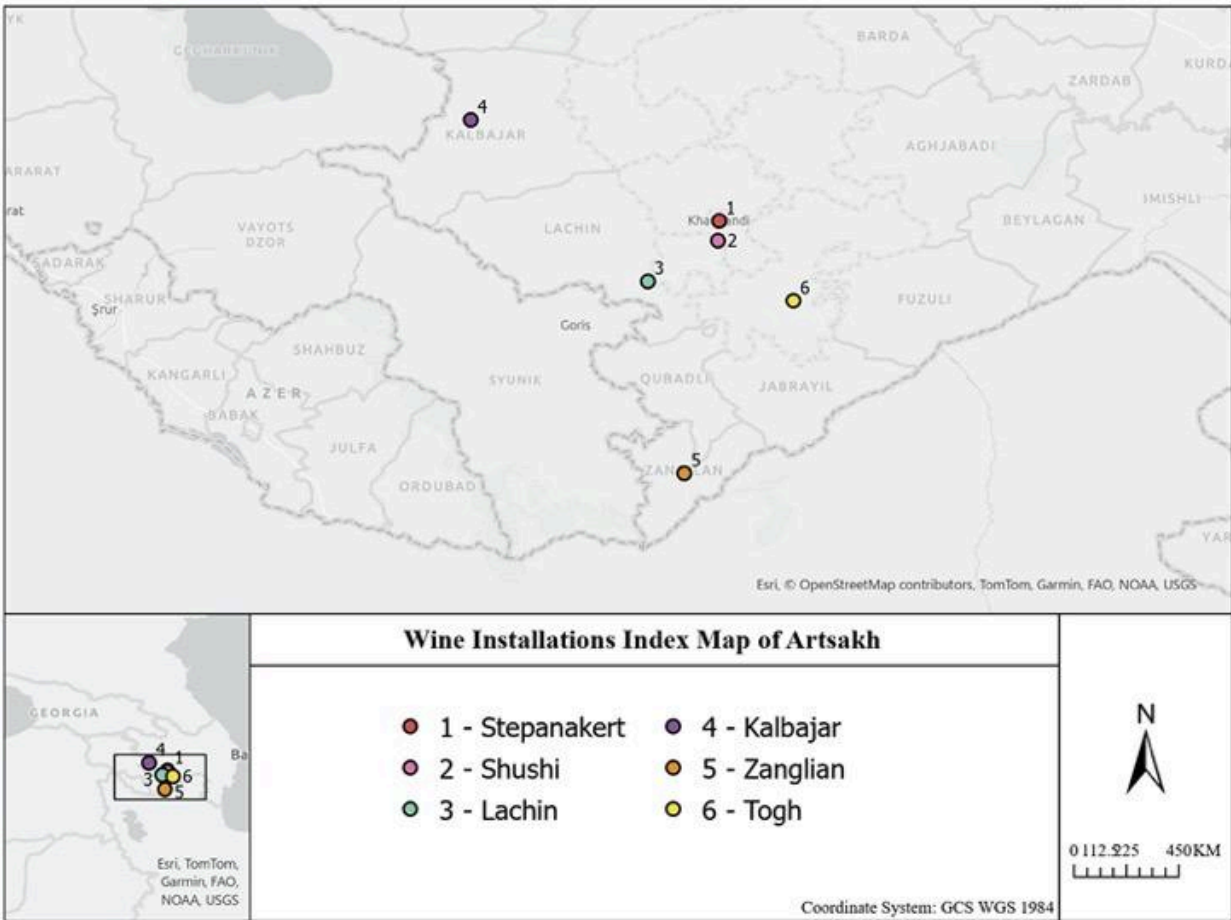
For small-scale production in Vayots Dzor, fig wine and vinegar were crafted using glass jars with tight seals. In contrast, medium-scale production employed ceramic storage vessels, which were internally coated with a specific lining. The production process varied: figs, preferably dried due to their high sugar content, were sometimes crushed, soaked in water and fermented over several weeks. Alternatively, whole dried figs were soaked in water and allowed to ferment naturally (Participant 4, personal communication, 2021). The equipment used for processing was similar to that used for fermenting grape juice but did not require the same processing equipment. This method yielded wine more quickly but was perceived as less refined, particularly in light of the significance of grapes and grape wine in Christian Armenian culture (Hobosyan, 2012; Sevak, 1982; Tumanyan, 2018). Similar processes were employed for other pitted fruits, such as dates and apricots.

5.6 Lost Wineries in Conflict

Before the recent genocide in Artsakh, the region produced 4 million liters of wine annually, representing 31% of mainland Armenia's total production of 13 million liters per year (Nazaretyan, 2023; Kirakosyan, 2021). Artsakh had around 15 large-scale wineries with around 70% of the wine being derived from the indigenous grape variety Khndoghni/Խնդողի (Margaryan et al., 2021; Margaryan et al., 2023; Khachatryan; 2024). The destruction of Artsakh's vineyards and wineries during the genocide has had a significant impact on Armenia's wine industry. Furthermore, Armenian material culture, including vineyards, monasteries and wineries, has been systematically targeted as part of this genocide. Satellite imagery has documented the Azerbaijani military destroying various elements of Armenia's cultural heritage, such as churches and wine-related infrastructure (Khatchadourian et al., 2022; Ghulyan et al., 2023). In this

context, it is essential to document and preserve knowledge about wineries and winemaking traditions to fully understand the extent of cultural loss, ensure that these historical practices are not forgotten and catalogue historic wineries and their associated equipment to gain a comprehensive understanding of the historic wine industry. In addition to the documented losses, interviews with Artsakh refugees conducted during the aforementioned ethnographic study have revealed the presence of historic rock cut wine presses in the region. However, it is unclear whether these installations have been previously catalogued or analysed. Despite searching through Russian, Armenian and Azerbaijani archaeological reports, this researcher was unable to locate any references to these processing installations.

Six separate wine installations were reported across six areas: Stepanakert/ Ստեփանակերտ, Shishi/Շիշի, Lachin/Լեյլաք, Kalbajar/Գալաթա, Zanglian/Կոլասկան and Togh/Sող (Map 5.2). There is no confirmed time period for the wine presses described by the participants but many are associated with the 17th-18th centuries according to oral traditions. Five of the six presses were identified as Type 2 presses (see Chapter 8), characterised by a treading floor, channel/bore and a collection vat. Five of the six presses had rectangular treading floors, while one press had a circular treading floor. Three of the collection vats were rectangular and three were circular in shape (Appendix 2, Sheet 2).



Map 5.2: Possible wine installations of Artsakh.

To address the economic and cultural loss caused by the loss of Artsakh, some wineries are exploring innovative solutions to continue honouring their cultural winemaking heritage. For instance, some Artsakh refugees are reviving the kakhani/կախանի, a grape-drying method, that involves suspending harvested grape bunches on strings in the air (Photo 5.2) (personal communication, 2021). This method, when applied to Areni and Haghtanak red grape varieties, produces a full bodied sweet wine. One individual is currently experimenting with this technique on white grape varieties.



Photo 5.2: Kakhani, a grape drying method, traditionally used in a lot of Armenian and Artsakh wineries (Photo by V. Newson, 2020).

At least seven small to mid-sized wineries were established between 2020 and 2022 due to the situation in Artsakh (personal communication, 2022). Some of the viticulturists who survived were forced to flee and were able to restart and transfer their wineries to their new locations. One example involves a winemaker who fled Artsakh in 2020 and rebuilt their winery in mainland Armenia using the same architectural design as the small-scale winery left abandoned in 2020 (Photo 5.3, courtesy of the winemaker). Based on the description provided by the winemaker, one winepress was located beneath the family farmhouse and featured a screw press on top of the *aragast* and a smaller screw press mounted on what is likely a mediaeval *tarapan* for pressing pomegranates to be added to the wine. Another winepress, with a Concentrated Layout, was reportedly a later addition, according to the winemakers' grandfather and was situated at the opposite end of the vineyard from the farmhouse. They rebuilt a larger version of the second winepress using a modern wine press on the ancient-looking treading floor and the building had several arches built from red tuff stones. The press represents an evolution in winemaking technology, incorporating contemporary equipment to enhance functionality while preserving the historical aesthetic of the treading floor. This juxtaposition of old and new highlights the continuity and adaptation of winemaking practices within the family's heritage. They have used the Khndoghni grape as a way to reconnect with their roots and preserve the memory of their homeland. They were able to obtain Khndoghni grapes from the Amaras region in Artsakh, since

there was still communication with mainland Armenia. They left behind the original winery, oak barrels and over 200,000 bottles of wine (personal communication, 2021).



Photo 5.3: Winery in Artsakh that was left abandoned in 2020 when Azerbaijan invaded. The winery was rebuilt in 2021 using indigenous Artsakh grapes.

Another winemaker established a winery in 2014 in their parents' villages in Artsakh but was forced to flee in 2020 (personal communication, 2022). They initially refurbished and expanded an existing 19th century winery. The original winery was characterised as a hybrid between a No Gub Layout and Separate Cellar Layout. However, the wine cellar was located in a separate space from the press and housed numerous barrels. It originally featured a large two-screw press dating to the 1920s on the *aragast*. The absence of a *gup* or *tarapan* suggests that the winery may have initially prioritised white wine production and/or employed in-vessel maceration for red wine production. This observation is supported by the winemaker's statement that they focused on white wine production during their period of ownership. The expansion involved the construction of a modern winery adjacent to the original 19th century facility.

The family had been fermenting wine in Artsakh oak barrels for almost a century but are now unable to do so, except for three barrels that were transported when the family escaped.

According to the winemaker's daughter, the Artsakh oak gives “գինու ավելի հարուստ, բայց նուրբ համ, ինչ-որ տեղ ֆրանսիական կաղնու նուրբ բնավորության և հայկական կաղնու ամուր հատկությունների միջև/a richer

yet refined taste to the wine, somewhere between the subtle character of French oak and the robust qualities of Armenian oak” (personal communication, 2021). The shortage of *karases* and the fairly limited knowledge on how to make new ones, has led to experimentation with animal skin fermentation methods, a technique with historical antecedents (Photos 5.4 and 5.5). The skins are tanned and treated to hold liquids, providing a flexible and durable container for fermenting grapes (History Museum of Armenia).



Photo 5.4: Wineskins made of cows used in the southern Caucasus dating to the 19th/20th centuries (History Museum of Armenia ALF 73).



Photo 5.5: An Armenian winemaker from Lori, pouring wine from a wineskin into a ceremonial horn drinking vessel (History Museum of Armenian ALF 115).

These examples highlight the resilience of winemaking traditions and their capacity to evolve. Modern winemakers are not only preserving their cultural heritage but also ensuring the sustainability of their craft in challenging times by introducing some modern approaches. This trend also highlights a continuity in the use of similar press layouts, pressing mechanisms and materials across Aragatsotn, Ararat, Vayots Dzor and Artsakh. This consistency suggests a shared cultural and technological tradition in winemaking that transcended regional boundaries. The replication of these techniques and designs across different areas over time indicates the enduring influence of established practices, likely passed down through generations and adapted to local needs and conditions. Moreover, this continuity underscores the interconnectedness of these regions in their approach to viticulture, reflecting not only their shared heritage but also changing historical and economic contexts.

5.7 Conclusion

In conclusion, this chapter has provided a comprehensive ethnographic analysis of traditional wine processing equipment in Aragatsotn, Ararat and Vayots Dzor, demonstrating the cultural significance and regional variations in production methods. The winemaking practices in Ararat, Vayots Dzor and Aragatsotn collectively illustrate the complex ways in which tradition and

modernisation coexist and evolve across regions. This chapter demonstrates how winery layout and equipment choices were influenced by both practical considerations and cultural traditions.

The shift from Separate Cellar Layouts to Concentrated Layouts, along with the adaptation of simpler pressing mechanisms like basket presses and treading, reveals how economic pressures and taxation (e.g., the *Müskirat resmi*) incentivised smaller-scale, cost-efficient production methods. This transition reflects a response to market variability, where producers sought to minimise operational costs while maintaining product quality, catering to localised demand for affordable wines. From an archaeological perspective, the variability in equipment layouts and pressing mechanisms provides valuable insights into production scale and labour organisation. Smaller, compact facilities with minimal equipment, such as No Gub Layouts, indicate limited production capacity and reliance on fewer workers. In contrast, larger operations using Separate Cellar Layouts and advanced pressing technologies (e.g., two-screw presses) are clearly designed for higher throughput (also demonstrated in Chapter 4). Separating processing equipment from the cellar streamlines workflow, reduces bottlenecks and allows continuous movement of materials. Two-screw presses handle larger volumes, more central and constant pressure and operate continuously, enabling rapid processing. This distinction offers a framework to interpret the scale of production and economic orientation of archaeological installations.

The analysis of winery installations showed that variations in internal equipment layouts influenced winemaking outcomes. Regional differences in pressing mechanisms, such as basket or screw presses and the occasional use of foot treading, were tied to the size and scale of operations. In terms of quantity and labour, facilities with advanced presses and separate cellars were capable of producing larger quantities of wine, reflecting a focus on a broader market. In contrast, compact setups like concentrated layouts prioritised efficiency and flexibility, supporting smaller batch production tailored to local consumption. Regarding labour requirements, traditional methods, such as treading and basket pressing, demanded significant labour investment, emphasising communal and manual processes. On the other hand, mechanised systems, such as screw presses, reduced labour needs while enhancing efficiency in terms of throughput and output.

This ethnographic study not only offers a foundational understanding of wine production equipment in Armenia but also provides a heuristic tool and framework for analysing and interpreting the archaeological remains in Chapters 7 and 8. By identifying equipment types, materials and layouts, researchers can infer the economic strategies, labour organisation and market dynamics of past winemaking communities. Additionally, the continuity of similar layouts and materials across regions points to a shared cultural tradition, assisting future analyses in exploring how regional identities intersected with broader economic trends. Additionally, the findings in this chapter will contribute to the broader understanding of Urartian wine processing equipment, as explored in Chapter 8. This ethnography, alongside archaeological evidence, will help pinpoint what Urartian equipment may have looked like, where it would be located and what materials were used in its construction. This chapter thus serves as a bridge between the study of living winemaking traditions and the archaeological investigation of ancient practices, ultimately contributing to a deeper understanding of both historical and modern Armenian viniculture.

Chapter 6 - Fruitful Transitions: Wild Flora to Developed Horticulture

Chapter 6 provides a comprehensive overview of archaeobotanical macro-remain data from the Eastern Mediterranean and Armenia, spanning the Pre-Pottery Neolithic through the Iron Age, focusing on *Vitis sylvestris* and *Vitis vinifera* (wild and domesticated grapevine), *Olea* (*oleaster* and *europaea*), *Ficus carica* (common fig), *Ficus sycomorus* (sycamore fig), *Punica granatum* (pomegranate) and *Phoenix dactylifera* (date palm). It does not seek to determine the earliest domestication area(s) or trace each fruit's transition from wild to domesticated forms. As explained in Chapter 3, both wild and domesticated fruits can be used to produce value-added products (e.g., raisins, dried fruit, wine, vinegar, oil) with similar levels of efficiency, so these distinctions are not a primary focus here. Instead, this chapter aims to establish when clear evidence of each tree fruit emerges in the studied regions, acknowledging that once they appear, they could be consumed or processed into various value-added products. Two specific objectives guide the analysis: (1) identifying when and where each fruit species is documented in the archaeobotanical record; and (2) tracking increases or decreases in site-phase presence of those species whenever substantial evidence exists. The observed increase in the number of site-phases containing fruit remains does not automatically indicate greater use or consumption of a particular fruit. Rather, it is more plausibly explained by the expanding number of archaeological sites that have been investigated and documented within the region. Recognising this distinction is essential to avoid overinterpreting the evidence as a direct reflection of dietary or cultural change. Further discussion of alternative methodologies for addressing this issue is provided in section 9.5.2.

These broad aims narrow to a more focused examination of site-phases containing notable concentrations of archaeobotanical macro remains in particular contexts or stratigraphic layers, thereby illuminating whether these fruits were likely consumed fresh or processed as dried fruit, wine, vinegar or oil. For instance, a cache of grape pips could indicate large-scale processing, potentially for winemaking, raisin production or other preservation methods. By systematically analysing such evidence, the chapter reconstructs overarching patterns of fruit cultivation, consumption and processing, shedding light on regional variations, distinguishing between subsistence and surplus production and briefly addressing the economic significance of specific

fruits. These interpretations build upon the foundational information from Chapter 3, offering deeper insights into how fruit resources were utilised and integrated into daily life across the regions and periods under study. For details on the methodological framework, as well as potential biases and issues associated with archaeobotanical data, see Chapter 2.

Table 6.1 outlines the specific criteria applied in identifying and classifying different categories of fruit utilisation, specifically fruits consumed fresh as table fruits, those preserved through drying and those transformed into liquid value-added products such as wine, vinegar or juice. The criteria serve as a framework for evaluating archaeobotanical macroremains, ensuring that each type of fruit use is recognised based on consistent and measurable indicators.

Species	Table Fruit	Dried	Liquid Value-Added Product
Grapes	30+ pips within one context/stratigraphic layer	"Re-inflated" grapes	Pips with ≥ 2 plant parts; association with processing equipment (general or specialised, incl. <i>pithoi</i> /storage vessels); 30+ broken pips pre-discard
Olives	30+ stones within one context/stratigraphic layer	"Re-inflated" olives	Stones with ≥ 2 plant parts; association with processing equipment (general or specialised, incl. <i>pithoi</i> /storage vessels); 30+ broken stones pre-discard
Figs	30+ seeds within one context/stratigraphic layer	"Re-inflated" fig	Seeds with ≥ 2 plant parts; association with processing equipment (general or specialised, incl. <i>pithoi</i> /storage vessels); 30+ broken seeds pre-discard
Pomegranates	30+ seeds within one context/stratigraphic layer	"Re-inflated" pomegranate	Seeds with ≥ 2 plant parts; association with processing equipment (general or specialised, incl. <i>pithoi</i> /storage vessels); 30+ broken seeds pre-discard
Date	30+ stones within one context/stratigraphic layer	"Re-inflated" date	Stones with ≥ 2 plant parts; association with processing equipment (general or specialised, incl. <i>pithoi</i> /storage vessels); 30+ broken stones pre-discard

Table 6.1: Criteria used to determine the evidence of table fruits, dried fruits and liquid value-added fruit products.

For table fruits, the main criterion is the recovery of a large number of plant remains, specifically, 30 or more pips, stones or seeds within a single archaeological context and

stratigraphic layer. Such concentrations are unlikely to occur by chance and instead point to deliberate collection and consumption of fresh fruits. Evidence for dried fruits is identified through the presence of specimens that appear “re-inflated” (see Section 6.1.8.2). Such a feature indicates preservation through drying, a common practice for extending the storage life of fruits in antiquity (Cartwright, 2015; Margaritis and Jones, 2006).

The most complex criteria relate to liquid value-added products such as juice, wine, vinegar and olive oil. In these cases, multiple lines of evidence are considered together. First, the recovery of pips, stones or seeds in association with two or more plant parts. Second, their direct connection with processing equipment, whether non-specialised tools (e.g., grinding stones, pestles, mortars) or specialised installations (e.g., treading floors, vats or stone-lined wine presses, as described in Chapter 7), as well as the presence of large storage vessels such as *pithoi*, which are often linked to fermentation and bulk storage. Third, an additional indicator is the discovery of 30 or more broken or crushed plant remains, which suggests intentional processing rather than casual discard.

6.1 Vitis sylvestris and Vitis vinifera

Evidence of both *Vitis sylvestris* and *Vitis vinifera* was found in 664 site-phases from across eleven regions ([Appendix 4](#)) (Table 6.2). As established in Chapter 3, value-added products such as wine and vinegar could be produced with comparable quantity, quality and ease regardless of whether the grapes were wild or domesticated. Therefore, all species are discussed together, no matter if they were wild or domesticated. This approach allows for a more comprehensive and unified analysis of grape utilisation and product transformation.

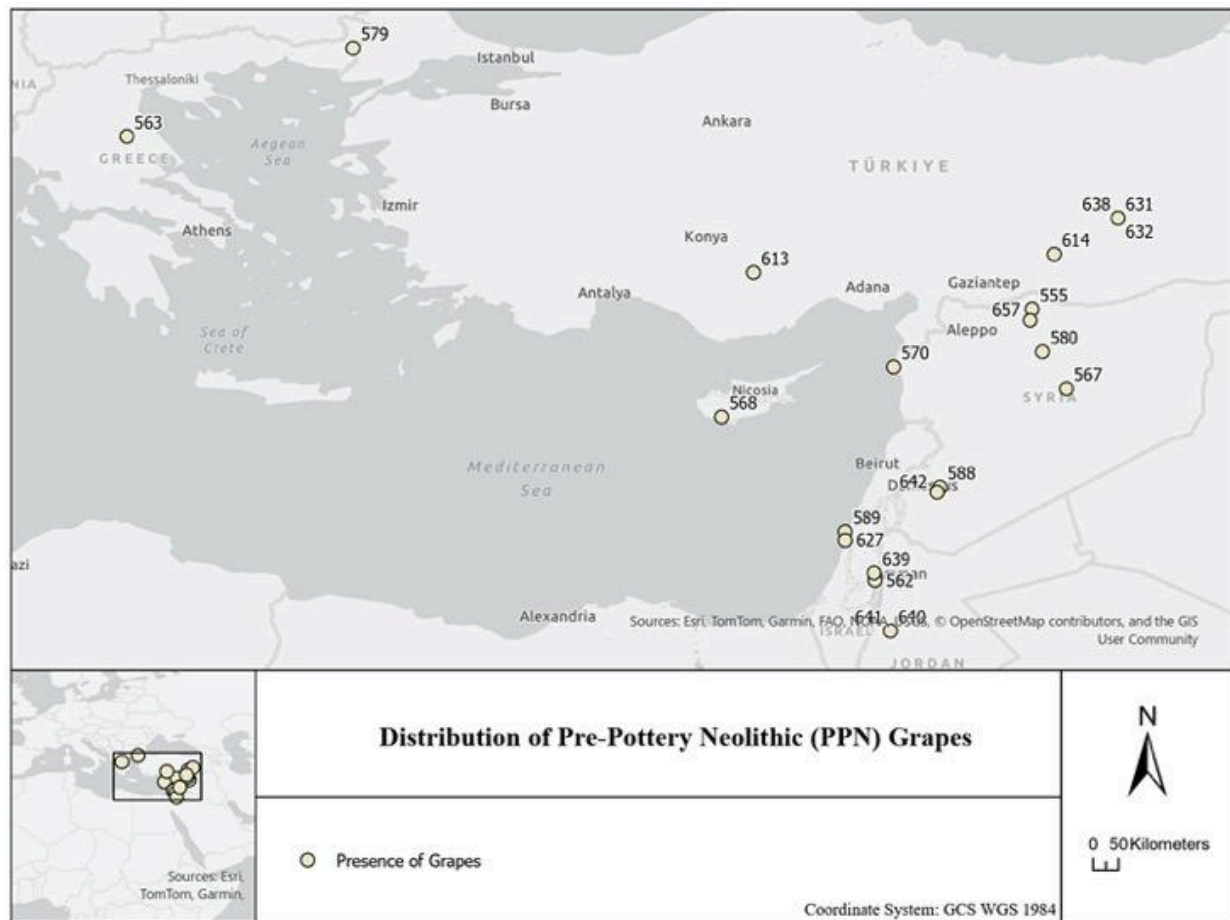
	PPN	Neo	Chal	EBA	MBA	LBA	IA
Greece	2	31	3	12	14	23	13
Crete	-	2	-	2	4	9	-
Cyprus	1	9	9	6	15	9	4
Turkey	5	9	8	40	20	23	9

Lebanon	-	2	-	10	6	6	7
Syria	7	10	1	35	29	21	28
Palestine	4	-	-	30	10	36	34
Jordan	2	2	2	22	10	10	8
Egypt	-	2	1	10	6	9	1
Georgia	-	-	-	1	1	-	3
Armenia	-	2	4	2	2	2	4
Total:	21	69	28	170	117	148	111

Table 6.2: Site-phases for the areas and time periods under study that have evidence of Vitis. Dashes indicate that no information is currently available or published. The total number of site-phases is shown in bold. The small increases and decreases are probably the result of preservation issues, site bias, etc.

Evidence of two grape pips dating as far back as the Pleistocene (c. 730,000–720,000 BP) was discovered at Gesher Benot Yaaqov, outside the natural distribution range of grapes (Wallace et al., 2018). This finding suggests that humans were already interested in grapes, likely for their taste or sugar content and were possibly consuming them. Additional examples from later periods, such as the Epipaleolithic (e.g., Nahal Oren, Jordan River Dureijat and Okuzini Cave), were also located outside the natural grape distribution area (Stevens and Fuller, 2019; Wallace et al., 2018; Martinoli, 2004). However, due to the low quality of the archaeobotanical data (scoring a 1), these examples were not included in the formal analysis. Nonetheless, it is important to acknowledge the potential presence of grapes at sites for consumption predating the Pre-Pottery Neolithic.

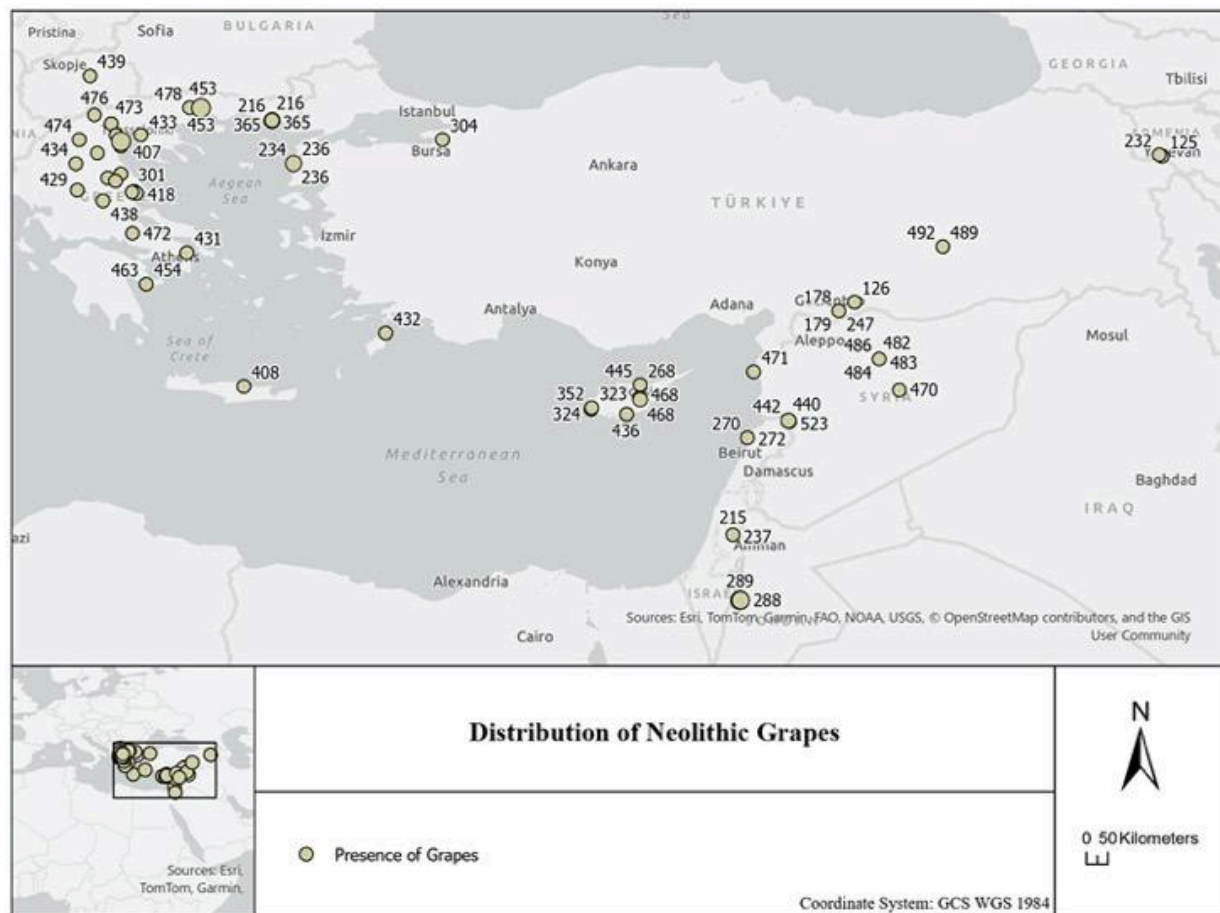
6.1.1 Pre-Pottery Neolithic Distribution



Map 6.1: Distribution of Pre-Pottery Neolithic *vitis* evidence.

Grapes were initially limited to the Mediterranean Levant (Jordan, Syria and Palestine) in the 10th and 9th millennia BCE, including regions outside their natural distribution, such as the southern Levant and part of Syria (Map 6.1). Early grape discoveries were concentrated in the Jordan Valley and the northern Fertile Crescent. By the 8th millennium BCE, grapes had spread more widely across the Levant, Turkey, Cyprus (where it is unclear if wild grapes were native) and northern Greece. Despite this expansion, sites in the southern Levant and parts of Syria, including El Kowm II and Abu Hureyra, remained outside the natural grape distribution area.

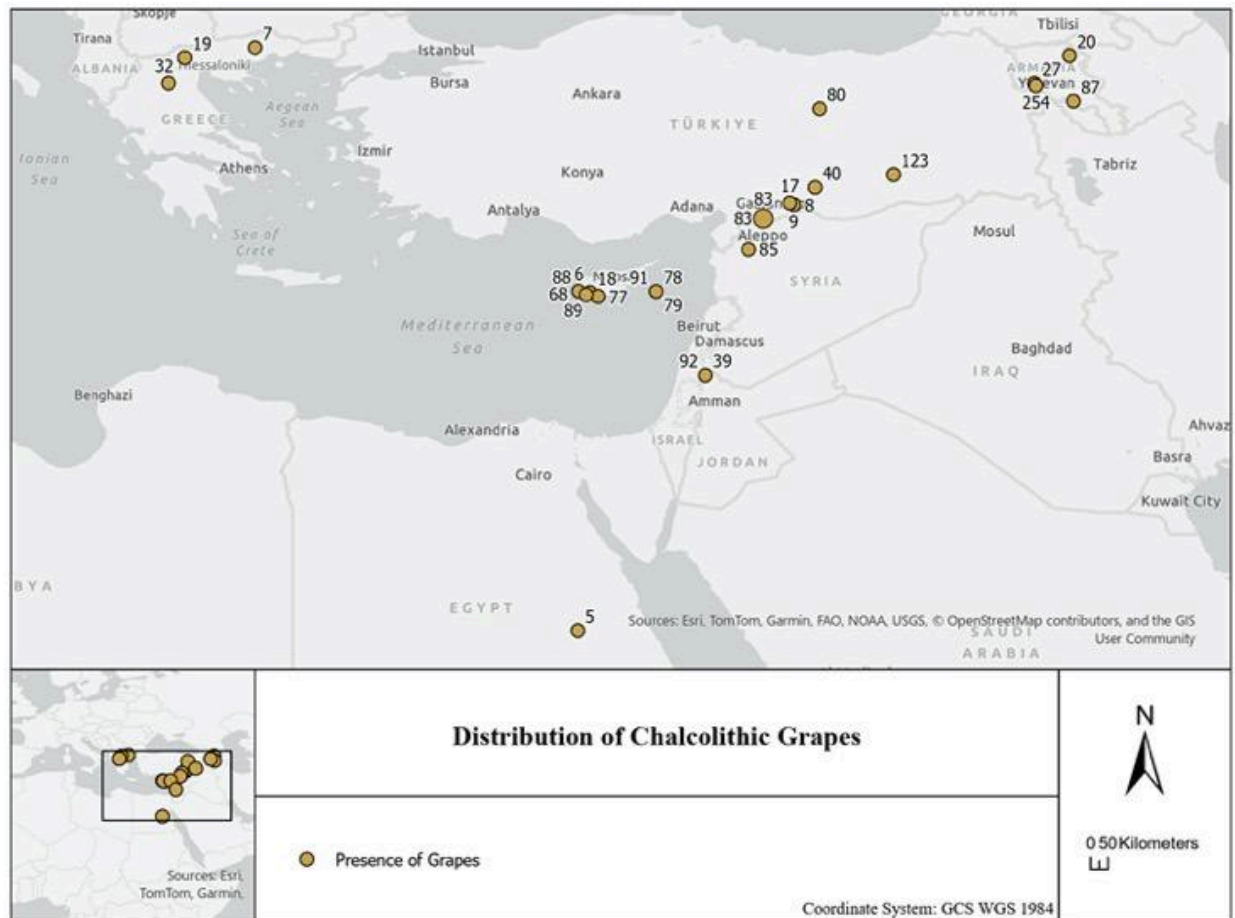
6.1.2 Neolithic Distribution



Map 6.2: Distribution of Neolithic vitis evidence.

By the Neolithic period, grape sites had expanded westward into the Aegean region, including Greece and Turkey. The number of site-phases more than doubled, with the most significant increases occurring in Greece and Cyprus. This period also saw the first archaeobotanical evidence of grapes on Crete, Armenia and Egypt, while site-phases in Palestine disappeared. The Neolithic map (Map 6.2) shows a much denser clustering of grape sites, particularly around the Aegean Sea, western Turkey and Cyprus. This suggests not only an increase in grape cultivation but also the intensification of agricultural practices and domestication.

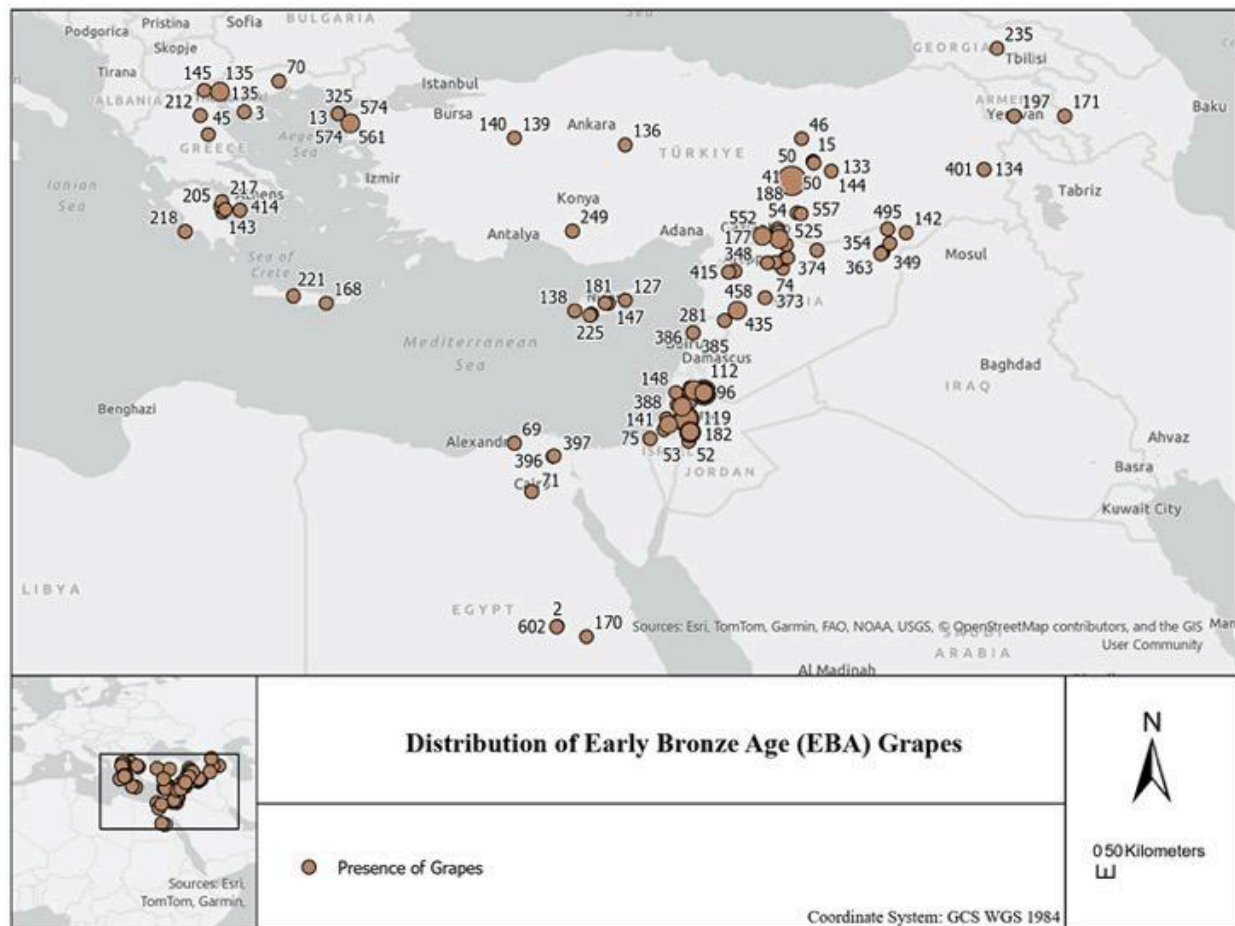
6.1.3 Chalcolithic Distribution



Map 6.3: Distribution of Chalcolithic *vitis* evidence.

The transition from the Neolithic to the Chalcolithic period reveals significant shifts, more than half, in the geographical range, density and clustering of grape site-phases (Map 6.3). The decrease in site-phases is likely due to the shorter time frame of the Chalcolithic rather than an actual decline in grape exploitation. Site-phases decreased in nearly every region, except for Jordan and Cyprus, which remained stable and Armenia, which saw a slight increase. Some areas, such as the southern Levant, experienced a complete disappearance of grape sites.

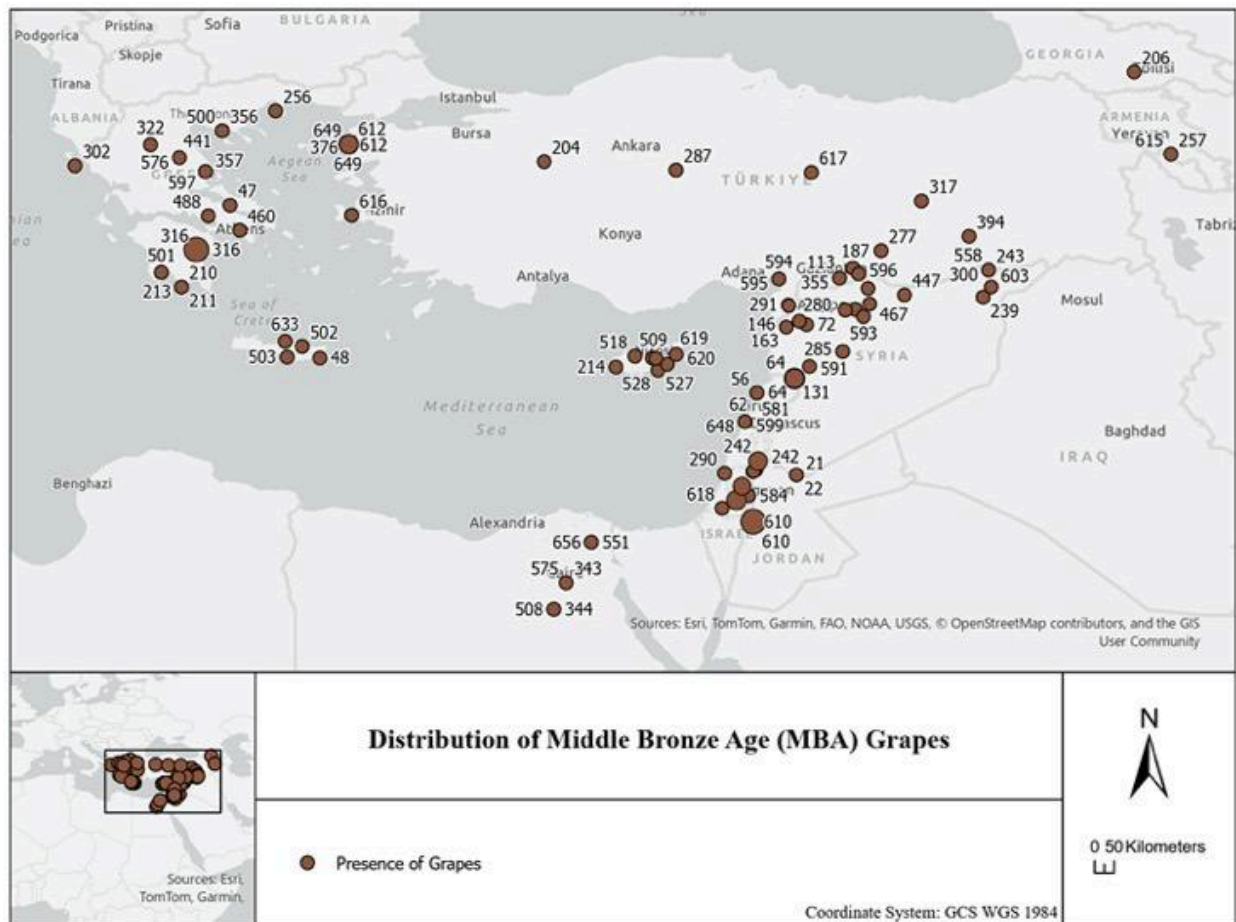
6.1.4 Early Bronze Age Distribution



Map 6.4: Distribution of Early Bronze Age *vitis* evidence.

The transition from the Chalcolithic to the Early Bronze Age marks a sixfold increase in grape site-phases (Map 6.4). This expansion was likely driven by the growth of trade networks, early city-states and agricultural intensification (Murray, 2023). Turkey, Syria, Palestine and Jordan saw the most significant increases, while Greece, Lebanon and Egypt experienced a more moderate rise. In contrast, Cyprus and Armenia saw slight declines and grapes appeared for the first time in Georgia. The Aegean, particularly Greece and western Turkey, saw a major increase in site density, forming dense clusters, while the Levant rebounded after its Chalcolithic decline, especially in Syria, Jordan and Palestine. Armenia and Georgia displayed more concentrated clusters, reinforcing their role in early wine production.

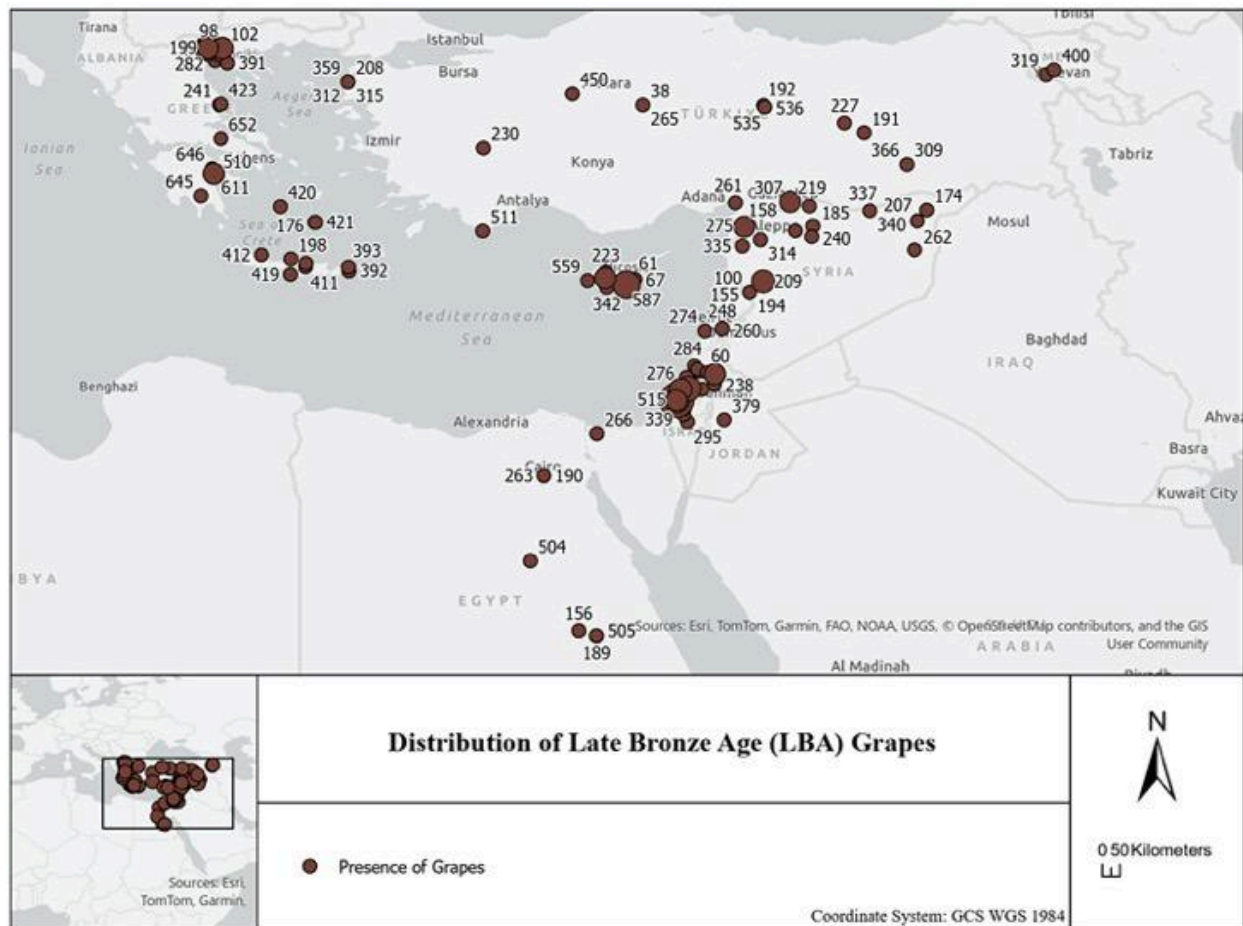
6.1.5 Middle Bronze Age Distribution



Map 6.5: Distribution of Middle Bronze Age *vitis* evidence.

Grape presence remained widespread, with sites recorded in the Aegean, Anatolia, the Levant, the Caucasus and Egypt but there was a significant decrease in site-phases from the EBA to the MBA (Map 6.5). While Greece, Crete and Cyprus saw a slight increase in site-phases, there was a dramatic decline in Jordan, Palestine and Turkey. Despite this decrease, the Levant and Cyprus exhibited dense clustering of grape site-phases, indicating continued regional importance. Over 40 wine vessels, confirmed through chemical analysis to contain different vintages and additives, were found *in situ* in at Tel Kabri (c. 1900 BCE) in Palestine. This discovery suggests that wine was produced in significant quantities and likely stored for wine for trade or for local consumption. However, no wine presses were found at or surrounding the site (Yasur-Landau et al., 2018; Koh et al., 2014). Ancient documents indicate that the wine stored at Tel Kabri was valued at approximately 1,900 silver shekels, enough to purchase three merchant ships, highlighting its status as a luxury item (Koh et al., 2014).

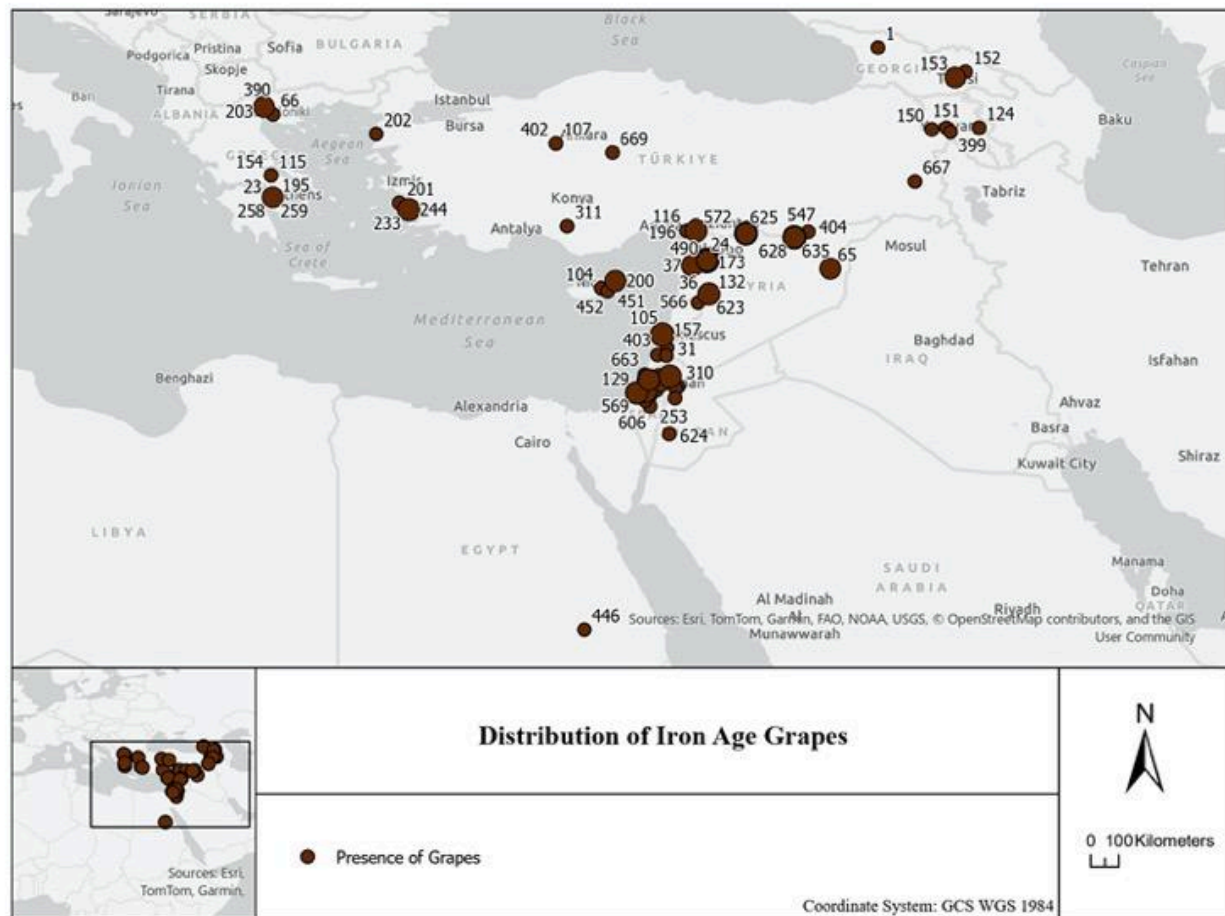
6.1.6 Late Bronze Age Distribution



Map 6.6: Distribution of Late Bronze Age *vitis* evidence.

During the LBA, the number of site-phases increased to a total of 148 (Map 6.6). The most significant increases occurred in Greece and Palestine, while Crete, Turkey and Egypt saw moderate growth. In contrast, Cyprus and Syria experienced a moderate decline, while Jordan and Armenia remained unchanged. These site-phases are mostly domesticated grapes. The presence of grapes and wine (and olives and olive oil) among the cargo of the Uluburun shipwreck (Haldane, 1991) signals the sophistication of the LBA trade networks and highlights the cultural and economic importance of wine. Not only was wine consumed locally but it also functioned as a tradable luxury item.

6.1.7 Iron Age Distribution



Map 6.7: Distribution of Iron Age *vitis* evidence.

The transition to the Iron Age marks a decline in overall site-phases to 111 recorded sites (Map 6.7). There was a significant decrease in site-phases in Greece, Turkey and Egypt, while Cyprus and Jordan experienced a more marginal decline. Notably, grape evidence reappeared in Georgia, whereas Crete saw a complete disappearance of site-phases. In contrast, Armenia, Lebanon and Syria experienced an increase, suggesting a shift in grape cultivation and trade patterns. The Levant cluster is the largest, with the increase in Lebanese site-phases potentially corresponding to the rise of the Phoenicians and their wine industry. However, despite this expected growth, grape evidence remains limited, likely due to the lack of well-documented archaeobotanical research in Lebanon.

6.1.8 Evidence of Consumption and Processing

Three distinct types of grape exploitation likely occurred: consumption as fresh table fruit, use as raisins and production of liquids (e.g., wine and vinegar). Table fruit consumption would likely have been the most immediate and accessible form of use, requiring no processing. Raisin production involves drying grapes for preservation, allowing for long-term storage and transport, making them an important food source for both local communities and trade networks. Liquid production, including wine and vinegar, required fermentation and more complex processing, indicating a deeper understanding of grape properties, their potential applications and processing equipment. These three forms of exploitation highlight the versatility of grapes in early human societies.

6.1.8.1 Table Fruit

It is likely that grapes were first exploited as table fruits (evidence as early as the PPN) because they did not need to be cured or processed before consumption, unlike other fruits like olives. Table 6.3 provides evidence of likely consumption of tree fruits as table fruits. The idea that the simplest method/way of doing things will be repeated through time and space is very much possible here. Evidence of grape consumption as table fruits is rare since the pips would have been consumed and the other parts of the vine would have either been dumped into a refuse pit or burned as crude kindling. Therefore, any small amount of pips found in domestic context or refuse pits could indicate consumption, as seen by sites as early as the PPN. Ethnographic data from Armenia suggests that it was a common practice (Garabedian, 2020, personal communication)(Chapter 3). It is somewhat possible that this occurred in the ancient past as well.

Some of the evidence contexts have been documented at PPN sites, including refuse pits and unspecified domestic settings (Wallace et al., 2018; Zeist and Roller, 2003; de Moulins, 1997; Kislev et al., 2004) but have limited numbers or are simply noted as being present. The presence of grape remains in limited quantities, typically only a few within a single stratigraphic layer, indicates that grapes were more likely consumed as fresh fruit rather than used for any other process. When grapes are eaten, seeds and small remnants might be discarded, aligning with the small-scale finds in refuse pits and domestic contexts. In contrast, evidence of winemaking

would typically include a higher density of grape remains, including seeds, skins and dregs, as the winemaking process generates significant waste (Megaloudi, 2006; Valamoti et al., 2007).

Period	Sites
PPN	See above
Neo	Arjoune, Dhali Agridhi, Kumtepe, Makri, Makriyalos and Wadi Fidan
Chal	Areni-1 cave, Hacinebi Tepe, Oylum Hoyuk and Tell esh-Shuna
EBA	Arsilantepe, Beth Shean, Hirbet Ez-Zeraqon, Jericho, Kastanas, Leilan, Monastiraki, Myrtos, Ras an-Numayra, Tel Beth Yerah, Tel Yarmouth, Tell Abu en Ni'aj, Tell el-Fara'in, Tell esh-Shuna, Tell Ibrahim Awad, Tell Jerbalus Tahtani, Tell Mishrifeh, Tilbeshar, Troia and Tsoungiza
MBA	Ebla, Kenan Tepe, Kinet Hoyuk, Lerna, Manahat, Shiloh, Tell Abu en Ni'aj, Tell el-Hayyat, Tell Fadous-Kfarabida, Tell Mishrifeh, Tell Mozan, Tell Nebi Mend, Tell Tayinat, Troia, Umm el-Marra and Zahrat Adh-Dhra
LBA	Ashod, Assiros Toumba, Ayios Dhemetrios, Hala Sultan Tekke, Jaffa, Kastanas, Tel Aphek, Tell Abu Al-Kharaz, Tell Atchana, Tell Mishrifeh, Tell Nebi Mend (Kadesh), Tilbeshar, Tiryns
IA	Ain Dara, Ashkelon, Deir'Alla, Dighomi, Kastanas, Kinet Hoyuk, Miletos, Salamis, Shiloh, Tell Afis, Tell el-Burak, Tell Mishrifeh, Tell Qarqur, Tell es-Safi (Gath), Tell Mishrifeh, Tell Qarqur, Tell Schech Hamad and Tell Shioukh Faouquani

Table 6.3: Site-phases with evidence of table fruit-consumption and/or processing based solely on *Vitis* archaeobotanical data.

6.1.8.2 Raisins

Raisins or dried grapes, were highly marketable commodities, as their extended shelf life made them easier to store and trade compared to fresh table grapes. Additionally, they provided a higher caloric return and could be used to enhance the sweetness of various foods and beverages, including wine (Unwin, 1991; Margaritis and Jones, 2006). Despite their potential importance, archaeobotanical evidence of raisins is limited, likely because they were either consumed or traded away rather than discarded.

Cartwright (2015) and Margaritis and Jones (2006) have proposed a method for distinguishing raisins from charred grapes based on morphological differences. They suggest that a whole grape, when exposed to heat, develops an "exploded" appearance on both its exterior and interior, whereas a raisin, having already undergone dehydration, would appear "re-inflated"

when subjected to similar conditions (Cartwright, 2015, p. 346). This distinction is used as a criteria to establish raisins based on the shapes and textures used to describe *Vitis* within the literature. To further explore their preservation potential, this author conducted an experiment artificially charring both sun-dried raisins (dried for over two weeks) and fresh grapes at a relatively low temperature (around 250°C). The results revealed distinct differences in how each type of fruit responded to heat. The raisins exhibited significant puffing, resembling a "re-inflation" effect, while the fresh grapes reacted differently, rapidly breaking down into water and carbon dioxide. As the heat caused the water within the berries to evaporate, the grape skins split and pulled apart, producing the characteristic "exploded" appearance described by Cartwright (2015). Given their delicate structure, it is unlikely that raisins would have survived well in the archaeological record or remained intact during excavation. This fragility may explain their infrequent appearance in archaeological contexts, though it remains uncertain whether their scarcity reflects an actual absence in antiquity or simply poor preservation.

The transformation of grapes into raisins, a value-added product, may have begun as early as the Pre-Pottery Neolithic, as the process required minimal time (both in preparation and waiting for the final product) and little investment in specialised equipment (see Chapter 4) (Table 6.4). The discovery of charred grape pips in the grill house of Çayönü (PPN) suggests that grapes may have been unintentionally burnt while being dried or deliberately heated to form raisins as a means of preserving the fruit from spoilage (Wallace et al., 2018; Zeist and Roller, 2003). If the latter is true, this could represent the earliest known instance of raisin production. However, no morphological studies have yet been conducted to determine whether there are distinguishing characteristics between the charred pips of raisins and those of fresh table grapes, leaving this hypothesis unconfirmed.

By the EBA, there is clear evidence of raisins appearing in two primary contexts: funerary offerings and food processing. At Saqqara, within the Pyramid of Djoser (c. 2600–2500 BCE), desiccated grape pips and skins were identified as raisins based on their distinctive reinflated appearance (Cartwright, 2003; Zohary et al., 2015; Zohary and Hopf, 1993). Their placement in a funerary setting suggests that raisins were intended for consumption in the afterlife, necessitating their preservation for the deceased's journey beyond death. Beyond their ritual significance, raisins were also integrated into food processing. At Tel Taanach (c. 3200–2005

BCE) and Tel Yarmouth (c. 2800–2200 BCE), raisins from grapes were discovered in the same loci as processing installations, suggesting their possible use as sweeteners for wine or as part of the early development of sweetened wine (Salevart, 2008; Liphshitz, 1989). The starburst-like shape of these preserved grapes further supports their identification as raisins, reinforcing their role in food production.

By the Middle Bronze Age, further evidence of raisin production appeared at Shiloh (c. 1700–1600 BCE), where 32 raisins were uncovered in Area F, Stratum 7 (Kislev, 1993; Liphshitz, 1993). Their reinflated appearance suggests they were preserved through drying rather than simple desiccation. Later, during the Iron Age phase at the same site, a significantly larger quantity of raisins, 269 raisins, 64 additional raisins and four raisin stalks, was found within two loci (335 and 1301) in Area C. These were associated with storage rooms filled with collared-rim pithoi, again showing signs of reinflation. The sheer volume of raisins recovered suggests an almost continuous production of dried grapes at the site, although no Late Bronze Age evidence has been found to date. Their presence in such quantities implies that raisins were being processed and stored, possibly to increase the sugar content of grapes, extend their shelf life or serve as additives for wine (Kislev, 1993; Liphshitz, 1993).

Further evidence of raisins in the LBA comes from the Egyptian tomb of Tutankhamun (14th century BCE), where whole dried grapes were found inside the burial chamber. The shape and texture of these fruits closely resemble modern raisins, supporting the interpretation that they were included as provisions for the afterlife (Germer, 1989; Hepper, 1990; De Vartavan, 1990). Similarly, at Ashdod, grape pips exhibiting a reinflated appearance, indicative of raisin formation, were found in association with storage jars (Melamed, 2003). This suggests that raisins were either being stored for later consumption or possibly added to liquids to enhance their sweetness, both plausible interpretations of their function. Another LBA site, Tell Schech Hamad, provides evidence of a different approach to raisin production. More than 50 grapes were discovered in a kitchen oven, suggesting that they may have been intentionally heated in an attempt to speed up the drying process (Frey et al., 1991; van Zeist, 2001). This indicates that methods of grape preservation were evolving, with people actively experimenting with techniques to extend the fruit's shelf life and adapt it for various uses.

Period	Sites and Sources
PPN	Çayönü (Wallace et al., 2018; Zeist and Roller, 2003)
Neo	N/A
Chal	N/A
EBA	Saqqara (Zohary et al., 2015; Zohary and Hopf, 1993) Tel Yarmouth (Salavert, 2008) Tel Taanach (Liphschitz, 1989)
MBA	Shiloh (Kislev, 1993; Liphschitz, 1993)
LBA	Tomb of Tutankhamun (Germer, 1989; Hepper, 1990) Ashdod (Melamed, 2013) Tell Schech Hamad (Frey et al. ,1991; van Zeist, 2001)
IA	Shiloh (Kislev, 1993; Liphschitz, 1993)

Table 6.4: Evidence of raisin production or consumption.

6.1.8.3 Liquid Transformation

Since liquid value-added products like wine and vinegar involve more time and investment in equipment, this could explain why the evidence for such products were found later in the archaeological record than table fruit consumption evidence and raisins. Wine is likely to have been used for consumption and trade purposes, while vinegar would have likely been used for keeping fruits for longer periods of time (e.g., pickling food) and preserving bodies during funerals.

Plausible evidence of liquid value-added products first appears as early as the Pre-Pottery Neolithic (PPN), though the evidence remains circumstantial since it lacks any associated processing equipment. At the site of Jericho (c. 8900–7000 BCE), whole and fragmented grape pips were discovered in a refuse pit, which may suggest the consumption of table grapes or crude treading. The random distribution of pressure-induced breaks and fragments hints at the possibility that grapes were processed using sacks or non-specialised equipment (Bar-Yosef, 1986; Hopf, 1983; Western, 1971). Further supporting this possibility, evidence from Atlit-Yam (c. 8069–7092 BCE) includes grape pips with short breaks (Kislev et al., 2004; Wallace et al., 2018). This pattern could indicate light treading, as such a process typically breaks pips without

crushing them completely. In contrast, pips consumed directly would not typically appear in the archaeological record, as they would either be fully ingested or discarded in an unrecognisable form. The presence of numerous broken pips suggests that their fragmentation was not simply due to preservation issues (weighted soil breaking them) but rather the result of an intentional processing activity. More likely examples of value-added processing appear in Table 6.5.

Period	Evidence
Neo	• Dikili Tash - >2000 burnt grape plant parts, associated with storage jars and positive chemical residue for wine making (Valamoti, 2004; Valamoti et al., 2007; Garnier and Valamoti, 2016) • Tell el-Fara'in - Evidence of <i>Vitis vinifera</i>, found within a storage jar imported from Palestine which showed traces of tartaric acid (possibly wine) within the jar (Thanheiser, 1997) • Abu Hureyra - Evidence of <i>Vitis sylvestris</i>, on a clay surface, possibly used for some processing as a non-specialised treading/crushing floor (Wallace et al. 2018; de Moulins, 1997)
Chal	• Areni-1 - grape pressing and simple installations (Smith et al. 2014; Hovhannisyann et al., 2015)
EBA	• Tel Yarmouth - grape pressing, paved floors, <i>pithoi</i>, basins, grinding stone and mortars (Salavert, 2008) • Myrtos - grape pressing in a <i>pithos</i> found near <i>lekanai</i> (Renfrew, 1972) • Tell Ibrahim Awad - grape pressings found within a storage jars imported from Palestine which also reportedly showed traces of tartaric acid (possible wine)(Thanheiser, 1992; McGovern, 1997) • Monastraki - grape pressing in a <i>pithos</i> (Hamilakis, 1996; Sarpaki, 1992 Pagnoux et al., 2021) • Tel Taanach - grape pressing found near a rectangular treading floor with a rectangular collecting vat and two plastered basins (Kislev et al., 2009; Liphshitz, 1989; Simchoni and Kislev, 2006, 2012)
MBA	• Phaistos - grape pressing found in a <i>pithos</i> (Hamilakis, 1996)
LBA	• Ashdod - grape pressing (1,9541 plant parts) found in a refuse pit near an installation associated with wine production, ceramic vessels and flint implements (Melamed, 2013) • Tel Aphek - grape pressing (460 plant parts) found in proximity to a rectangular treating floor with a round collecting vat (Liphshitz, 1989; Frankel, 1999)

IA	• Shiloh - grape pressing found in the same context as storage rooms filled with <i>pithoi</i> of the collared rim-type (Kislev, 1993; Liphshitz, 1993) • Tell el-Burak - grape pressing found within the same context as a simple wine installation, large treading floor and collection vat found outside the settlement (Nigro and Spagnoli, 2018; Orendi and Deckers, 2018)
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Table 6.5: Site-phases within the area and time periods under study that have both archaeobotanical evidence and processing equipment, with confirmed value-added products based on the criteria mentioned in the text.

Evidence of liquid value-added products associated with processing equipment first appears in the Neolithic and continues through the Iron Age (Table 6.4), with findings from Greece, Armenia, Crete, Palestine and Syria. The earliest indication of such production comes from Dikili Tash (c. 5000–4700 BCE), where over 2,000 burnt pressed grape pips and other plant remains were found alongside chemical evidence of wine in a storage jar (Valamoti, 2004; Valamoti et al., 2007; Garnier and Valamoti, 2016).

However, the earliest use of specialised winemaking equipment dates to the Chalcolithic period at Areni-1 Cave (c. 4300–3800 BCE), where grape pips, skins and pedicles were found alongside a treading floor, collection vats and fermentation vessels (Hovhannisyan et al., 2015)(Smith et al., 2014). Notably, Areni-1 Cave lies within the natural grape distribution range and likely processed grapes in a purpose-built facility. The establishment of a structured value-added industry, evidenced by increasingly specialised and large-scale processing equipment, may have contributed to the growth of grapes in Armenia, which occurs in the Early Bronze Age (EBA) according to archaeobotanical data. By the Late Bronze Age and Iron Age, large-scale processing equipment was found along with grape remains, most notably the Phoenician winepress of Tell el-Burak which consists of a larger treading floor, collection vat and some plaster found outside the settlement's walls (see Chapter 8 for more details).

6.1.9 Brief Conclusion

The archaeological record demonstrates a long history of grape exploitation, beginning with their early appearance in the Pre-Pottery Neolithic and evolving into large-scale value-added processing by the Iron Age. Evidence of grapes in the archaeological record dates back to the Pre-Pottery Neolithic (PPN), with findings from Greece, Cyprus, Turkey, Syria, Palestine and Jordan. Additional evidence from the Neolithic period has been identified in Crete, Lebanon, Egypt and Armenia (Table 6.6). The earliest evidence suggests that grapes were initially

consumed as fresh table fruit, likely due to their immediate availability and natural sweetness. By the Neolithic period, grape exploitation had expanded geographically, with increasing evidence of their presence in areas beyond their natural distribution, suggesting early human transportation and management of the species. The earliest clear evidence of grape consumption appears in the Neolithic, specifically in Syria, Turkey, Cyprus, Greece and Jordan, as well as in later periods, including the Chalcolithic in Armenia and the Early Bronze Age (EBA) in Palestine, Crete and Egypt.

Sites	Confirmed Presence (BCE)	Site Evidence/Sources
Greece	PPN - 8700-5400 BCE	Argissa-Magoula (Kroll, 1983)
Crete	Neo - 6500-5800	Knossos (Sarpaki, 1992)
Cyprus	PPN - 7800-7200 BCE	Prastio Mesorotsos (Fuller and Stevens, 2019)
Turkey	PPN - 8500-8300 BCE	Nevali Cori (Wallace et al., 2018; Pasternak, 1998)
Lebanon	NEO - 5200-4000 BCE	Tell Fadous-Kfarabida (Behre, 1970)
Syria	PPN - 9800-6500 BCE	Djade (ADEMNES)
Palestine	PPN - 9653-8636 BCE	Netiv Hagdud (Wallace et al., 2018)
Jordan	PPN - 9150-8350 BCE	El-Hemmeh (White and Makarewicz, 2011)
Egypt	NEO - 5200-3200 BCE	Tell el-Fara'in (Thanheiser, 1997)
Armenia	NEO - 5970-5470 BCE	Aknashen (Hovsepyan and Willcox, 2008)

Table 6.6: Site-phases with the first evidence of vitis based on archaeobotanical data found to date.

The transition from the Chalcolithic to the Early Bronze Age marks a significant shift in grape use, with a sixfold increase in site-phases indicating the widespread adoption of grapes. This period also saw the first clear evidence of value-added processing, including the production of raisins and liquid products such as wine. By the Middle and Late Bronze Ages, evidence suggests that grapes were fully integrated into agricultural economies, with large-scale production and trade networks. The presence of pithoi, fermentation vats and pressing

installations in various regions, including the Levant, Greece, Crete and Armenia, highlights the technological advancements in grape processing.

The production of raisins appears to have developed early, with possible evidence from the PPN (in Turkey), though archaeological confirmation remains limited due to preservation challenges. By the EBA in Egypt and Palestine, raisins were being more established, appearing in both funerary and processing contexts. Their extended shelf life made them valuable for storage, trade and dietary supplementation, as evidenced by their presence in tombs such as that of Tutankhamun and at processing sites in the Levant (e.g., Syria and Palestine).

Liquid value-added products, including wine and vinegar, required more specialised processing equipment and appear later in the archaeological record. The earliest evidence of grape treading, likely a precursor to winemaking, emerges in the Neolithic in Greece and Syria, where chemical residues indicate fermentation. However, it is not until the Chalcolithic in Armenia, that specialised installations become evident. By the EBA, wine production is attested in Palestine, Crete and Greece and the Iron Age in Lebanon.

6.2 Olea oleaster and Olea europaea

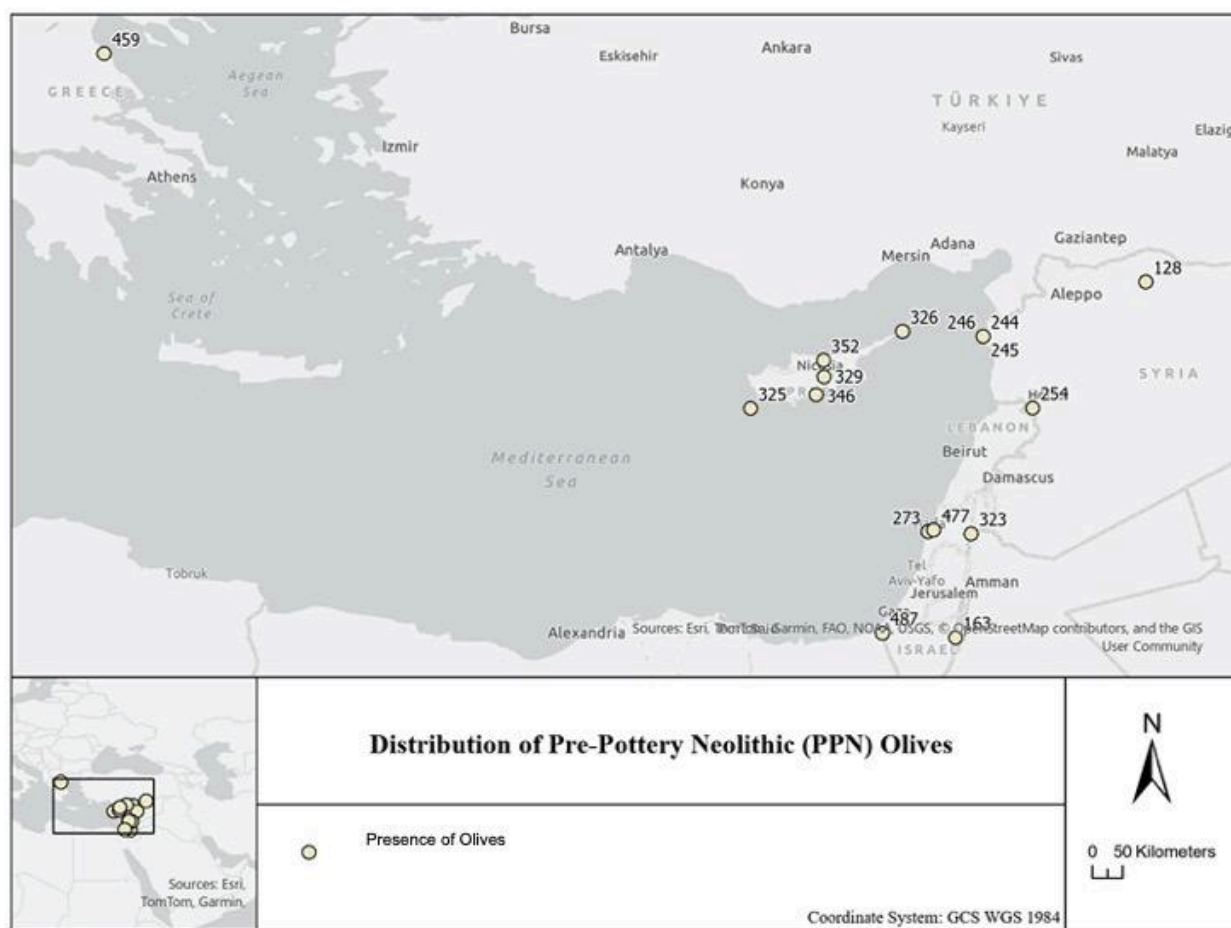
Evidence of both *Olea oleaster* and *Olea europaea* was found in 508 site-phases from across nine regions ([Appendix 5](#)) (Table 6.7). As discussed in Chapter 3, both wild and domesticated olives could yield similar quantities and quality with comparable ease, regardless of their origin. For this reason, all olive species are treated collectively in the analysis, without distinguishing between wild and domesticated forms. Many key sources refer simply to *Olea europaea* and do not specify whether the olives were wild or domesticated, unless the study specifically examines morphological changes.

	PPN	Neo	Chal	EBA	MBA	LBA	IA
Greece	1	25	8	13	8	27	23
Crete	-	1	2	15	19	21	7
Cyprus	5	6	4	11	8	10	2
Turkey	-	1	1	3	3	5	3
Lebanon	-	1	1	6	5	3	2
Syria	5	-	2	19	10	6	5

Palestine	5	4	17	53	17	35	29
Jordan	-	3	1	16	7	6	3
Egypt	-	-	-	-	2	8	1
Total	16	41	36	139	79	121	76

Table 6.7: Site-phases for the areas and time periods under study that have evidence of *Olea*. Dashes indicate that no information is currently available or published. The total number of site-phases is shown in bold. The small increases and decreases are probably the result of preservation issues, site bias, etc.

6.2.1 Pre Pottery Neolithic Distribution

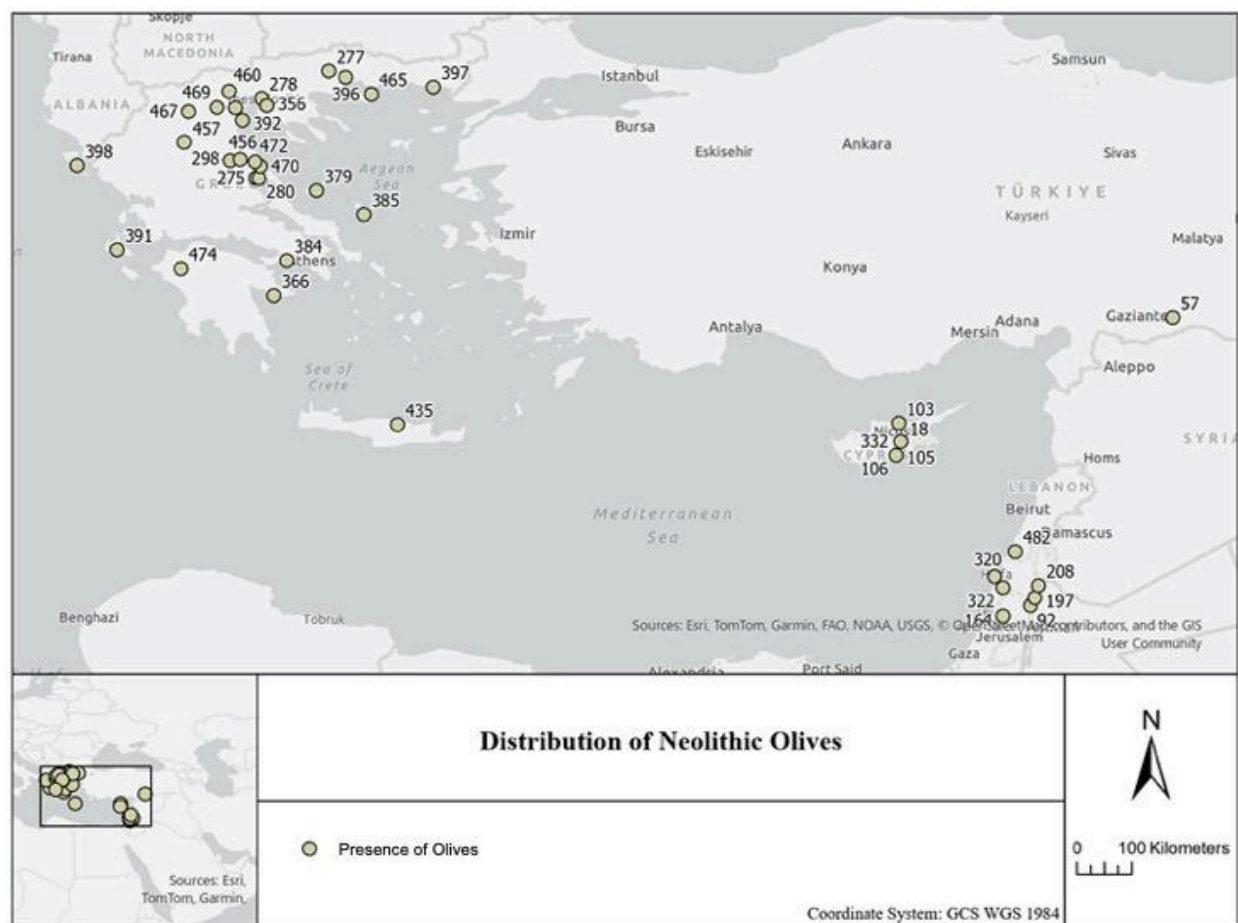


Map 6.8: Distribution of Pre-Pottery Neolithic *Olea* evidence.

Remains of *Olea*, including both *Olea oleaster* and *Olea europaea*, have been identified at multiple site-phases across Greece, Cyprus, Syria and Palestine during the Pre-Pottery Neolithic (Map 6.8) (Rodríguez Sousa et al., 2020). Although these olives are generally found in small numbers or as isolated specimens, their occurrence in both refuse pits and living areas indicates

that they were already being consumed. Consumption may have begun as soon as these olives first appear in the archaeological record.

6.2.3 Neolithic Distribution

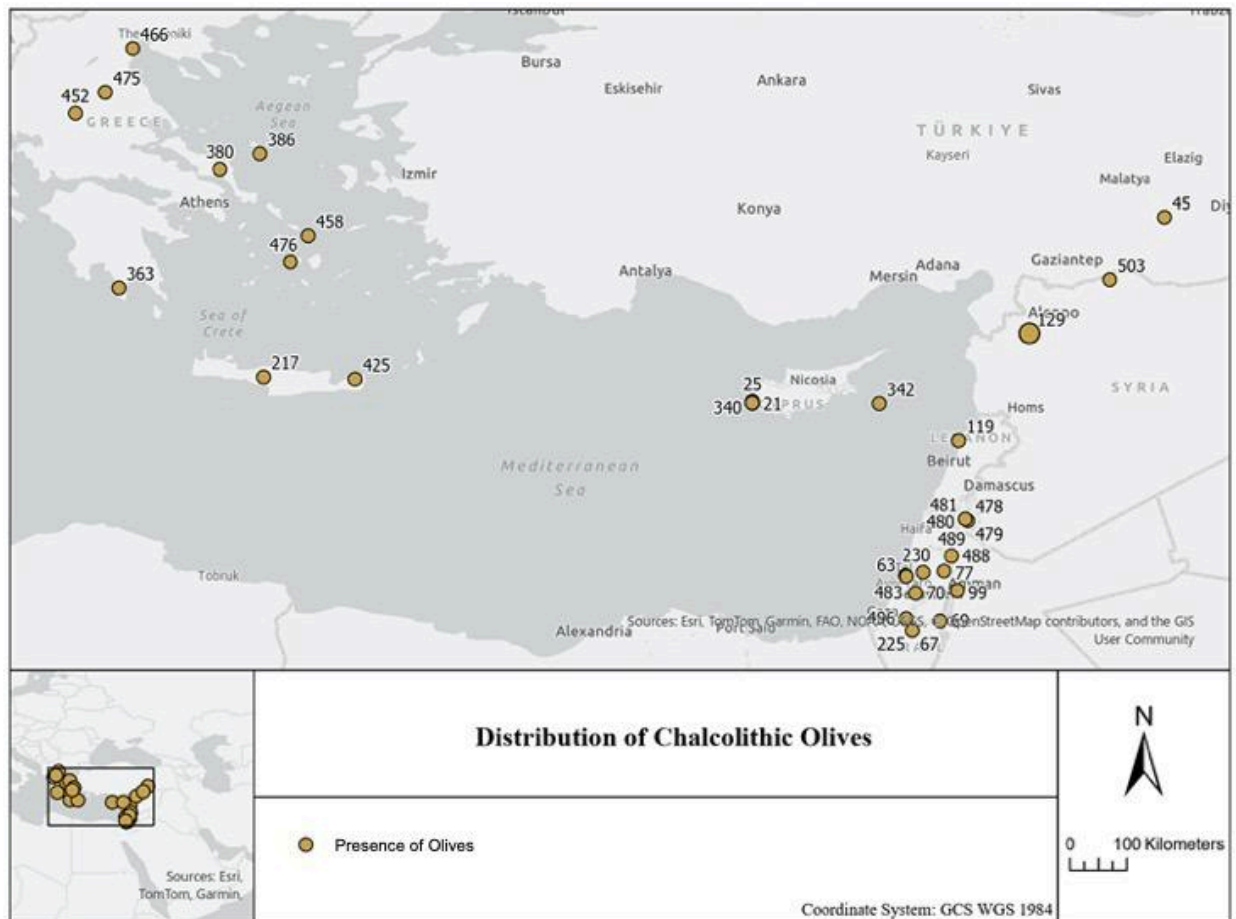


Map 6.9: Distribution of Neolithic *Olea* evidence.

There is a significant increase in site-phases from the PPN to the Neolithic, more than doubling in number (Map 6.9). This growth is largely driven by the 24 site-phases recorded in Greece. Notably, this period marks the first confirmed appearance of olive evidence in Crete, Turkey, Lebanon and Jordan, while Syrian site-phases do not appear as of yet. The evidence suggests that olives were either processed at designated industrial sites, such as the submerged site of Kfar Samir (see Section 6.2.8.2) or found in numerous domestic contexts. This indicates that by at least the 6th millennium BCE in Palestine, olive oil was being actively processed (see argument in section 6.2.8). Additionally, the widespread presence of olive remains in multiple domestic contexts in Greece suggests they were being gathered and consumed as early as the 7th

millennium BCE. Furthermore, their presence in caves may indicate processing activities (Sarris et al., 2002).

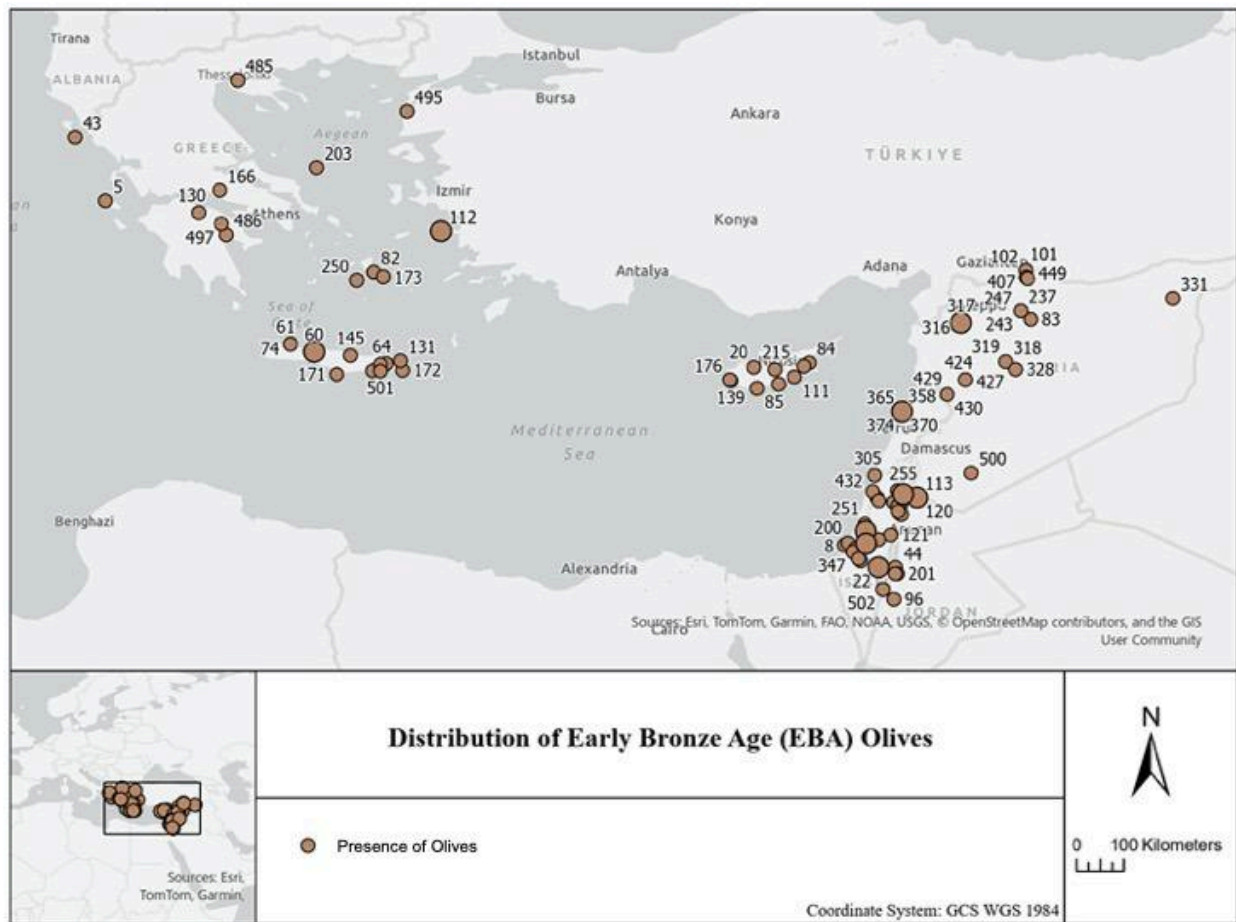
6.2.3 Chalcolithic Distribution



Map 6.10: Distribution of Chalcolithic *Olea* evidence.

During the Chalcolithic period, there is a slight decrease in the number of site-phases, likely due to the shorter duration of this period compared to the Neolithic (Map 6.10). However, regional variations are evident. In Greece, the number of site-phases declines significantly, whereas in Palestine, there is a drastic increase, with nearly half of all recorded site-phases originating from this region. One notable site from the Chalcolithic that contains more than 30 stones is Tel Afis; however, no contextual information is provided regarding their specific use or significance. In general, habitation sites and other domestic contexts continue to be the primary locations where stones are found, though their numbers typically remain low, with most sites containing fewer than 30 stones.

6.2.4 Early Bronze Age Distribution

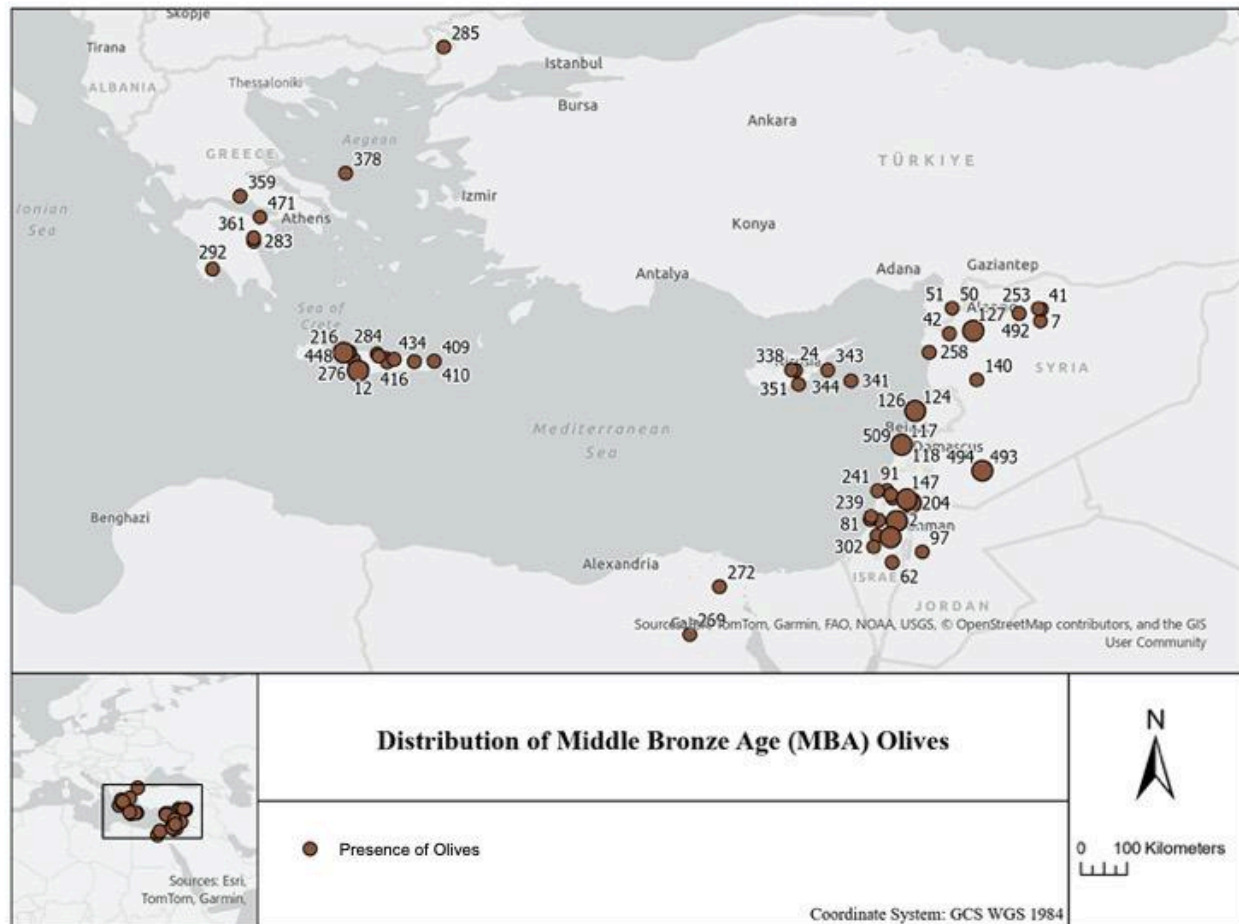


Map 6.11: Distribution of Early Bronze Age *Olea* Evidence.

There is a dramatic increase in the number of site-phases from the Chalcolithic period to the EBA (Map 6.11). The most significant contribution to this surge comes from site-phases in Palestine, which account for more than one-third of the total. Additionally, notable increases are observed in Jordan, Syria, Cyprus, Crete and Greece, further highlighting the widespread expansion of settlements during this transition. As is the case for most of the tree fruits under study, there is a substantial rise in site-phase numbers reported from the Chalcolithic to the EBA in most areas. The majority of the olives by the end of the EBA were found inside the settlements (e.g., oil processing facilities areas, habitats and kitchens) and tholos tombs. Over this period, there may have been more profound transformations due to the growing socio-economic complexity in the areas (Palumbo, 1991; Salavart, 2008). The expansion of specialised production has been associated with other economic developments and specialisations (such as the pottery industry). This could also correspond to the increase in

demand for olive products from Old Kingdom Egypt, since olives were not being cultivated in the region and the demand would have been met from the industries in other areas (Sabatini, 2019; Joffe, 2019).

6.2.5 Middle Bronze Age Distribution

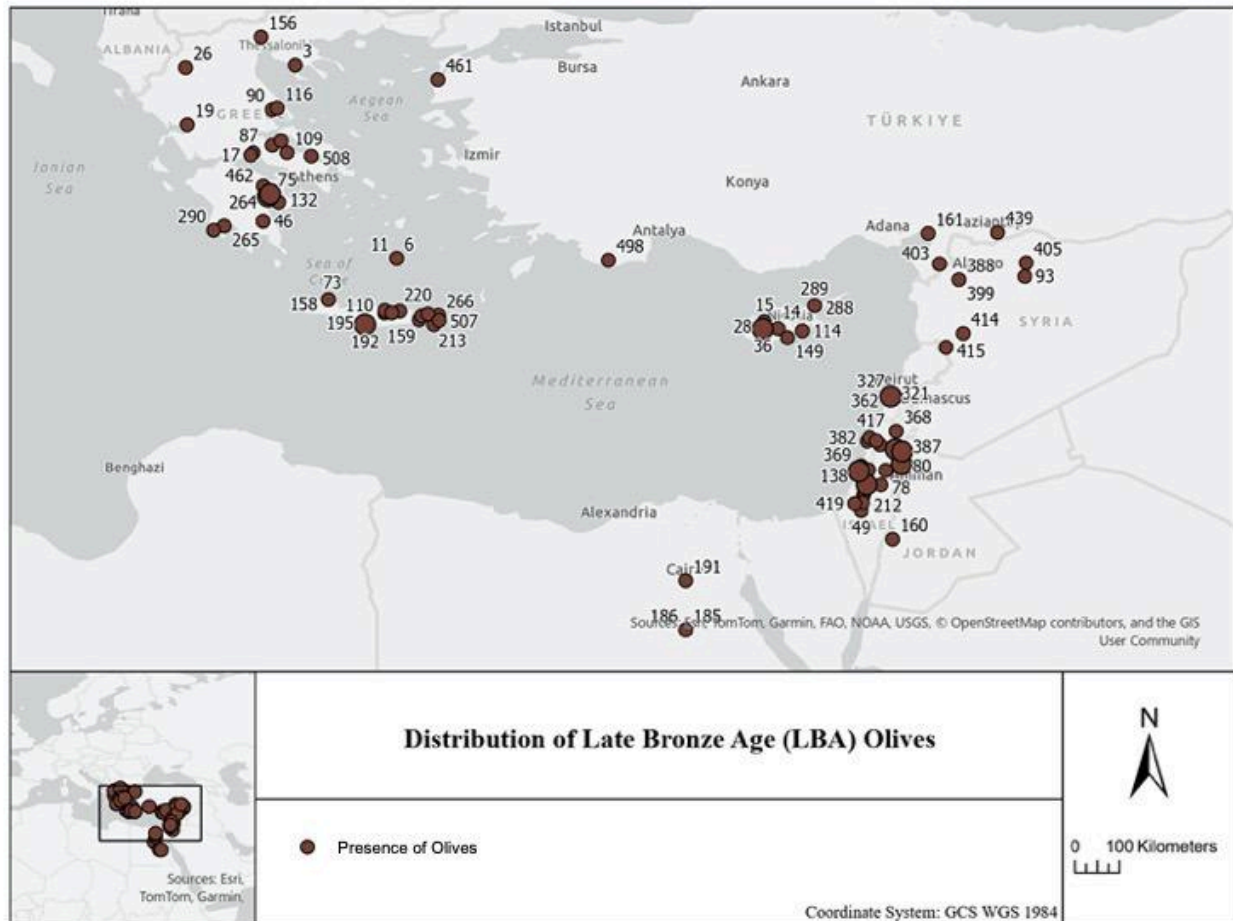


Map 6.12: Distribution of Middle Bronze Age *Olea* evidence.

There is a noticeable decline in the number of site-phases from the EBA to the MBA (Map 6.12). The distribution of MBA site-phases becomes more diffused. This reduction primarily reflects a decline in the number of MBA site-phases reporting olives across most regions, though some notable exceptions exist. The most significant decrease occurs in the southern Levant, where the previously larger cluster of site-phases shrinks considerably. In contrast, Crete stands out as the only region to show a clear increase in MBA site-phases with evidence of olives. Greece, Cyprus, Lebanon and Syria also experience declines, further reinforcing the broader regional trend. However, Egypt deviates from this pattern, as it records its first site-phase evidence for

olives during this period. Evidence of olives were found in all aspects of societal life, such as in different parts of the settlement (e.g., palace, kitchen, domestic contexts and roads) and in religious contexts (e.g., tombs).

6.2.6 Late Bronze Age Distribution

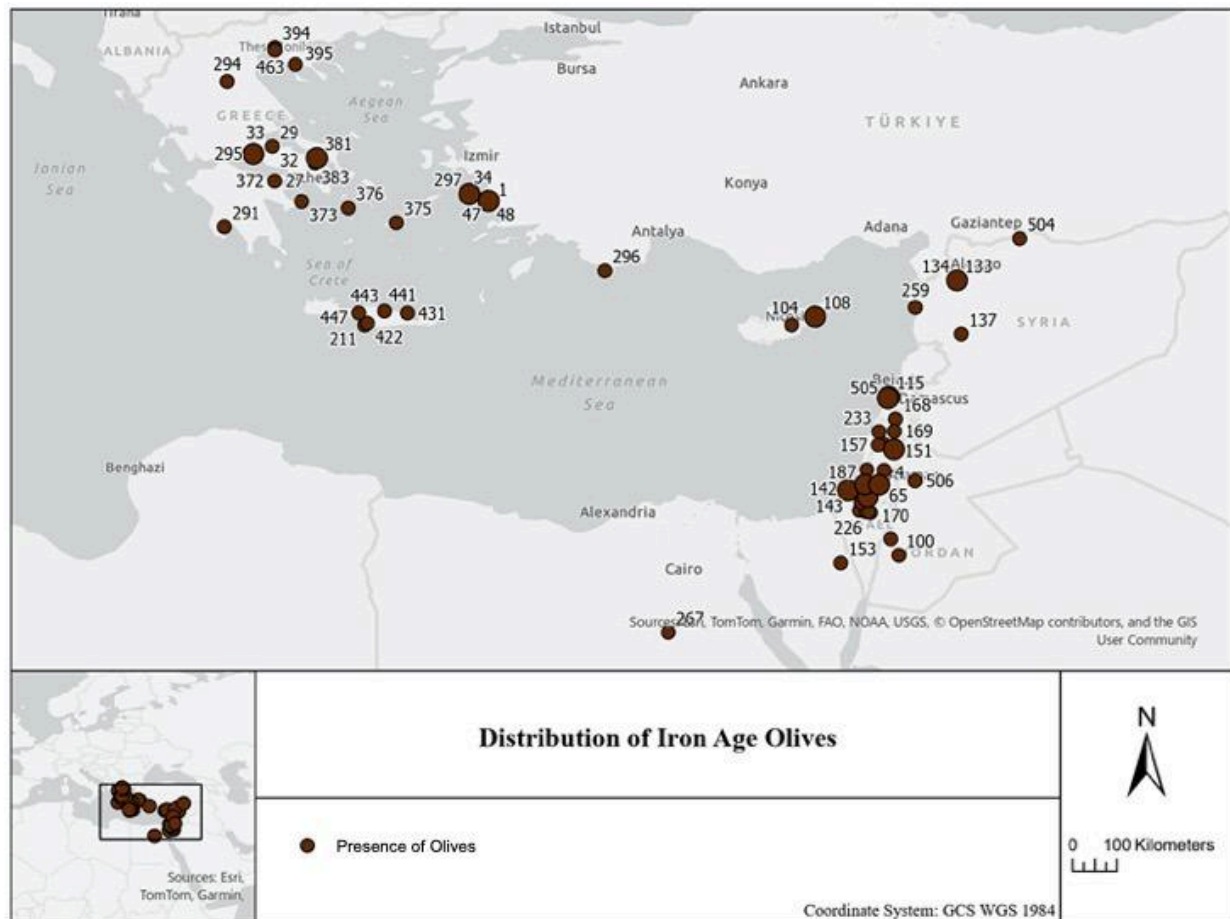


Map 6.13: Distribution of Late Bronze Age Olea evidence.

Overall, the total number of olive site-phases increases significantly from 79 to 121, reflecting a notable expansion in many regions (Map 6.13). This growth is particularly evident in Greece, Palestine and Egypt, where the number of site-phases rises substantially. More moderate increases are observed in Crete, Cyprus and Turkey. In contrast, slight declines are recorded in Lebanon, Syria and Jordan, indicating regional variability in olive presence. These shifts manifest in the form of new or expanding clusters, particularly in the Aegean, most notably on mainland Greece and in the southern Levant, with Palestine showing significant growth. Meanwhile, coastal clusters in the northern Levant, including Lebanon and Syria, exhibit a

contraction. Additionally, Egypt's increased number of olive sites suggests the emergence of a new locus of olive activity in the Nile region, contributing to the broader diffusion of olive cultivation and use by the LBA. Olive remains are found across various contexts within settlements, including palaces, elite buildings, kitchens, domestic spaces, roads and tombs (Shay et al. 1995).

6.2.7 Iron Age Distribution



Map 6.14: Distribution of Iron Age *Olea* evidence.

The number of olive-bearing sites declined significantly from 121 in the LBA to 76 in the Iron Age, with every region exhibiting a decrease in attested sites (Map 6.14). The most pronounced declines occur in Crete, Cyprus and Egypt. While Palestine and Greece maintain relatively high numbers, they still experience reductions. Meanwhile, the Levantine coast (modern-day Lebanon and Syria) and Jordan each lose approximately half of their LBA site counts. The spatial distribution of olive-bearing sites in the LBA forms a broad arc around the Eastern

Mediterranean, with dense clusters in the Aegean (Greece and Crete), the southern Levant and Egypt. By the Iron Age, these clusters contracted considerably, particularly in Crete, Cyprus and the Nile region, leaving a more dispersed pattern of sites concentrated in the Aegean, southwestern Anatolia and the southern Levant. Olive remains are discovered in various parts of settlements, including administrative buildings, counting houses, elite residences and kitchens, as well as in religious contexts such as tombs and sanctuaries. This suggests a multifaceted role for olives in both economic and ritual spheres across different regions and time periods.

6.2.8 Evidence of Consumption and Processing

Three distinct types of olive exploitation likely occurred: olive wood as fuel, consumption as fresh table fruit and liquid production (e.g., olive oil). At Gesher Benot Ya'aqov, olive wood was being gathered for fuel use as early as 790,000 BP (Goren-Inbar et al., 2004) and there is evidence suggesting that olives might have been exploited as far back as 19,000 BP at Ohalo II (Kislev et al., 1992)(Dighton et al., 2017). This practice of using olive wood for fuel most likely also continued until the Iron Age based on wood finds, like at the Neolithic site-phase of Abu Hamid (Liphschitz 1989; Neef 1988) and the Chalcolithic, EBA, LBA, Iron Age site-phases of Tell Shiukh-Fawqani in which both wild and domesticated wooden pieces were found (Pessin, 2004; Salavert, 2008; Cartwright, 1996; Hopf, 1978). Since they are outside the natural range of distribution, it would suggest that wild wood was still being used either for construction or fuel purposes. Both table olives and olive oil require processing before they can be consumed, though each demands different amounts of time, resources and equipment. Olives as tree fruits can be cured more easily than oil can be produced, often by soaking them in salt water, as a rudimentary form of brining and/or curing, from sources such as the Mediterranean Sea or the Dead Sea. Perhaps they could have been consumed raw since current humans cannot impose their taste preferences on those of the ancient past (Harutyunyan and Malfeito-Ferreira, 2022). In contrast, liquid production, olive oil, requires far more complex techniques, indicating a deeper understanding of olive properties and the use of processing equipment, either non specialised or specialised. It is possible that olives for both table consumption and oil were processed around the same time but current evidence remains limited. What is known is that olives were present on sites, presumably for direct consumption, whereas clear evidence for oil production appears

somewhat later. These two forms of exploitation highlight the remarkable versatility of olives in early human societies.

6.2.8.1 Table Fruits

Only evidence containing over 30 olive stones is highlighted in this section. The criteria for identifying olives as table fruit require either more than 30 stones within a single archaeological context and/or a significant number of stones found alongside other olive remains. The remains were not counted if they were heavily fragmented, since fragmented olives suggest actual crushing and or pressing (e.g., processing)(Braadbaart et al., 2016). This distinction helps differentiate between olives eaten as fresh fruit and those processed for olive oil.

Table 6.7 provides evidence of likely consumption of olives as table fruits. Evidence of grape consumption and/or overall presence should be the most predominant among tree fruits since grape, figs, pomegranate seeds would be consumed in entirety, with date pits likely being fed to animals as fodder (see section 5.5 below). However, they were not found in great numbers in caches. Any small amount of stones found in domestic context or refuse pits could indicate consumption but are not included here but can be reviewed in [Appendix 5](#). Additionally, any presence of olives as early as the PPN, could indicate consumption since olives were deliberately brought into human spaces.

Periods	Sites
NEO	Kfar Samir
CHAL	Rasam Harbush, Tell Afis
EBA	Arad, Chamalevri, Samos, Hirbet Ez-Zeraqon, Pella, Tel Beth Yerah, Tel Yarmouth, Tell Afis, Tell esh-Shuna, Tell Fadous-Kfarabida
MBA	Beth Shean, Chamalevri, Ebla, Kommos, Manahat, Pseira (only 10 but fragmented), Shiloh, Sidon, Tell el-Hayyat (fruit and stone), Tell Fadous-Kfarabida, Umbashi
LBA	Ayios Dhemitrios, Beth Shean, Citadel of Midea, Deir'alla, Jaffa, Kommos, Megiddo, Palaikastro, Sidon, Tell Abu Al-Kharaz, Tell Mishrifeh, Tell Qiri, Timnah (Tel Batash), Tiryns

IA	Ashkelon, Beth Shean, City of David, Delphi, Eretria, Euboea, Heraion Samos, Khirbet Er-Rasm, Knossos, Miletos (Kalabaktepe), Salamis, Shiloh, Sidon, Tel Masos, Tell Afis, Tell el-Burak, Timnah (Tel Batash) III
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Table 6.8: Site-phases with evidence of table fruit-consumption and/or processing based solely on Oleo archaeobotanical data.

While biases in the archaeological record are inevitable, the data shown in table 6.8, based on the criteria applied, indicates that the consumption or at least the significant presence of olives became more frequent from the Early Bronze Age onward. This trend suggests that olives were cultivated and used more widely during that period.

6.2.8.2 Oil Processing

Olive oil is likely to have been used for consumption and trade purposes and the basis for other industries, such as the production of oil for lamps and perfume. The presence of olives, found within the same context as either non-specialised (e.g., grinding stones, pestles and mortars) or specialised processing equipment (e.g., simple installations such as a treading floor, collection vat and SLWPs) (Chapter 7), was used to identify the most likely presence of olive oil. This assessment also includes the presence of *pithoi* and other ceramic storage vessels, which are typically associated with the storage process, provided that olive pressing evidence is found within or nearby. Additionally, if plant remains show signs of crushing and the olive stone exhibit fracture pressure breaks, it further suggests that they were likely the byproducts of value-added processing.

There are numerous installations that are indicative of olive oil processing but only a relatively few have evidence of olives found within the same context and even some of those do not have caches/strong numbers or were ‘not collected’ (Onozuka 2012, pp.72). Evidence of caches of olive seeds found in or beside unspecialised processing equipment like pestle and mortars, grinding stones and small rock cut installations, especially in domestic/community contexts, suggest small to medium-scale production (i.e., household or community level). Large amounts of olive stones (10>) found in association with specialised equipment like a stone floor connected to a collection vat with standing stones and stones rollers (especially in administrative and public contexts) or within a simple lever and weight press (SLWP), indicate larger scale or even industrial production which would allow for the commercial selling/trading of the oil (see

Chapter 7). The site-phases that have clear evidence of oil production, based on the amount of fractured stones and their context in or beside processing equipment can be seen in Table 6.9.

Periods	Small-Medium Scale	Medium-Large-scale
NEO	Kfar Galim, Kfar Samir, Megadim and Tel Hreiz	
CHAL	Tuleilat Ghassul	
EBA	Chamalevri, Kalavassos Ayios Dhimitrios II, Kalavassos Ayios Dhimitrios II (Cyprus), Pella	Apliki Karamallos, Enkomi, Erani, Hala Sultan Tekke, Meggido, Tell Taanach
MBA	Chamalevri	Chamalevri-Tzambakas House, Ebla, Kommos, Maroni Vournes, Tell Taanach, Tell Tweini
LBA	Mochlos	Apliki, Apliki Karamallos, Archanes Phourni, Hala Sultan Tekke, Kalavassos Ayios Dhimitrios, Knossos, Kommos, Malia, Palaikastro, Phasitos, Tell Abu Al-Kharaz, Tel Aphek, Tell Qiri
IA	Beth Shean, Tell Mishrifeh	Beth Shean, Megiddo, Tell Tweini

Table 6.9: Evidence of olives and their context to determine site-phases with evidence of oil production.

The earliest compelling evidence for the gathering of olives specifically for oil production dates to the 6th millennium BCE at several submerged sites along the Carmel Coast of Palestine (Zohary et al., 2012; Galili et al., 1997; Galili et al., 2007; Kislev, 1995). Remarkably, these sites provide clear indications of labour-intensive oil-production activities at a very early stage, challenging assumptions that such complex processing developed later. At the submerged site of Kfar Samir, thousands of olives were recovered, 84.4% of which were fragmented prior to charring, alongside abundant oil-processing debris and specialised equipment. Among these finds were stone basins, concave mortars, grinding and chipping tools and woven baskets interpreted as strainers (Galili et al., 1997), collectively demonstrating a sophisticated and well-established system for extracting olive oil.

The preservation of such early oil-production evidence is largely a result of the unique conditions of submerged archaeology. Waterlogged environments at these sites prevented decay and charring, allowing otherwise perishable plant remains and wooden or woven tools to survive,

which would typically be lost in dryland sites. Other contemporaneous Carmel Coast sites, including Atlit-Yam, Kfar Galim, Megadim and Tel Hreiz, show evidence of oil-production technology but lack the preserved olives themselves (Galili et al., 1997; Galili et al., 2007), further highlighting the role of exceptional preservation in revealing early labour-intensive production practices. This combination of technological sophistication and accidental preservation provides surprising insight into the scale and organisation of early olive oil production.

Further confirmation comes from vessels containing olive oil residues discovered at Ein Zippori in northern Palestine (Namdar et al., 2015). Collectively, these findings illustrate that by the late 6th millennium BCE, communities west of the Jordan River had already developed specialised tools and methods to process wild olives, reflecting a sophisticated understanding of the fruit's economic and dietary value before they were domesticated.

Evidence of processing from the EBA indicates that domesticated olives were also now being used to process oil, with both non specialised and specialised processing equipment. This may also indicate the shift from a personal household economy to a larger industrial sector that fostered economic growth. Almost all of the olive stones found to date from all areas come from domestic/habitat and community specialised industry contexts. By the MBA, the majority of the evidence comes from botanical remains linked to simple installations. It should be noted that the Mari texts (c. 1900 BCE) name olive oil as a main trade product in the Levant (Knapp and Demesticha, 2016; Zemer, 1978). By the LBA sites like Cyprus and Crete had some evidence of more sophisticated pieces of equipment, like SLWPs, being used for olive oil production, while Palestine site-phases have evidence attached to simple installations (for details on this phenomenon see Chapter 7). By the Iron Age, the majority of the botanical remains are linked to specialised equipment. In conclusion, archaeobotanical and archaeological evidence for olive processing first appeared in Palestine as early as the Neolithic period. In Jordan, the earliest traces date to the Chalcolithic, while in Cyprus, Greece and Crete, olives were processed by the Early Bronze Age. Syria follows with evidence from the Middle Bronze Age. Currently, no comparable botanical or processing equipment data have been documented in Lebanon or Turkey. These gaps highlight the uneven distribution of archaeological research and underscore the need for further investigation in these regions.

6.2.9 Brief Conclusion

From the PPN onward, the archaeological evidence demonstrates that olives played a pivotal role in the diet and economy of communities located within their natural distribution range. Early exploitation focused on wild populations, while domesticated varieties increasingly appeared by the EBA, reflecting a shift toward more intensive cultivation (Table 6.9). Over time, patterns of production, consumption and distribution fluctuate, as seen in the rise and fall of site-phases across different periods and regions. Evidence of olives appears in the Pre-Pottery Neolithic (PPN) from Greece, Cyprus, Syria and Palestine. Additional evidence dates to the Neolithic in Crete, Turkey, Lebanon and Jordan, as well as the Middle Bronze Age (MBA) in Egypt (Map 6.10).

Sites	Confirmed Presence (BCE)	Site Evidence/Sources
Greece	PPN - 8000-6700 BCE	Ghediki (Renfrew, 1966; Pagnoux, 2019)
Crete	Neo - 6700-3500 BCE	Knossos (Badal and Ntinou, 2016; Sarpaki, 2009,2013)
Cyprus	PPN - 8900-8000 BCE	Cape Andreas-Kastros (van Zeist, 1981; Fuller and Stevens, 2019)
Turkey	Neo - 5900-5680 BCE	Fistikli Hoyuk (Bernbeck and Pollock, 2003)
Lebanon	Neo - 5500-4200 BCE	Qana (ADEMNES)
Syria	PPN - 7450-7100 BCE	Halula (Willcox, 1996)
Palestine	PPN - 9000-8000 BCE	Carmel (Noy et al., 1973)
Jordan	Neo - 5200-4300 BCE	Abu Hamid (Neef, 1988)
Egypt	MBA - 2060-1690 BCE	Kom Ran'ia (Memphis) (Murray, 1990; Fuller and Stevens, 2019)

Table 6.10: Site-phases with the first evidence of oleo based on archaeobotanical data found to date.

Meanwhile, olive processing, whether for table fruit or oil, developed alongside broader socio-economic changes. Evidence of olives as table fruits is found from the Neolithic period in Palestine, the Chalcolithic in Syria, the Early Bronze Age in Crete, Greece and Lebanon, the Middle Bronze Age in Jordan and the Iron Age in Cyprus and Turkey. Wild olives were first exploited for both consumption and oil as early as the Neolithic period in Palestine, followed by Jordan in the Chalcolithic and then Cyprus, Greece and Crete in the Early Bronze Age. Syria

provides its first clear evidence by the Middle Bronze Age, while no comparable botanical or processing equipment data have yet been identified in Lebanon or Turkey. Ultimately, the widespread distribution of olives and the emergence of processing technologies across multiple regions underscore the centrality of this resource in shaping early agricultural societies around the Mediterranean.

6.3 Ficus Carica and Ficus Sycomorus

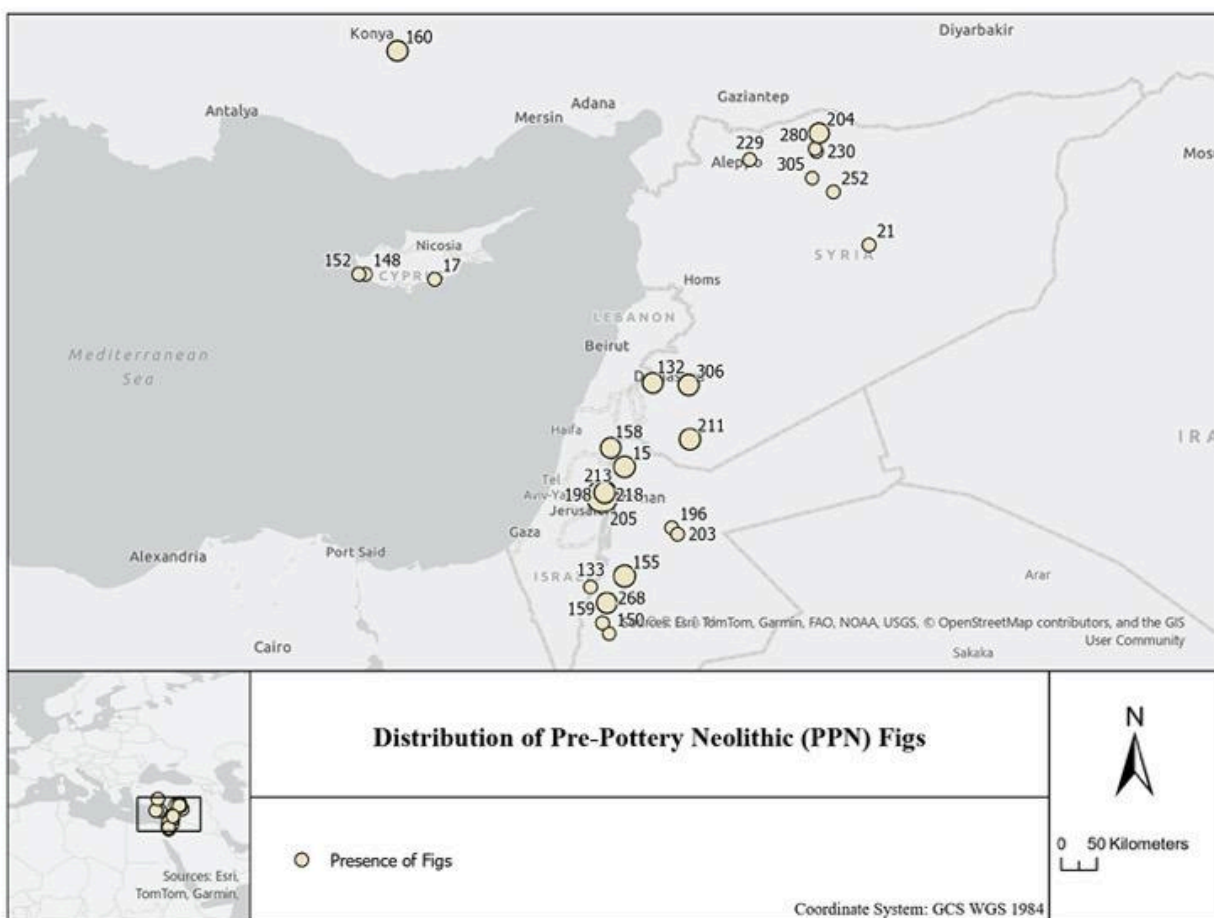
Evidence of figs has been identified in 311 site-phases across nine regions ([Appendix 6](#)) (Table 6.11). For the purposes of this analysis, all fig species, including *Ficus sp.* (58 site-phases), *Ficus carica* (234 site-phases) and *Ficus sycomorus* (19-site-phases), are considered under a single general *Ficus* category, as the focus is on the presence of figs and establishing evidence of their consumption and processing in past societies. This approach is justified by the fact that these species produce similar fruits with comparable value-added products, such as sugar content, seed sizes and fruit flesh. Combining data from all fig species not only allows for a more comprehensive analysis of fig consumption but also helps reveal broader patterns in fig use, trade or cultivation practices. In addition, compiling data across species helps to address potential biases that arise from preservation or recovery processes. Some fig species may be more likely to survive in the archaeological record due to their seed size, structure or environmental conditions, while others might be underrepresented. A multi-species approach can reveal temporal and spatial trends in fig use that would otherwise remain hidden. For instance, certain species may have been favored in particular historical periods or specific regions, reflecting local agricultural practices, trade networks or dietary preferences. Conversely, shifts in the prevalence of different species over time may indicate changes in cultivation strategies, climate conditions or cultural preferences. Ultimately, integrating data from all fig species not only strengthens the robustness of archaeological interpretations but also provides a richer, more comprehensive picture of the ecological, economic and social roles that figs played in past human societies.

	PPN	Neo	Chal	EBA	MBA	LBA	IA
Greece	-	25	4	7	4	12	7
Crete	-	-	-	1	2	4	1

Cyprus	3	6	7	4	2	4	2
Turkey	1	4	4	2	3	5	4
Lebanon	-	-	1	1	1	1	3
Syria	10	11	1	14	7	9	4
Palestine	5	5	3	8	4	9	28
Jordan	9	4	2	6	2	1	9
Egypt	-	-	5	10	6	10	2
Total:	28	55	27	54	31	56	60

Table 6.11: Site-phases for the areas and time periods under study that have evidence of *Ficus*. Dashes indicate that no information is currently available or published. The total number of site-phases is shown in bold. The small increases and decreases are probably the result of preservation issues, site bias, etc.

6.3.1 Pre-Pottery Neolithic Distribution



Map 6.15: Distribution of Pre-Pottery Neolithic Ficus evidence.

There are 29 site-phases across Jordan, Palestine, Syria, Turkey and Cyprus that date to the Pre-Pottery Neolithic period, which can be grouped into two primary clusters (Map 6.15). The largest cluster is located within the Jordan Rift Valley. The high concentration of sites along the Jordan Valley may be attributed to the favorable microclimates and the presence of water sources, which would support fig growth. The other cluster is situated in the Upper Euphrates and north Levant. This region, characterised by fertile alluvial plains, would have been ideal for the cultivation of figs and other crops (Maher et al., 2011; Akkerman, 2014). A smaller, isolated cluster is present in Cyprus. The earliest evidence of figs comes from Iraq Ed Dubb in Jordan, dating to approximately 11,200–8,800 BCE. This dating is based on charcoal evidence from an assemblage (with no context) containing 480 samples identified by their shape and size.

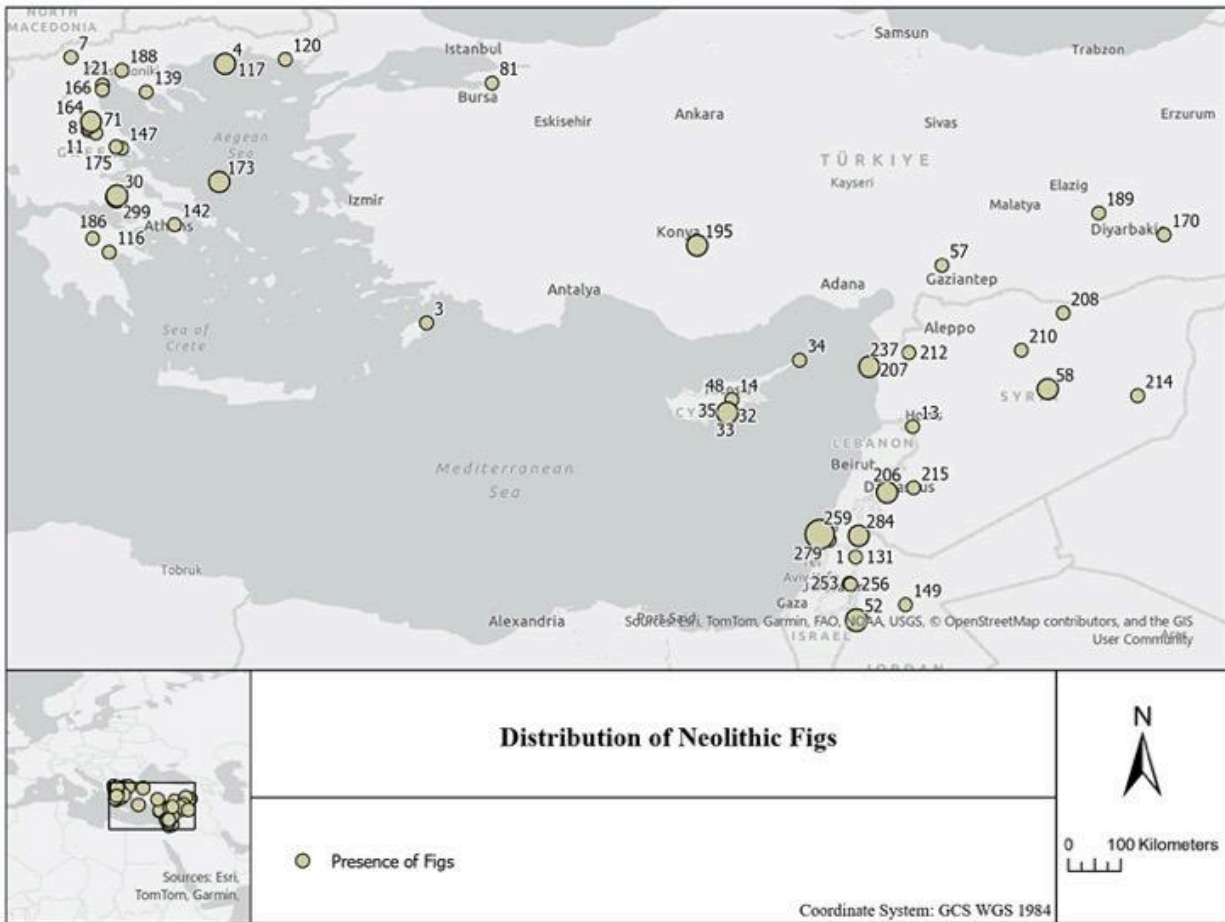
Over a third of the site-phases with fig evidence from four different regions contain fig seed remains exceeding 30 seeds per site, with quantities ranging from 42 to an impressive 4,918 seeds. However, despite the significant seed counts across all site-phases, the contexts provided are vague, often limited to general references to middens or mentions of multiple layers or contexts, as seen at Netiv Hagdud and Wadi Feynan. The absence of detailed contextual data, such as storage facilities, processing areas or specific consumption contexts, makes it challenging to determine the exact role of figs within these prehistoric communities. Nevertheless, the sheer volume of fig remains at several sites, their consistent presence across multiple regions and site-phases strongly indicates that figs were not only present but also likely played a role in the diet of Pre-Pottery Neolithic societies.

Two sites in the Jordan Valley provide compelling evidence for the intentional drying of figs for human consumption. At Gilgal I (c.9300-9256 BCE), archaeologists recovered nine whole figs and 313 seeds, offering rare and valuable evidence of early fig preservation (Kislev et al., 2006). The carbonised figs showed little to no distortion, suggesting that they had been deliberately dried rather than accidentally charred, indicating their preparation for consumption. There is much debate if the figs from Gilgal I were wild or domesticated (consult Kislev et al., 2006; Gibbons, 2006; Denham, 2007 for more details on this debate). However, if the figs were indeed domesticated, this would imply that fig cultivation was widespread at the time and could predate the domestication of cereal crops by approximately 1,000 years in certain regions, highlighting

the significant role figs may have played in early Neolithic diets (Stevens and Fuller, 2019). A second notable example comes from Sharara (c. 9250 BCE), where over 700 fig fruits were discovered within a single structure interpreted as a processing area, likely used for the storage and preparation of plant foods. Evidence suggests that the figs were laid out to dry on the roof of the structure, which was subsequently destroyed by fire (Whitley et al., 2023). These findings collectively demonstrate the early and sophisticated management of fig resources in the Jordan Valley, highlighting both the dietary importance of dried figs, likely used for storage and their role in providing increased sugar and caloric returns.

Figs from Galil, Jericho, Netiv Hagdud and Gesher significantly outnumber other fruits in period assemblages (Bar-Yosuf 1986; Hopf 1983; Western 1971; Wallace et al., 2018), which is unusual given the small size and quick degradation of fig seeds. Figs' unique traits, parthenocarpy and vegetative propagation, would have made them ideal for early agricultural experimentation, contributing to their overrepresentation in the archaeological record. Their abundance might also suggest preservation methods or practices like drying, bulk storage or processing into fig cakes or pastes, concentrating seeds in specific contexts such as middens or storage pits. The strong presence of figs compared to other fruits might reflect a cultural preference, a significant role in the diet of these communities or simple availability.

6.3.2 Neolithic Distribution



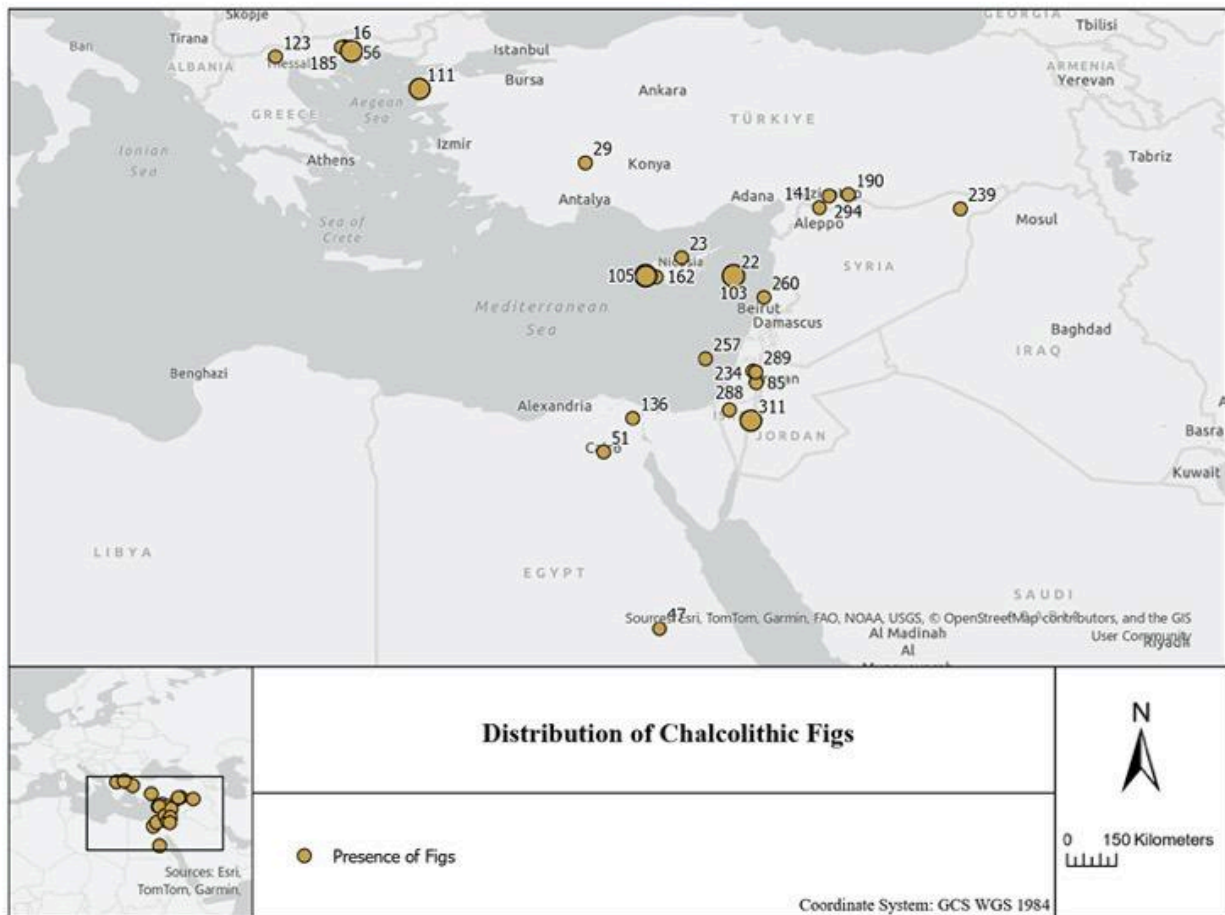
Map 6.16: Distribution of Neolithic *Ficus* evidence.

From the Pre-Pottery Neolithic to the Neolithic period, the number of fig-related site-phases increased significantly, rising from 28 to 55 (Map 6.16). This growth was primarily driven by the introduction of 25 new site-phases in Greece, marking the first observable to-date evidence of fig use in the region. In contrast, site-phases in Cyprus, Turkey, Syria, Palestine and Jordan exhibited general continuity. The geographical distribution of figs expanded markedly westward into the Aegean region, including Greece and its islands, while also spreading further into Anatolia (modern-day Turkey) and the northern reaches of Syria. This broader distribution may reflect a combination of natural fig tree propagation and human-driven dissemination through early agricultural practices, trade routes and the movement of Neolithic communities (Özdoğan, 2023; Stevens and Fuller, 2019).

As in the PPN, fig site clusters remained dense in the Levant and Euphrates areas, with new clusters emerging in the Aegean, particularly in central and northern Greece. High-density evidence in these new clusters suggests figs were being integrated into the diet. Additionally, there was a slight increase in site-phase clustering in Turkey and Cyprus, indicating a gradual but steady expansion of fig use across these regions. Most of these site-phases were located near water sources or along trade routes, highlighting the potential role of figs in early trade networks and cultural exchanges. The Neolithic period also offers the earliest evidence of sycamore in Palestine, specifically at Jericho, dating to approximately 5500–4500 BCE.

Thirteen site-phases contain more than 30 fig seeds each, ranging from 30 to 3689 , yet, as before, there is a lack of detailed contextual information. This collection represents a mix of wild and domesticated fig varieties, consistent with previous findings. The absence of contextual data may be attributed to the fact that figs, while present, are often not a primary focus in botanical analyses of archaeological sites, compared to cereals and legumes. Despite the limited contextual data, the substantial quantity of figs remains at numerous sites, along with their consistent appearance across diverse regions and site-phases, strongly suggests that figs were not merely present but likely contributed to the diet of Neolithic communities.

6.3.3 Chalcolithic Distribution



Map 6.17: Distribution of Chalcolithic *Ficus* evidence.

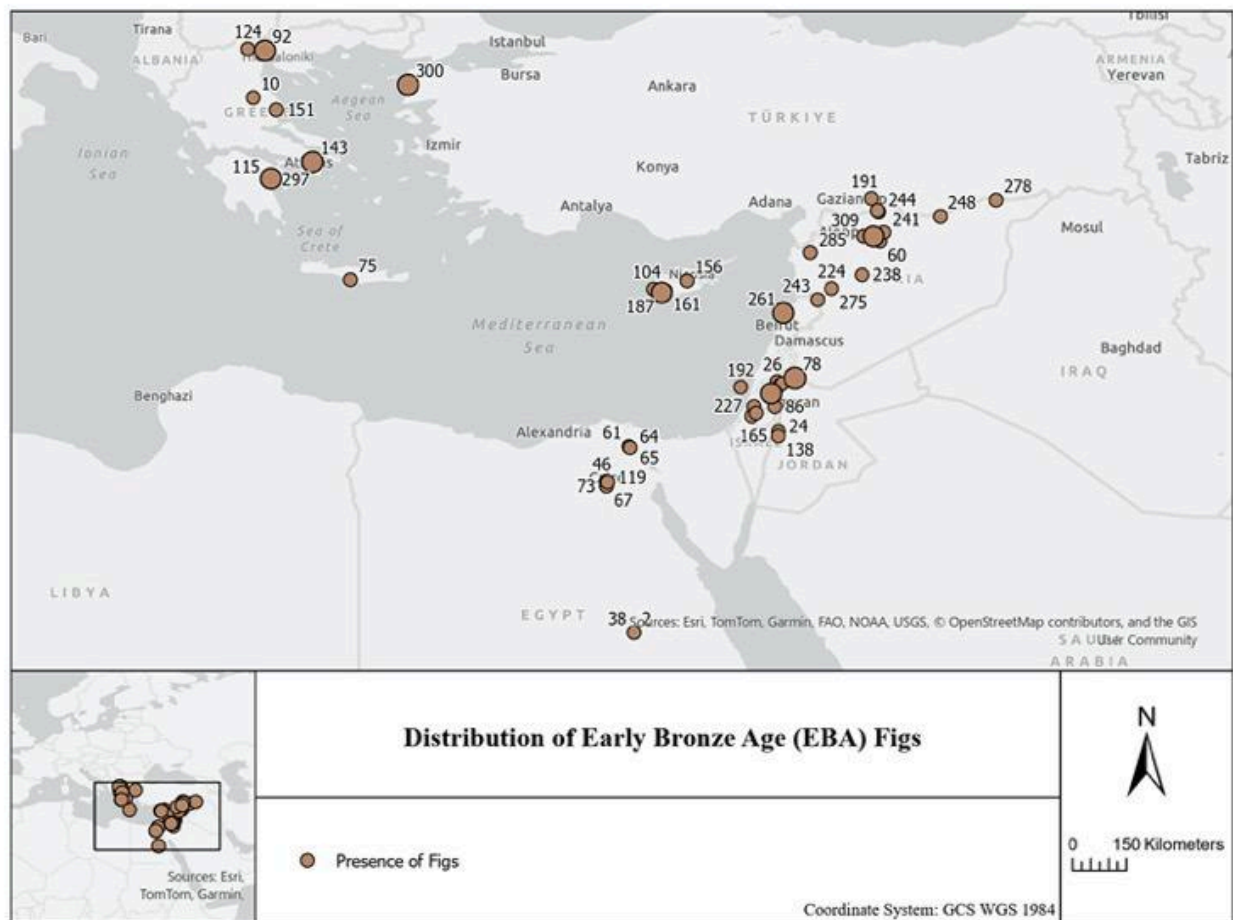
There is a notable decrease in site-phases during the Chalcolithic period, Greece and Syria, in particular, experience a significant decline in site-phases (Map 6.17). However, this reduction is likely a consequence of the limited time frame rather than indicative of a broader trend or pattern. The Chalcolithic marks the first recorded presence of site-phases in Lebanon and Egypt, with Egypt featuring both common and sycamore figs. Egypt, in particular, emerges as a new region of fig presence, suggesting potential trade routes along the Nile or the adoption of new cultivation practices in the northeastern African context. It is noteworthy that the majority of site-phases, from the Chalcolithic onwards, with evidence of sycamore figs are found in Egypt.

Six site-phases from the Chalcolithic period contain over 30 fig seeds each, yet only one site offers detailed contextual information. At the site of Dikili Tash (circa 4460–4000 BCE), archaeologists uncovered 425 domesticated fig seeds and whole figs, all charred and preserved

within the remains of four houses. What makes this discovery particularly compelling is its proximity to morphological evidence of grape wine-pressing (Valamoti, 2004; Valamoti et al., 2007), suggesting a more complex and nuanced use of fruits in this settlement. Since they were found in domestic contexts, it suggests that the figs were being consumed/processed in private places as table fruits. This close association between figs and the grape wine-pressings suggests that figs might not have been merely a dietary staple but could also have played a role in early fermentation practices and food processing techniques. It is possible that figs were integrated into early winemaking processes, serving as a sweetening agent, a fermentation starter or a flavour enhancer.

At Kissonerga Skalia (c. 4000–3000 BCE), 667 domesticated fig seeds were uncovered in three caches in Trench B (household) in which 16, 176 and 232 seeds were uncovered (Colledge, 2003). According to Lucas (2012), figs demonstrated 80% ubiquity among the main crops identified at the site, indicating they were not merely present but likely a significant component of the local diet, as either table fruits or value-added products. If they were being consumed, it is unlikely that all those figs would have been discarded in specific stratigraphic layers but rather they are the byproduct of figs being crushed and fermented for wine and/or vinegar. The dominance of figs among other dry foodstuffs suggests they were readily consumed and may have held a preferential status due to their high sugar content, calorific value and wide availability (Cyprus was within the natural range). Their abundance, coupled with their versatility, implies figs were valued for their nutritional benefits and culinary uses. Figs could have been eaten fresh, dried for preservation or incorporated into other foodstuffs or fermented products. The consistent presence of figs across multiple site-phases and regions further supports the idea that figs played a role in the diet of Chalcolithic societies.

6.3.4 Early Bronze Age Distribution



Map 6.18: Distribution of Early Bronze Age *Ficus* evidence.

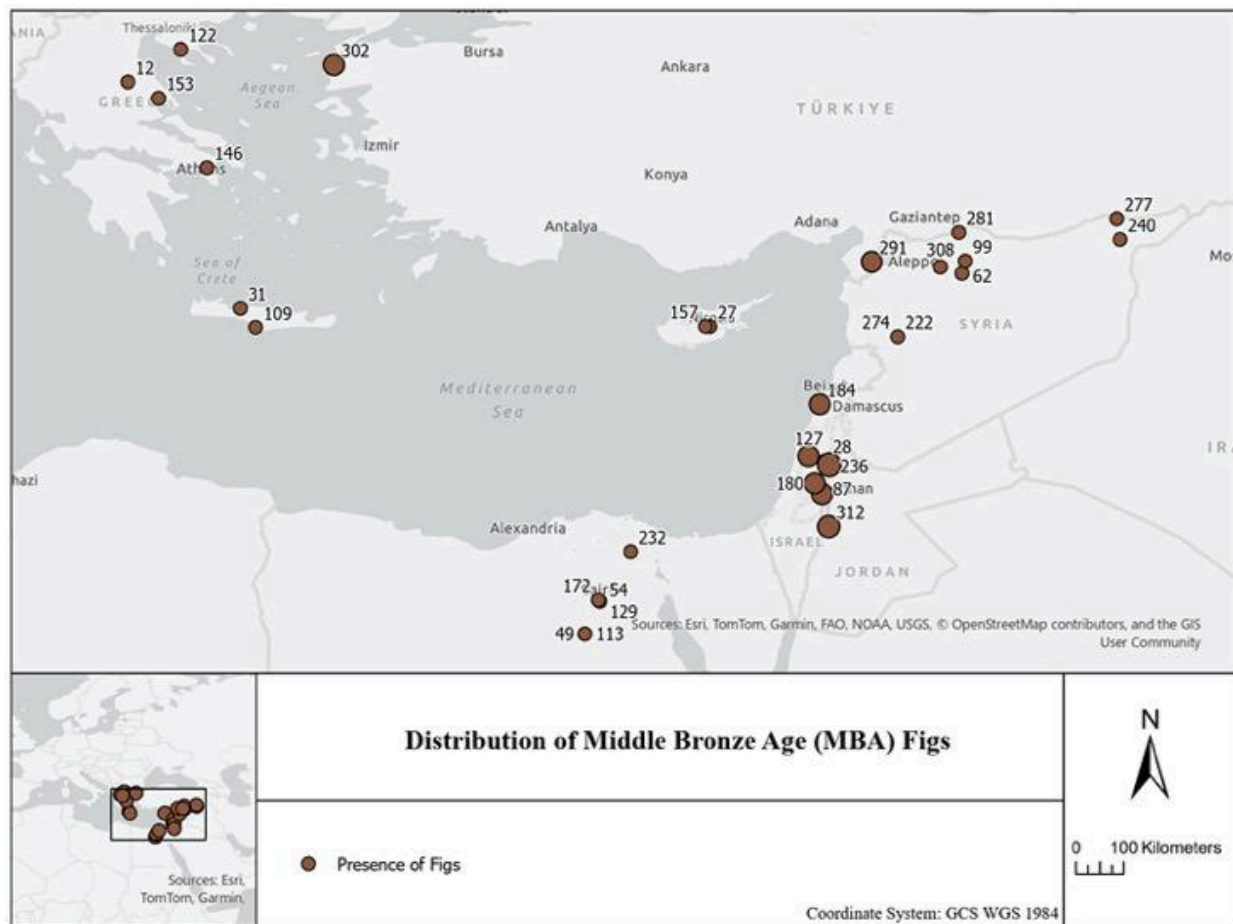
The distribution of figs expands significantly from the Chalcolithic to the Early Bronze Age, nearly doubling to 54 site-phases and covering a much broader geographic area (Map 6.18), including the first evidence on Crete. New fig sites appear in the Southern Levant, northern Syria and along the Aegean coast, reflecting a pronounced westward spread into Greece and the Aegean and re-establishing a cluster that had diminished during the Chalcolithic. The Levant maintains a strong presence, with an even denser concentration of fig sites, particularly in Syria, while Egypt sees an increase in site-phases and Turkey experiences a slight decline.

Nine site-phases from the EBA contain over 30 figs each but only two site-phases have contextual information. Hirbet Ez-Zeraqon (c. 2800-2600 BCE) has 458 domesticated figs (Riehl) which were found in a residential building (B1.6 in the lower city), indicating that they were being consumed by common, not necessarily elite, people as table fruits or other

value-added products (Riehl, 2004). The ubiquity compared to other plant remains is 30%. While, at the site of Selenkahiye (circa 2350–2000 BCE), 42 wild figs were uncovered within a single stratigraphic layer of refuse, located near what appears to be a town hall (van Zeist and Bakker-Heeres, 1985). Tell Fadous-Kfarabida has 177 domesticated fig seeds found from one context in a residential building (Genz, 2010; Genz et al., 2016; Damick and Woodwarth, 2015). Typically, when figs are eaten fresh, their seeds are also ingested and thus rarely discarded intact. However, if figs were crushed or processed, such as being used as a sweetening additive or fermented to create fig wine, the seeds would be left over and could then end up in a residential building or in a refuse pit, since they could no longer be consumed. This concentration of fig remains may therefore indicate more specialised processing or culinary practices rather than simple consumption.

At Kissonerga Skalia (c. 2300-1550 BCE), domesticated fig seeds were uncovered, although no detailed contextual information was provided and the figs demonstrated 50% ubiquity among the main crops identified at the site (Lucas, 2012). The evidence suggests that figs were not just present but likely formed a key part of the local diet, like the 80% ubiquity from the Chalcolithic. Their apparent dominance among other dry foodstuffs implies they were widely consumed and may have been favored for their high sugar content, calorie density and broad natural range. Their abundance and versatility point to figs being consumed continuously over a long period.

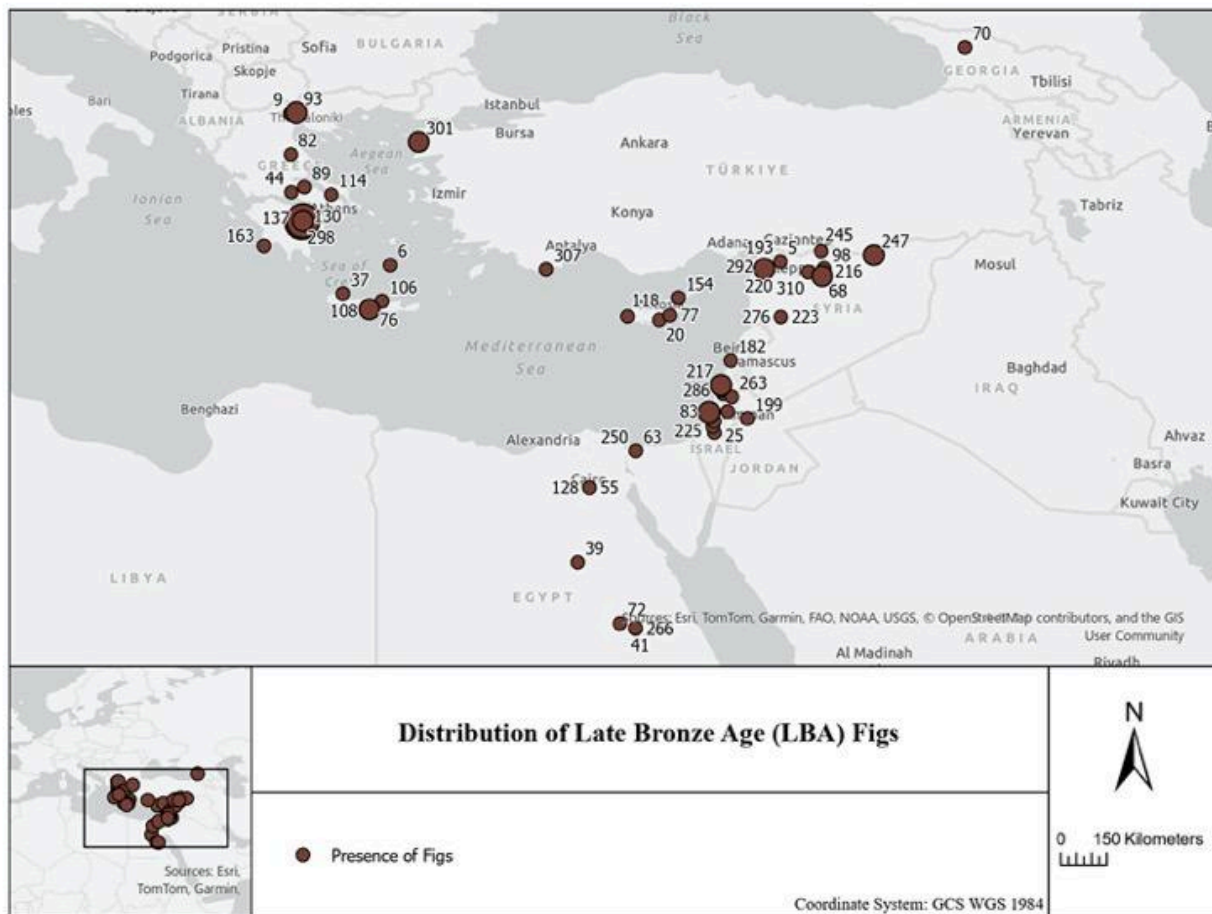
6.3.5 Middle Bronze Age Distribution



Map 6.19: Distribution of Middle Bronze Age *Ficus* evidence.

Figs still maintain a wide distribution in the Middle Bronze Age (Map 6.19). Eight site-phases (including one from Lebanon, two from Jordan, two from Turkey and three from Palestine) contain evidence of more than 30 fig seeds, yet none provide detailed contextual information beyond their presence within settlement areas. At the site of Sidon (circa 1800–1600 BCE), 41 domesticated fig seeds and whole fruits were discovered (Kislev et al., 2009; Liphshitz, 1989; Simchoni and Kislev, 2006, 2012). This find indicates that figs were stored within the settlement and actively consumed, reinforcing the notion that figs played a role in the local diet.

6.3.6 Late Bronze Age Distribution

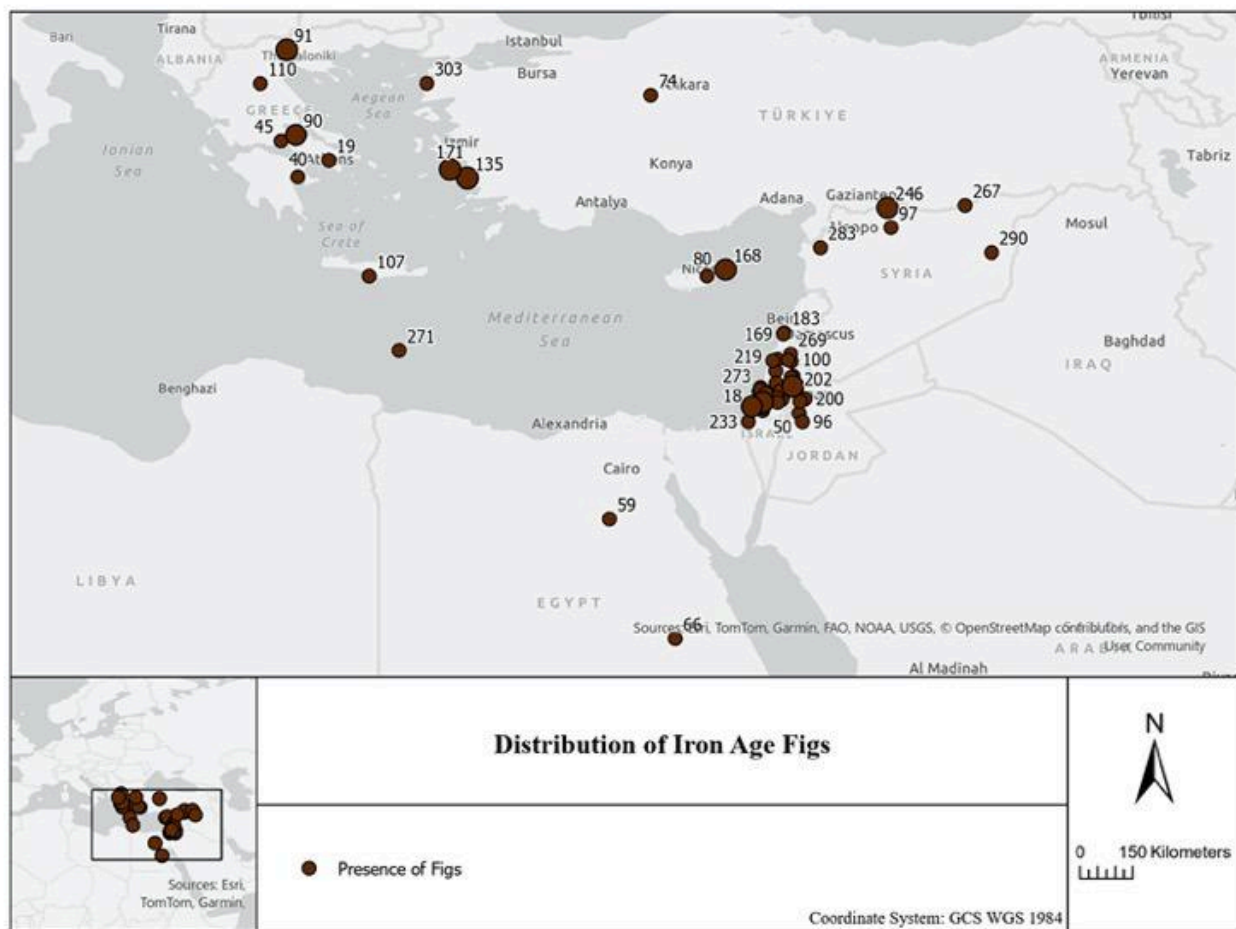


Map 6.20: Distribution of Late Bronze Age *Ficus* evidence.

The LBA exhibits a wider distribution of fig sites, with more intensive clustering in previously established regions and a noticeable increase in site-phases, almost double, with a modest expansion in the Aegean and Egypt (Map 6.20). The cluster in the Levant grows even denser, with numerous new site-phases identified. The fig cluster in the Aegean and Greece expands significantly, indicating robust trade networks and the possible rise of fig cultivation as a regional agricultural practice. Increased maritime trade during this era may have facilitated the spread and use of figs. Fig evidence in Anatolia increases, particularly in southern areas, suggesting that figs may have become more integrated into local agricultural systems or gained importance through trade networks connecting the Levant. While Armenia shows no evidence of figs, Georgia presents a single site-phase from the Late Bronze Age. Due to Georgia's close geographical proximity to Armenia, it has been included in this analysis.

Eleven site-phases have more than 30 seeds, with two site-phases that have over 5700 figs each (Midea and Tiryns) both found in Greece. Hagia Triada (c. 1550-1200 BCE) has 60 seeds and fruits found but no given context (Willerding, 1973; Wallace et al., 2018), indicating some evidence for either storage or consumption of the tree fruits. The sheer volume of fig remains at several sites, their consistent presence across multiple regions and site-phases strongly indicates that figs were not only present but also likely played a role in the diet of Late Bronze Age societies.

6.3.7 Iron Age Distribution



Map 6.21: Distribution of Iron Age *Ficus* evidence.

Fig distribution during the Iron Age maintains the broad geographic spread of the LBA (Map 6.21). The Levant maintains its status as the primary cluster for figs, with consistent density. Fig distribution in the Aegean and Greece remains relatively stable, with some shifts in site distribution but no major expansions. The Anatolian fig cluster remains stable, with a slight

northward shift. The fig presence in Cyprus continues to be minimal, with little change from the LBA.

Nine site-phases from the Iron Age contain over 30 fig seeds each, yet none provide detailed contextual information. The only site-phase with any contextual detail is from Tel el Burak (circa 800–650 BCE), where archaeologists uncovered 18 domesticated and 3 wild figs within a firepit in a room (Nigro and Spagnoli, 2018; Orendi and Deckers, 2018). This suggests that both wild and domesticated figs were being consumed together and that there might not have necessarily been a preference with people still using the wild ones available. There is evidence from Ashkelon in which 46 domesticated fig seeds were uncovered (Weiss and Kislev 2004; Weiss et al. 2008). The figs from this site-phase make up a significant proportion of the IA I phase (>54%), which suggests that they were likely being stored for raw consumption or processing into a value-added product or were possibly a by-product of fig wine (e.g., fig maceration). The significant quantity of fig remains found at various sites, coupled with their widespread and consistent presence across different regions and site-phases, suggests that figs were not merely incidental finds but likely played a meaningful role in the diet of Iron Age societies.

6.3.8 *Brief Conclusions*

Jordan provides the earliest evidence of fig use, dating back to the Pre-Pottery Neolithic. Other early adopters include Palestine, Syria, Cyprus and Turkey, all during the PPN, highlighting the Levant and adjacent regions as primary hubs of early fig use evidence (Table 6.12). Greece's fig presence is first recorded in the Neolithic around 6800 BCE, suggesting a westward expansion of fig use. Fig evidence in Crete emerged much later during the Early Bronze Age, likely influenced by Mediterranean trade networks. Both Lebanon and Egypt first show fig evidence in the Chalcolithic period, indicating a later adoption of figs, possibly through trade or cultural exchange with neighbouring regions.

Sites	Confirmed Presence (BCE)	Site Evidence/Sources
Greece	Neo - c.6800 BCE	Chaeronea -Balomenos (Megaloudi, 2006)
Crete	EBA - 3400-1100 BCE	Hagia Triada (Sarpaki 2009; Sarpaki 2013)

Cyprus	PPN - 8700-8270 BCE	Kissonerga Mylouthkia (Murray, 1998)
Turkey	PPN - 8700-5400 BCE	Catalhoyuk (Fairbairn et al, 2002; Bogaard et al. 2017)
Lebanon	Chal - 5200-2000 BCE	Tell Fadous-Kfarabida (Genz 2010; Damick 2015; Hoflmayer 2014; Genz 2016)
Syria	PPN - 9000-8850 BCE	Tell Aswad (Zohary et al., 2012; van Zeist and Bakker Heeres, 1985)
Palestine	PPN - 9653-8636 BCE	Netiv Hagdud (Fuller and Stevens, 2019)
Jordan	PPN - 11200-8800 BCE	Iraq Ed Dubb (ADEMNES)
Egypt	Chal - 5200-3200 BCE	Tell el-Fara'in (Thanheiser, 1997)

Table 6.12: Site-phases with the first evidence of figs based on archaeobotanical data found to date.

The analysis of fig distribution from the PPN to the IA reveals distinct phases of growth, decline and stability in fig site-phases across the eastern Mediterranean. The data indicates significant fluctuations over time, with notable increases during the Neolithic (55 site-phases) and the Late Bronze Age (56) and the highest number of site-phases recorded in the Iron Age (60). Periods of contraction occur in the Chalcolithic (27) and Middle Bronze Age (31), likely due to the shorter durations of these periods or shifting regional dynamics. These trends highlight the dynamic nature of fig use and distribution, influenced by both environmental and cultural factors. Overall, the distribution of fig site-phases from the PPN to the Iron Age reflects not only the adaptability of figs to diverse environments but also their integration into the diets, economies and cultures of ancient Mediterranean societies. The distribution of Pre-Pottery Neolithic figs aligns closely with early centers of agriculture and sedentism.

Periods	Sites
PPN	Catalhoyuk, Djade, El - Hemmeh, Gesher, Gilgal I, Iraq Ed Dubb, Netiv Hagdud, Ramad, Tell Aswad, Tell Qarassa and Wadi Feynan
Neo	Agios Ioannis, Atlit-Yam, Catalhoyuk,, Chaeronea-Balomenos, Dhra', El Kowm II, Khrokitia, Rachmani, Ramad, Ras Shamra (Ugarit), Sarakinos, Sha'ar Hagolan and Tomb Balomenous
Chal	Dikili Tash, Kissonerga -Mylouthkia, Kissonerga Skalia, Kumtepe, Lemba and Wadi al Fidan

EBA	Hirbet Ez-Zeraqon, Kastanas, Pefkakia, Selenkahiye, Souskiou Laona, Tell el-Dara'in, Tell Fadous-Kfarabida, Tiryns and Troia
MBA	Jericho, Megiddo, Shiloh, Sidon, Tell el-Hayyat, Tell Tayinat, Troia and Zahratt Adh-Dhra I.
LBA	Emar, Hagia Triada, Jaffa, Kastanas, Midea, Tel Aphek, Tell Shioukh Faouquani, Tell Tayinat, Tiryns and Troia
IA	Ashkelon, Deir;Alla, Kalapodi, Kastanas, Miletos, Salmais, Samos Tel Migne (Ekron) and Tell Shiukh Fawqani

Table 6.13: Evidence of fig caches from the different regions and time periods under study.

While numerous site-phases contain over 30 fig seeds, most lack detailed contextual information, limiting insights into their exact role within ancient communities. The first evidence of fig caches comes from site-phases in Pre Pottery Neolithic in Turkey, Syria, Jordan and Palestine, Neolithic in Greece and Cyprus, Early Bronze Age in Lebanon and Egypt and in Late Bronze Age in Crete (Table 6.13). Only a few sites provide detailed context, such as Dikili Tash (Chalcolithic), suggesting figs' role in early fermentation practices and Sidon (Middle Bronze Age), where fig storage indicates active consumption.

One of the most significant observations is that figs were being transformed into value-added products, specifically dried figs, during the PPN period. This development occurred roughly contemporaneously with the basic consumption of fresh, raw figs, indicating that early communities were not only eating the fruits as they were harvested but also experimenting with methods to preserve and enhance their utility. This challenges the common assumption that early humans initially consumed fruits in their raw form and only later developed techniques for processing or preservation. Instead, the evidence from sites such as Gilgal I and Sharara suggests that the processing of figs into dried products, likely for storage, extended use or improved caloric and sugar content, was already taking place very early in the Neolithic, reflecting a sophisticated understanding of food management and resource maximisation.

6.4 Punica Granatum

Punica granatum L. (pomegranate) has the least evidence among all tree fruits analysed in this study, being present in only 60 site-phases across eight regions ([Appendix 7](#)) (Table 6.14), due to a limited bias in the dataset (see Section 2.4.3). Importantly, no archaeobotanical evidence of

pomegranates has been documented in Armenia for the period covered by this study. The only indication is a gold vessel depicting pomegranates from the 8th century BCE at the Urartian fortress of Teishebaini (Թեյշեբաինի), regardless of sources in English, Russian or Armenian (Stepanyan-Gandilyan, 2014; Stepanyan, 2007). This absence is particularly puzzling given that wild pomegranates currently thrive abundantly in the region, occupying both secondary and tertiary wild pomegranate forests (Zohary and Spiegel Roy, 1975; Holland et al., 2019). Moreover, the Transcaucasian-Caspian area is widely regarded as the original center of pomegranate domestication in the 5th millennium BCE (Levin, 2006; Still, 2006). The likely reason for this domestication site is the natural abundance of wild pomegranates in the region, especially considering the lack of established archaeobotanical criteria to differentiate between wild and domesticated pomegranates (Chandra et al., 2010, pp. 2-5).

Country	Early Bronze Age	Middle Bronze Age	Late Bronze Age	Iron Age
Greece	-	-	1	4
Cyprus	1	-	1	-
Turkey	-	-	2	3
Lebanon	-	4	-	1
Syria	1	3	1	3
Palestine	6	4	4	7
Jordan	1	-	2	1
Egypt	-	2	8	-
Total	9	13	19	19

Table 6.14: Site-phases for the areas and time periods under study that have evidence of *Punica*. Dashes indicate that no information is currently available or published. The total number of site-phases is shown in bold. The small increases and decreases are probably the result of preservation issues, site bias, etc.

Sarpaki (1995, pp. 294-295) claims that one seed of *Punica sp.* dating to the Early Neolithic (6400-5800 BCE) was found in a funeral context at Toumba Balomenou, Greece. However, the publication did not include a description or photograph of the specimen, only a highly fragmented drawing of a possible seed (Sarpaki, 1995, p. 295, fig. 16b; Photo 6.1). Comparative analysis of pomegranate seeds from both modern-day Greece and Armenia (including wild and domesticated varieties) using the University of Sheffield and NAS RA Institute of Archaeology

and Ethnography reference collections revealed distinct morphological differences from the Sarpaki one. These seeds are generally more bulbous on the lateral side, with a more pointed apex and a less rectangular shape overall.

The earliest subsequent appearance of pomegranates in the Eastern Mediterranean is represented by *Punica* sp. L. specimens from Jericho and Tel Halif, dated to between 3200 and 2000 BCE. This creates a considerable chronological gap of at least 3,200 to 4,400 years following the previous occurrences. In the context of Greece, the next evidence of pomegranates comes from Tiryns, dated to 1300–1200 BCE, which corresponds to an even larger temporal gap of approximately 5,100 years. These substantial intervals, combined with observable morphological differences between the specimens, strongly suggest that the seed in question is unlikely to belong to a pomegranate. Despite occasional earlier mentions or depictions, the first credible archaeobotanical evidence of pomegranates in the study area can be confidently placed in the Early Bronze Age. This timing aligns with broader patterns of the diffusion of pomegranates in the Eastern Mediterranean.

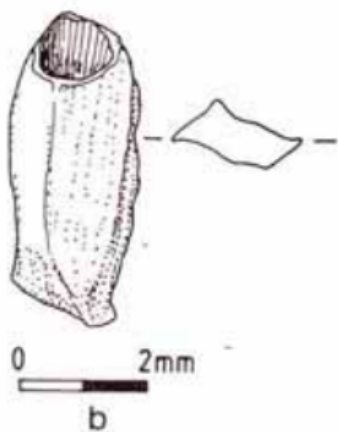
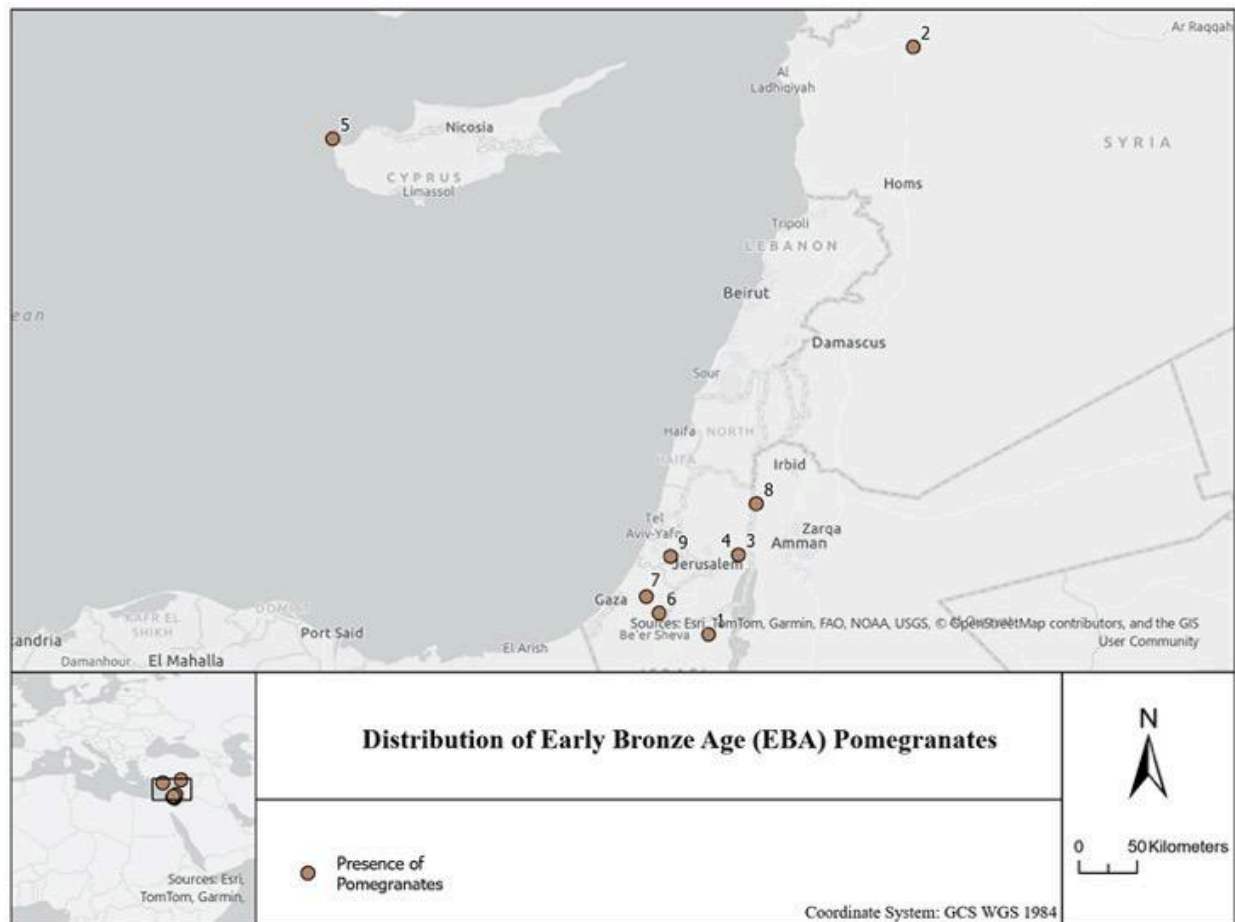


Photo 6.1: Drawing by Sarpaki (1995, fig. 16b) of a possible Neolithic pomegranate.

6.4.1 Early Bronze Age Distribution



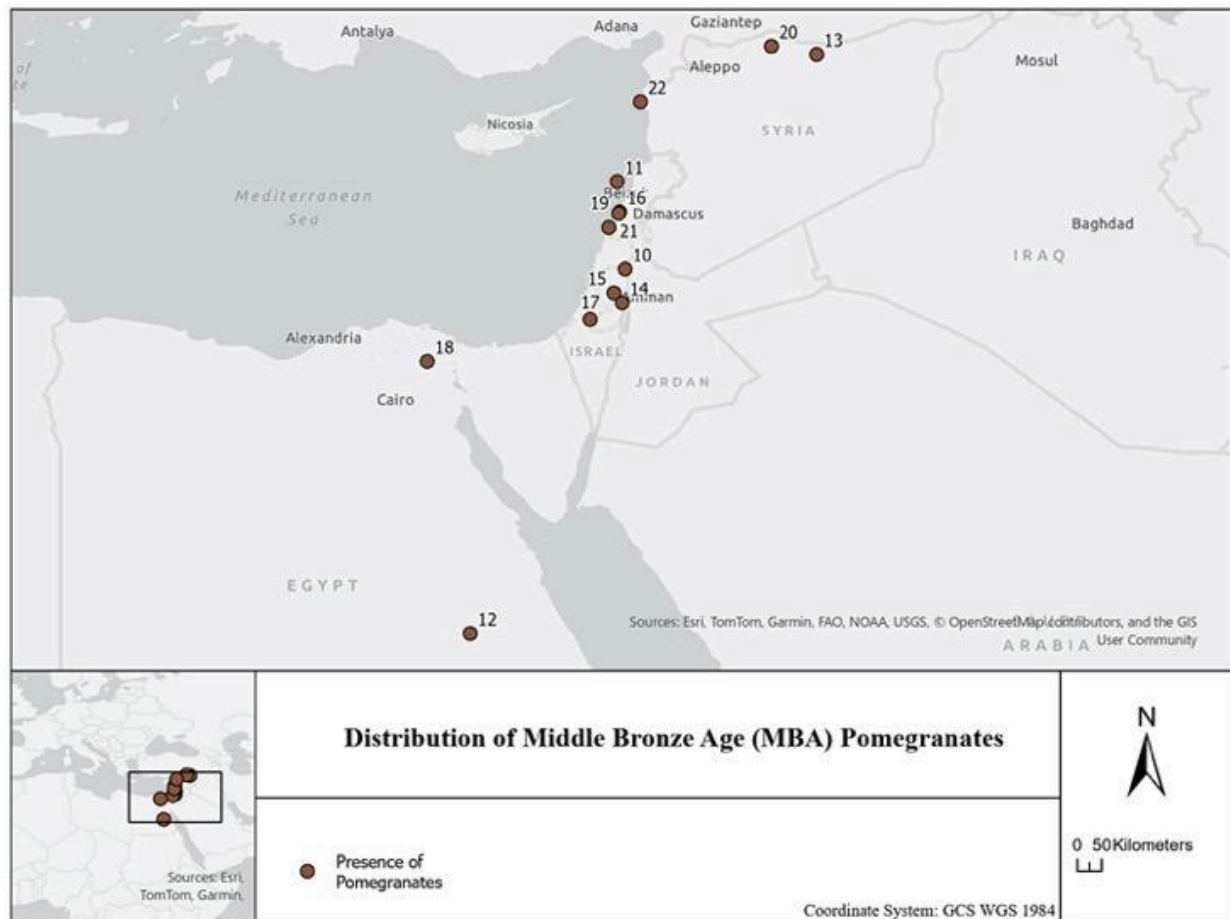
Map 6.22: Distribution of Early Bronze Age *Punica* evidence.

The earliest evidence of pomegranates (*Punica* sp. L.) in the regions under study comes from Tel Halif and Jericho in Palestine, dating to approximately 3200 BCE (Laustrop and Seger, 1990). Notably, more substantial evidence of pomegranate cultivation has been found in Palestine, with six site-phases recorded, compared to only one site-phase in Cyprus, Syria and Jordan (Map 6.22). Although no direct evidence of pomegranates has been found in Egypt before the Early Bronze Age, pollen data from *Punica* sp., dating to the 4th–3rd millennium BCE, suggests the possibility of early cultivation (Nicholson and Shaw, 2000). It remains possible that pomegranate remains from Egyptian sites have yet to be discovered. Furthermore, the presence of pomegranates in Cyprus further highlights the role of maritime trade or at least connectivity in their spread, appearing in c.2650 BCE. The active ports along the Levantine coast facilitated trade across the Mediterranean, making it likely that pomegranates reached Cyprus via these

networks (Lawall and Lund, 2013). The distribution pattern of the limited pomegranate data can suggest that they spread to new regions through both trade and human migration, reinforcing their significance in early agricultural economies.

The discovery of pomegranate seeds and wood in Jericho, dating to approximately 2200 BCE, suggests that the tree was likely already under local cultivation rather than the fruit being solely imported. This interpretation is reinforced by the presence of pomegranate wood, which is particularly significant given the tree's relatively thin and hard trunk. Such characteristics make it an unlikely candidate for long-distance transport, especially when more readily available local hardwoods could have fulfilled similar utilitarian purposes.

6.4.2 Middle Bronze Age Distribution



Map 6.23: Distribution of Middle Bronze Age Punica evidence.

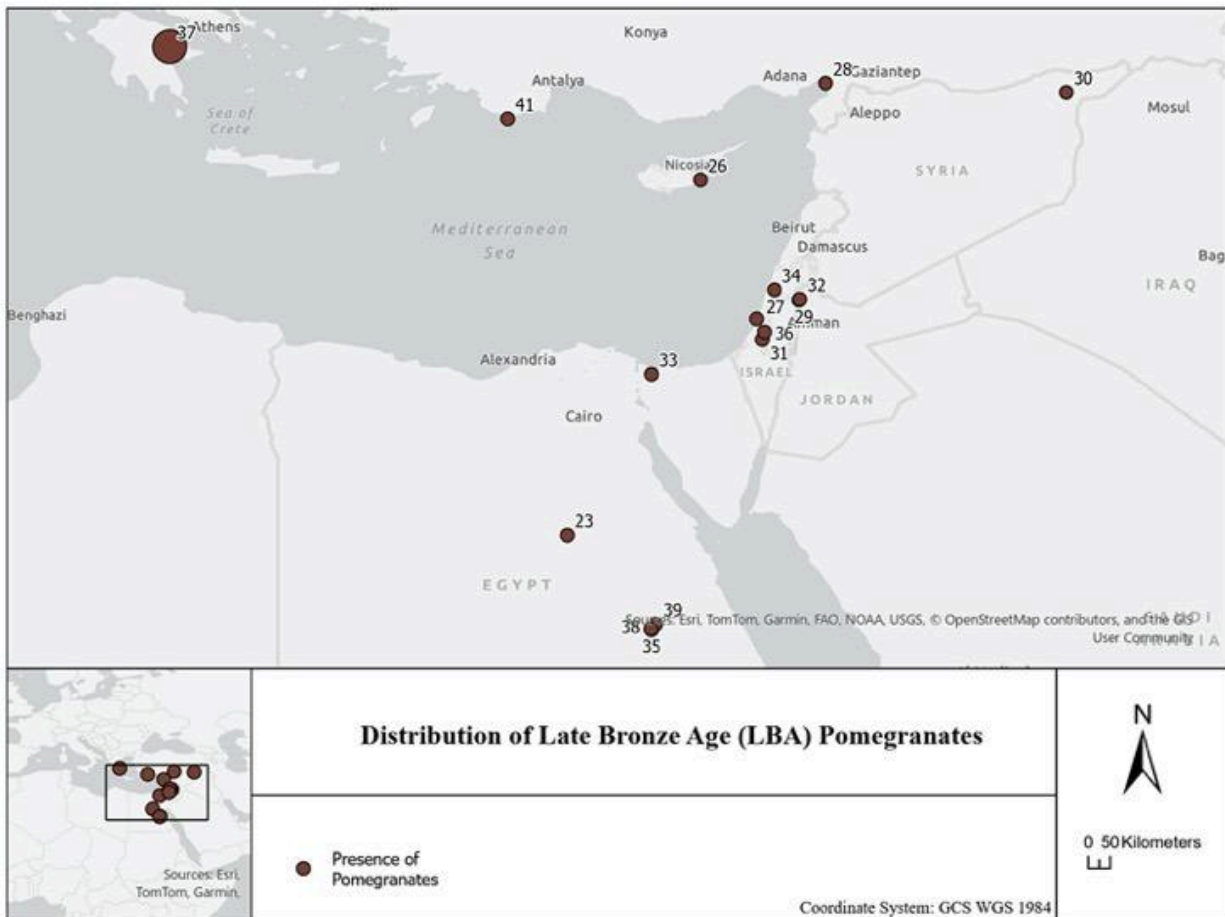
During the Middle Bronze Age, pomegranates appear in Egypt and Lebanon, where they are found in elite residences or tombs, indicating their status as high-value or symbolically significant items (Map 6.23). The emergence of pomegranates in these regions may reflect expanding trade networks, cultural exchange and the adoption of exotic or prestige crops by the elite, suggesting that their cultivation and consumption were closely tied to social status and regional connectivity.

All the sites are located either along the shores of major bodies of water, such as the Nile River, the Mediterranean Sea and the Dead Sea or along well-established trade routes. These routes played a crucial role in connecting the natural distribution zones of pomegranates in the Caucasus to the Mediterranean and further westward (Eren, 2010). However, the publications do not provide detailed descriptions of the specific contexts and locations of these sites, with the exception of three explicitly mentioned locations: a tomb in Jericho (Fuller & Stevens, 2019), a storeroom within a shrine in Shiloh (Kislev, 1993; Liphshitz, 1993) and an elite residence at Tell el-Dab'a in Egypt (De Vartavan & Asensi Amorós, 1997; Fuller & Stevens, 2019).

Since only three locations are under consideration, the analysis remains limited but it may offer some possible insights. The presence of pomegranates in a tomb in Jericho could suggest that the fruit may have held symbolic or ritual significance, potentially linked to beliefs about the afterlife, in a manner that might be somewhat comparable to practices in ancient Greece (Immerwahr, 1989, p. 408). Similarly, the discovery of pomegranates in what appears to be an elite residence at Tell el-Dab'a in Egypt may indicate that they were possibly consumed by the upper classes, which could suggest that pomegranates were perceived as a prestigious or luxury item (Haldane, 1993). The presence of pomegranates in a storeroom within a shrine in Shiloh might imply that they were stored for later use, perhaps for religious or ceremonial purposes, including possible consumption. This could indicate that the fruit was processed in some way, possibly dried or preserved. The association of pomegranates with both an elite residence and a religious shrine may suggest that they were regarded as a high-status commodity, which were likely either carefully cultivated or still imported. This interpretation aligns with the fruit's limited natural distribution and the necessity of trade to acquire it in certain regions. Furthermore, their presence in a tomb could reinforce the idea that pomegranates held symbolic

value, as their role may have extended beyond mere consumption to include ritualistic or spiritual significance (Ward, 2003).

6.4.3 Late Bronze Age Distribution



Map 6.24: Distribution of Late Bronze Age Punica evidence.

By the Late Bronze Age, pomegranates were more widely distributed across the Eastern Mediterranean, with the first evidence of their presence in the Aegean and Turkey dating to approximately 1300–1200 BCE (Map 6.24). There was an increase in site-phases in Egypt, a reappearance in Cyprus and Jordan and a slight decrease in Syria. However, these numbers are not substantial enough to suggest any meaningful conclusions.

Two main contexts have been associated with pomegranates in the archaeological record: tombs and elite residences, as well as kitchen or floor deposits, with 12 out of 19 site-phases falling into these categories. For example, at the elite residence of Tiryns in c. 1300 BCE, there is evidence

of at least 3 whole pomegranate fruits based on 1518 seeds being found within the same context (Kroll, 1982). A typical pomegranate ranges on average 600 seeds per pomegranate. It indicates that people in this elite residence either had them on display as a luxury item or an item for prestige or were consuming them. Their presence in tombs and elite residences suggests that pomegranates were likely considered a luxury item, consumed or displayed by the wealthy and ruling classes. Furthermore, the discovery of pomegranates, along with seeds, skin fragments and flower parts, in the Uluburun shipwreck indicates that they were already being cultivated in some quantity in Syro-Palestine and transported west of Cyprus, possibly to the Aegean, where data remains limited. Their inclusion in the cargo further reinforces the idea that pomegranates were valuable and important enough to be traded over long distances (Haldane, 1991).

While these findings highlight the high status and symbolic significance of pomegranates, evidence from Kinet Höyük suggests their use in everyday consumption. Ten pomegranate seeds were found in a kitchen floor deposit near a large bowl, indicating possible processing for food preparation. According to Hynd (1997), this deposit likely resulted from kitchen activities, with archaeobotanical remains accumulating along the edges after being swept aside. The presence of fine sieve by-products from cereal processing further supports the idea that crops were cleaned just before being prepared as food. This suggests that pomegranates were actively processed in kitchens, with some drupelets falling onto the floor during food preparation. However, the presence of the seeds near the bowl could indicate alternative uses. The bowl may have been used to submerge pomegranates in water to help separate the seeds more easily or to crush them for juice or another additive, functioning similarly to a pestle and mortar (see Chapter 7). Once done, they could have been discarded like Hynd suggested.

6.4.4 Iron Age Distribution



Map 6.25: Distribution of Iron Age *Punica* evidence.

Pomegranate findings continue to be broadly spread across the Eastern Mediterranean in the Iron Age (Map 6.25). The IA shows more evidence of site-phases with over 30 pomegranate seeds than any other period, likely due to preservation bias, as these are more recent finds. Both Corinth and Deir'Alla have evidence of pomegranate seeds (46 and 258, respectively) but from unspecified contexts (Bookidis, 1990; Neef, 1989). The lack of detailed context limits conclusions about their role but their presence suggests pomegranates were used during this period.

Ashkelon has yielded evidence of 42 pomegranate seeds from around 900–700 BCE. One concentration, found in a silo (267), includes 16 pomegranates, making up the majority of a rich plant assemblage with all considered local. A second concentration, also containing 16 pomegranates, was found near Silo 267 in a deposit between the administrative center, counting

house and warehouse magazine (Weiss and Kislev, 2004). Additional seeds were found in various rooms: three in an administrative building (Room 252/260), one in a counting house (Room 221), three in a warehouse magazine (Room 421) and three in a shop (Room 406). This distribution suggests the movement of pomegranates within the site, likely following a process where they were first delivered to the administrative building for handling, counted in the counting house for record-keeping, stored in the warehouse and eventually sold in shops for consumption or rituals. However, the lack of clarity about how they were stored before being sold, whether fresh, dried or processed into wine with seed dregs, remains an open question.

At the Heraion at Samos, over 750 pomegranate seeds were found near shrines and cultic objects, dating to approximately 900–700 BCE. Pomegranates, along with pomegranate-shaped items, were customary offerings to the goddess Hera and were discovered in large quantities at the site (Kucan, 1995; Immerwahr, 1989). This suggests that pomegranates held significant religious value. Their prominent role in these offerings indicates that pomegranates were not only important religious symbols but may also have been associated with elite status, as only those of higher social standing would likely have placed them at the shrines. The large quantity of seeds found suggests that whole fruits were likely offered in rituals, implying they were not for human consumption but rather for the goddess Hera and other deities.

6.4.5 Brief Conclusions

There is evidence of pomegranates dating back to the Early Bronze Age in Syria, Palestine and Cyprus, followed by Middle Bronze Age findings in Egypt and Lebanon and Late Bronze Age evidence in Greece (Table 6.15), while the first evidence of pomegranate caches comes from the Late Bronze Age in Greece (Tiryns), Iron Age in Palestine (Ashkelon) and Jordan (Deir'Alla), along with the site-phase of Corinth.

Regions	Confirmed Presence (BCE)	Site Evidence/Sources
Greece	LBA 1300-1200 BCE	Tiryns (Kroll, 1982)
Cyprus	EBA 2650-2200 BCE	Kissonerga-Skalia (Lucas and Fuller, 2020)
Turkey	LBA 1300-1200 BCE	Kinet Hoyuk (Hynd 1997; Nesbitt and Samuel 1996)

Lebanon	MBA 1700-1600 BCE	Byblos, Sidon, Tyre, Tell el-Burak (Nigro and Spagnoli, 2018)
Syria	EBA 3000-2000 BCE	Ebla (Wachter-Sarkady, 1995; Ward, 2003)
Palestine	EBA 3200-2000 BCE	Tell Halif (Laustrop and Seger, 1990); Jericho (Bar-Yosef, 1986; Hopf, 1983; Western, 1971)
Jordan	EBA 2300-2000 BCE	Tell es-Sa'idiyeh (Cartwright, 1996; Ward, 2003)
Egypt	MBA 1991-1803 BCE	Dra' Abu el Naga (Zoahry and Hopf, 1993)

Table 6.15: Site-phases with the first evidence of pomegranates based on archaeobotanical data found to date.

The spread of pomegranates across the Eastern Mediterranean from the Early Bronze Age to the Iron Age likely marks a likely and gradual shift from local consumption to more systematic cultivation, trade and possibly value-added products. By the Iron Age, pomegranates became more integrated into daily life, appearing in diverse regions and social contexts, including elite residences, tombs and kitchens. However, evidence for processed pomegranate products, such as wine or dried fruit, remains inconclusive, with most evidence pointing to raw fruit consumption.

In places like Ashkelon and Corinth, pomegranates are part of local consumption patterns, found in administrative and commercial areas, suggesting some processing (e.g., seed separation, storage or drying). In contrast, at the Heraion at Samos, pomegranates were symbolic, found near shrines in large quantities, likely for ritual purposes. This suggests that while pomegranates may have been consumed or used in rituals in some areas, in others they were more symbolic or luxury items.

Sites like Ashkelon hint at pomegranates being part of trade and market systems, while the Heraion at Samos associates pomegranates with religious and elite practices. The lack of detailed context at most sites limits our understanding of processing methods but the high concentration of pomegranates in elite and ritual contexts suggests a growing market for pomegranates as luxury items. While there is potential evidence of processing at sites like Ashkelon, the absence of clear proof for products like wine or dried fruit prevents definitive conclusions about market trends. Overall, the widespread use of pomegranates highlights their increasing prominence and value in both daily life and ritual practices.

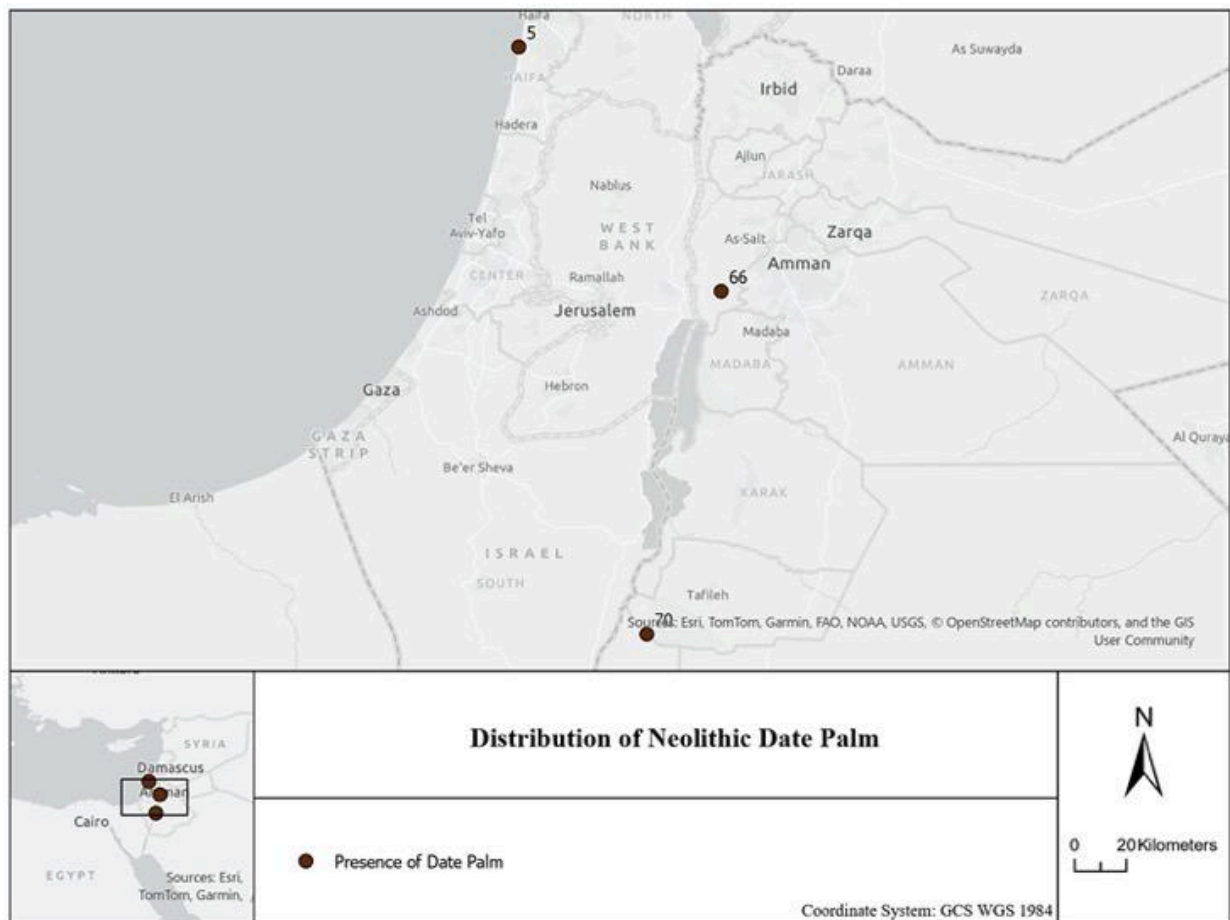
6.5 Phoenix Dactylifera

The *Phoenix dactylifera* (date palm) has some of the scarcest evidence among the tree fruits examined in this study, appearing in only 64 site-phases across four regions ([Appendix 8](#)) (Table 6.16). Therefore, only tentative and sometimes ambiguous conclusions can be drawn.

	Neo	Chal	EBA	MBA	LBA	IA
Lebanon	-	-	1	-	-	1
Palestine	1	1	4	1	2	24
Jordan	2	2	3	-	2	1
Egypt	-	1	2	7	8	1
Total	<u>3</u>	<u>4</u>	<u>10</u>	<u>8</u>	<u>12</u>	<u>27</u>

Table 6.16: Site-phases for the areas and time periods under study that have evidence of *Phoenix Dactylifera*. Dashes indicate that no information is currently available or published. The total number of site-phases is shown in bold. The small increases and decreases are probably the result of preservation issues, site bias, etc.

6.5.1 Neolithic Distribution



Map 6.26: Distribution of neolithic *Phoenix* evidence in the Levant.

The earliest evidence of date palm remains originates from the Levant, specifically from the site of Ghwair I (Simmons and Najjar, 2003; De Vartavan and Asensi Amoros, 1997). Both the Neolithic (Map 6.26) and Chalcolithic (Map 6.27) periods show minimal evidence of date palm cultivation, with three site-phases in the Neolithic period (one in Palestine and two in Jordan) and four site-phases in the Chalcolithic period (one in Palestine, two in Jordan and one in Egypt).

The Neolithic distribution of date palms is concentrated within the Jordan Rift Valley and along the Mediterranean coast. This distribution aligns well with the ecological requirements of date palms, as they need a consistent water supply and can thrive in saline environments (Tripler et al., 2011), including in areas near bodies of water like the Mediterranean Sea and the Dead Sea. The sites within the Jordan Rift Valley experienced very limited rainfall, receiving less than 200 mm per year (Bonn, 2013). These arid conditions would have made the cultivation of other

fruit-bearing trees challenging. The date palm with its high caloric yield would have been an ideal crop for such an environment. The sites are also all situated on trade routes (Fall et al., 2002).

At Atlit-Yam, it is unclear whether the specimen belongs to *Phoenix dactylifera* or *Phoenix theophrasti* (the latter being native only to Crete). If the Atlit-Yam sample is indeed *P. theophrasti*, it could suggest that this species had a wider distribution than previously thought, as its range is typically associated with Crete, the surrounding Aegean islands and possibly southwestern Turkey. Alternatively, it could indicate that Crete had already established direct or indirect connections with the Levant (Garcia-Granero et al., 2020).

6.5.2 Chalcolithic Distribution

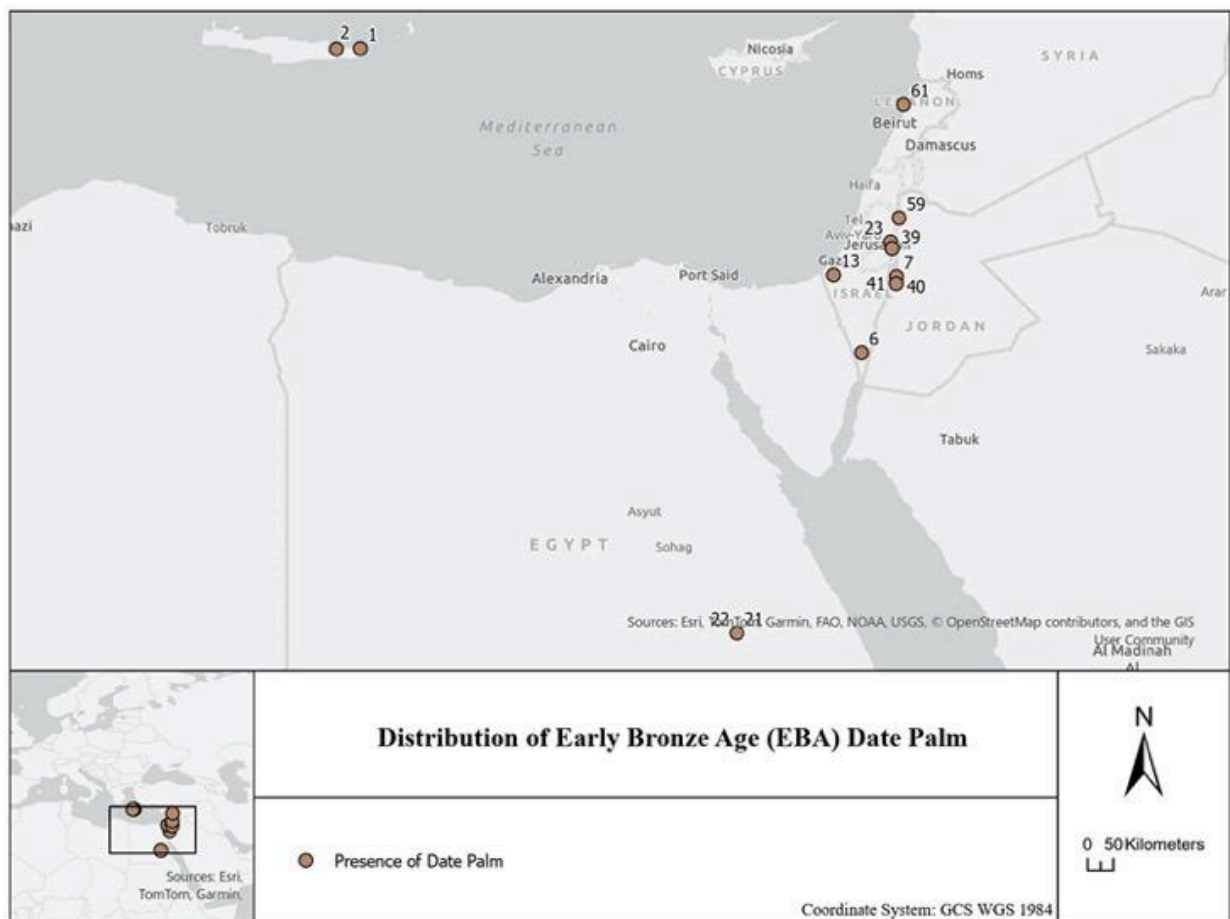


Map 6.27: Distribution of chalcolithic *Phoenix* evidence.

The first appearance of date palms was found in Egypt at the settlement of El-Omari (c.4000-3150 BCE) during the Chalcolithic (Map 6.27). In the Levant, archaeological sites

continued to be located in traditionally lower-quality land areas characterised by higher soil salinity and access to salty water sources for irrigation and watering. If date palms were being cultivated in these areas, it suggests that people were already differentiating agricultural and horticultural lands based on the specific requirements of plant species or were intentionally utilising "marginalised" land for cultivation. This pattern persists across all the time periods under study. Additionally, the consistent presence of date palm evidence at Teleilat Ghassul from both the Neolithic and Chalcolithic periods could indicate either the local cultivation of date palms or continuous contact with regions where date palms were being grown.

6.5.3 Early Bronze Age Distribution



Map 6.28: Distribution of Early Bronze Age Phoenix evidence. Evidence of *P.theophrasti* was found on Crete (Pseira Island and Palaikastro) dating from c. 3000-2000 BCE)(García-Granero et al., 2020).

The EBA exhibits the highest regional diversity in this small dataset, with evidence present in all five regions, Lebanon, Palestine, Jordan, Crete and Egypt and the earliest evidence emerging

from Lebanon (Map 6.28). The data provides three interesting insights. Firstly, at the site of Hierakonpolis, five date palm fruits (flesh part only) were found amongst palm leaves in a vat, suggesting possible wine making since the fruits would have likely been crushed without the pits and then water added to the fruits to ferment (for more information on date wine see Chapter 7)(Amer 1994; Darby et al. 1977). Ethnographic evidence from Palestine and Nigeria suggest that palm leaves were added to the fermentation process for flavour and colour (Oladoja et al. 2021; Amponsah et al. 2019). Date palm wine production was almost exclusively linked to large vats/pithoi (see Chapter 7). Furthermore, the presence of additional date wood, roots, palm flower and leaflets from Egyptian sites in the Chalcolithic suggests that it could have been easily cultivated in Egypt by this period (de Vartavan and Amoros, 1997).

Secondly, the earliest confirmed evidence of date palms in Lebanon was discovered at Tell Fadous-Kfarabida, where echinate spheroid phytoliths were found in large storage bins within an administrative complex, appearing in "not insignificant numbers" (Damick, 2019, p. 486). The presence of these phytoliths in nearly every phase of the EB III compartment, but not in earlier pits, suggests either the introduction of the date palm to the area, the initiation of trade involving dates or the potential harvesting of dates from nearby regions. This timing may coincide with the realignment of Egyptian trade connections (evidence already for wine). The findings indicate either the storage of whole dates or their processing into a value-added product, specifically through the maceration of dates before fermentation. The stone storage areas, considering their size, may have also been used to crush dates with stones or rollers. Given the capacity of the storage vessels and the consistent presence of phytoliths, this evidence strongly supports the intentional storage of dates for consumption during the EBA.

Thirdly, based on their size and shape, seven wild date seeds (*P. sylvestris*) were found at the EBA site of Qumran Cave 24. The EBA seeds are 2-3 times smaller in both width and length compared to their domesticated Roman counterparts from the 1st to 3rd centuries CE (Liphschitz and Bonani, 2001). This size difference could suggest that wild date palms did indeed grow in Palestine, potentially indicating a broader distribution of wild dates than previously recognised. The presence of smaller, wild dates at this site, despite the more favorable consumption qualities of the larger domesticated varieties, may imply that dates were being consumed earlier than

previously thought and that not all communities engaged in date domestication, even when domesticated varieties were available for cultivation.

The majority of site-phases are located either on poor-quality land with minimal rainfall but access to water sources (such as the Mediterranean, the Sea of Galilee, the Dead Sea and the Nile) and/or along the Jordan Rift Valley and the coastline. All of these locations are connected to trade routes (Fall et al., 2002; Kafafi, 2014). The date palm's adaptability to arid conditions, along with its high calorific content and economic value (due to its transportability and long shelf life), likely promoted its spread along these routes.

6.5.4 Middle Bronze Age Distribution



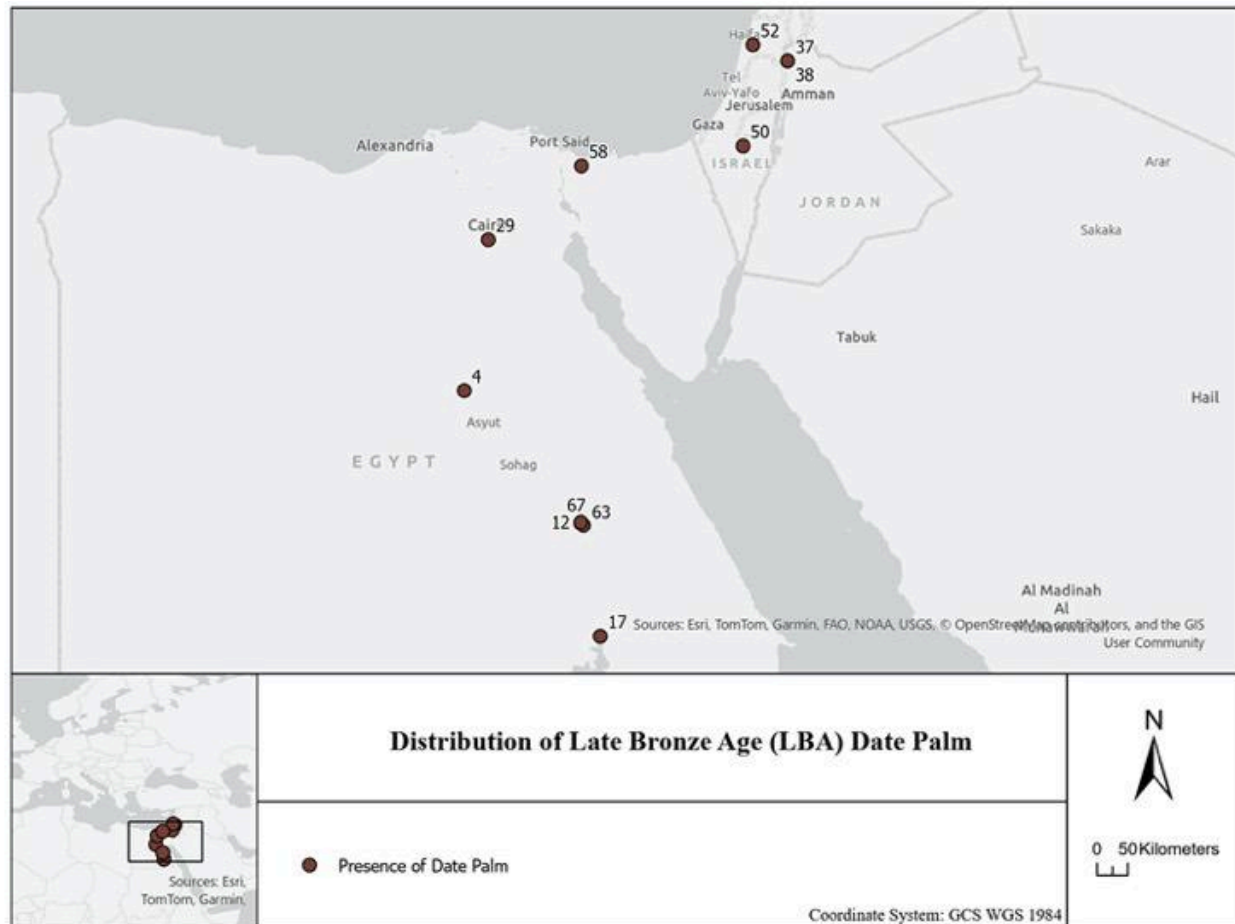
Map 6.29: Distribution of Middle Bronze Age Phoenix evidence.

During the Middle Bronze Age (2200-1500 BCE), date palm seeds were predominantly found in Egypt, with limited recorded evidence in Palestine (Map 6.29). These changes are minimal at

best and primarily reflect a presence-absence bias, rather than indicating any significant trend. There is still a clear clustering of sites along major water sources, such as the Nile River and the Mediterranean and Red Seas. This pattern aligns with the ecological needs of date palms and also suggests potential connections to ancient trade routes, particularly since trade links between Egypt and Palestine have been documented as early as the Early Bronze Age (García, 2022; Kafafi, 2014; Joffe, 2019).

The lack of evidence from Palestine and Jordan is likely due to appearance bias but it could also be related to lower population levels, limited agrotechnological development and smaller, more heavily fortified urban centers (Broshi and Gophna, 1986). The increase in the appearances of site-phases and the spread in Egypt by the Middle Bronze Age could be partially explained by Egypt's centralised authority, economic stability and flourishing state, as well as by the introduction of artificial pollination and vegetative propagation. This was not practiced until sometime in the Middle Kingdom according to iconographic examples and the development of African date palm cultivars (Nicholson and Shaw 2000; see Flowers et al. 2019 for more information on genomic species differentiations). These factors created a social and political environment that was more conducive to agricultural innovation and the systematic cultivation of new crops. The incorporation of different *Phoenix* varieties, combined with changing patterns of agricultural practice and storage, likely contributed to an increase in the archaeological presence of dates, particularly in contexts associated with consumption, storage and redistribution. Such developments not only reflect advances in agricultural practice but also indicate broader shifts in the social and economic role of the date palm within Egyptian society during this period.

6.5.5 Late Bronze Age Distribution



Map 6.30: Distribution of Late Bronze Age Phoenix evidence.

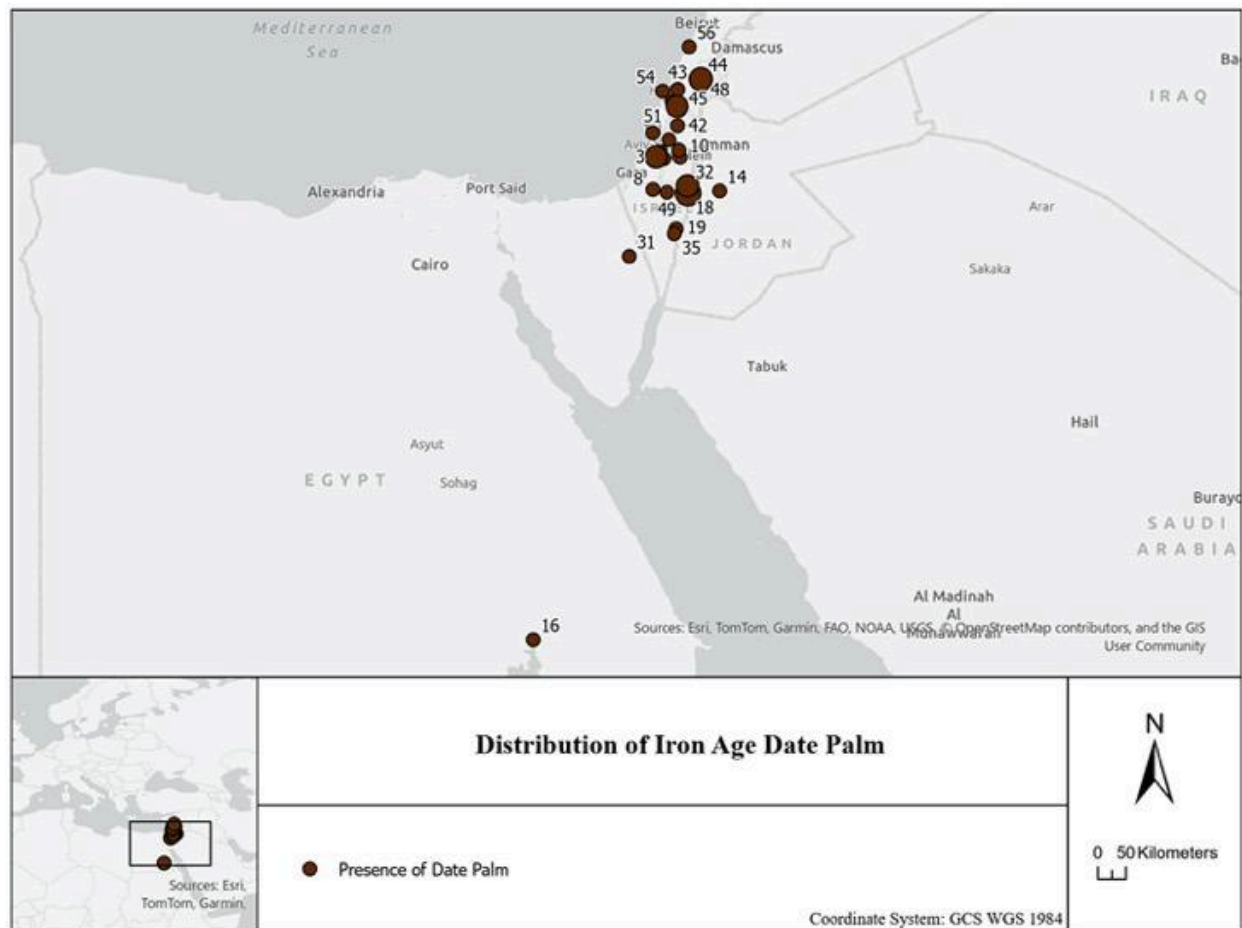
In the Late Bronze Age, date palm seeds were discovered throughout Egypt and in the southern Levant (Map 6.30). The number of site-phases in Palestine and Egypt remained generally unchanged, while evidence of date palms reappeared in Jordan. These minimal changes primarily reflect a presence-absence bias rather than any significant shifts in cultivation or distribution. The clustering of date palm evidence around water sources and trade networks remained consistent with previous periods.

Almost all of the archaeobotanical evidence for dates has been recovered within settlement contexts, suggesting that dates were actively consumed, stored or possibly processed on-site. However, the precise nature of their use remains ambiguous. It is unclear whether the dates were stored for immediate raw consumption, deliberately dried in order to extend their shelf life or transformed into more complex, value-added products. The challenge in interpretation arises

because the published reports often provide little or no contextual detail about the precise find spots of the remains. Mentions are usually limited to general references to middens or refuse deposits, with little accompanying information on storage facilities, processing installations or associated artefacts. In effect, the evidence documents presence rather than practice, making reconstructions of economic or culinary behavior highly tentative.

Despite these limitations, notable examples shed light on consumption practices. Notably, there is clear evidence of consumption at Tutankhamun's tomb (c. 1329–1327 BCE), where seeds, whole fruits, leaves and fibers were discovered together (Germer, 1989). This assemblage was likely intended for consumption in the afterlife but it simultaneously provides insights into the role of dates in the daily life of the living. The assemblage reflects their status as a staple or valued foodstuff, while the inclusion of leaves and fibers points to an appreciation of the plant's broader utility. The increasing frequency of remains of other date palm parts, such as leaves, fibers and bark, further suggests that by the New Kingdom and later periods, a recognizable date palm industry had emerged across Egyptian sites. This trend likely reflects not only the intensified cultivation of date palms but also their integration into multiple sectors of the economy. Beyond their use as table fruits, date palms provided a versatile range of resources: wood for beams and construction, fibers for ropes, sandals and wigs and pits that could be diverted for animal fodder. At the same time, it is possible that fruits were occasionally processed into derivative products, whether fermented beverages, sweeteners or foodstuffs with longer shelf lives (Nicholson and Shaw 2000). These patterns point to the rising economic and cultural value of the date palm, demonstrating its deep entrenchment in everyday subsistence as well as in the broader material culture of Egypt.

6.5.6 Iron Age Distribution



Map 6.31: Distribution of Iron Age Phoenix evidence.

Unlike the MBA and LBA maps, the Iron Age map reveals a pronounced shift in date palm distribution toward the Levant region, particularly Palestine and almost no presence in Egypt (Map 6.31). The limited data from Egypt, Lebanon and Jordan likely reflects a bias in the archaeological record rather than an actual shift in consumption and production trends. The clustering of sites along the Mediterranean coast reflects their strategic placement within major Iron Age trade networks, particularly the extensive Phoenician maritime routes (Puckett, 2013; Sommer, 2019). In contrast, the inland sites appear to be oriented along overland trade corridors that connected Egypt and the Levant with Mesopotamia, the Arabian Peninsula and other parts of the Near East (Bauer, 2002; Liverani, 2003). The arrangement of coastal and inland settlements highlights a twofold system of trade, in which sea and land routes functioned together to facilitate the economic and cultural interactions of the Iron Age.

Only five site-phases (Tel Ekron, En Boqeq, Masada, Megiddo and Tannach) contain a substantial concentration or cache of date palm seeds exceeding 30, all of which are from Iron Age sites in Palestine. This concentration may indicate a significant increase in date palm consumption during this period, potentially reflecting broader dietary or cultural shifts. Alternatively, the pattern could be influenced by preservation biases. The notable absence of similar concentrations at other contemporary sites may reflect these preservation issues rather than a true absence of date palm use elsewhere.

Unfortunately, the lack of clear provenance and contextual information for these deposits complicates any definitive interpretation. For instance, at Masada (c. 900-600 BCE), archaeologists discovered not only large wood samples but also a cache of 43 date palm seeds. However, the specific context of these finds was not recorded (Liphschitz and Lev-Yadun, 1989). Similar issues arise with other significant discoveries, including 37 seeds at Tel Mique (Ekron) (Eitam, 1986; Eitam and Shomroni, 1987), 45 seeds at Megiddo (Hopf, 1983), 141 seeds at En Boqeq (Liphschitz and Waisel, 1993) and 78 seeds at Tannach (Beerli, 2008; Frankel, 1999). The absence of detailed contextual data at these sites makes thorough analysis challenging. At Tel Mique, over 161 simple lever and weight presses have been discovered. Although these presses were not found in association with date seeds, they may still have been used to crush dates, which were then fermented into date wine. This usage is plausible, considering the equipment would likely have been in use for several months each year, especially since olives and dates were harvested at different times. Nevertheless, the Iron Age does exhibit not only an increase in the number of archaeological sites with evidence of date palms but also a significant rise in the total number of date palm seeds recovered. This trend aligns with historical accounts suggesting that Palestine, particularly the Kingdom of Judah, became renowned for both the quality and quantity of its dates. These dates were celebrated for their large size, sweet taste, ease of fermentation, extended storage potential and medicinal properties (Sallon et al., 2020). The archaeological evidence, paired with historical records, suggests that date palms played an increasingly important economic and cultural role in Iron Age Palestine.

6.5.7 Brief Conclusions

The cultivation and trade of date palms during ancient periods were largely influenced by a delicate balance between ecological suitability and trade potential. Ecologically, date palms thrived in regions with access to water, even in areas with poor-quality soil and limited rainfall. This adaptability made them an ideal crop for arid and semi-arid regions, where few other crops could survive. Economically, the proximity of date palm cultivation sites to trade routes enhanced their distribution and integration into broader trade networks, especially due to their long shelf life and long-distance trade potential. Whether along river valleys like the Nile or coastal trade routes used by the Phoenicians, date palms were well-positioned to become a valuable commodity in both local and long-distance trade.

The first evidence of date palm use appears in Jordan during the Neolithic (Ghwair 1), in Palestine (Nahal Mishmar) and Egypt (El-Omari) during the Chalcolithic and in Lebanon (Tell Fadous-Kfarabida) and Crete (Pseira Island and Palaikastron) during the Early Bronze Age. This early distribution demonstrates the adaptability of date palms to diverse ecological zones and their integration into early agricultural systems (Table 6.17).

	Confirmed Presence (BCE)	Site Evidence/Sources
Lebanon	EBA (c. 2900-2500 BCE)	Tell Fadous- Kfarabida (Damick, 2019)
Palestine	Chal (c. 4500-3200 BCE)	Nahal Mishmar (Liphschitz, 1989; Zaitschek, 1961)
Jordan	Neo (c. 7000-6000 BCE)	Ghwair 1 (Simmons and Najjar, 2003)
Egypt	Chal (c. 4000-3150 BCE)	El-Omari (Nicholson and Shaw, 2000)

Table 6.17: Site-phases with the first evidence of date palms based on archaeobotanical data found to date.

While most documented date palm remains from the Iron Age and the only date palm caches (En Boqeq, Masada, Megiddo, Taanach and Tel Migne), have been discovered within settlement sites, this evidence alone does not conclusively demonstrate that date wine was produced there. However, it is plausible that date wine could have been made using a simple fermentation process, possibly involving basic fermentation vessels (see Chapter 7 for more details on processing equipment). Given that date palms are typically harvested a few times a year, the fruit might have been crushed either on-site or nearby, then transported to the settlement and

combined with water in fermentation vessels. This approach would have minimised the challenges associated with transporting the heavy fruit or liquid mixture, allowing for the possibility that both processing and storage occurred within the settlement.

The sharp increase in date palm evidence during the Iron Age, especially in Palestine, could signify a transition toward more systematic agricultural and economic practices. The high concentration of date palm remains, including large caches of seeds, suggests an increase in consumption or possibly the processing of dates into products like date wine. This shift might also reflect enhanced cultivation and trade practices. In contrast, the consistent presence of date palms in Egypt throughout various periods indicates a well-established tradition of fruit use. The increase in fruit visibility in site-phases during the Iron Age likely correlates with increased stability and population growth, necessitating a reliable food supply. Due to their high calorific return, multiple harvest periods and ability to grow and adapt in diverse environments, date palms became an attractive crop for supporting expanding communities.

The scarcity of date palm remains on Crete and Cyprus is perplexing. Despite strong iconographic and epigraphic evidence of *Phoenix dactylifera* (García-Granero et al., 2020), only a few *P. theophrasti* seeds have been discovered. From as early as 1900 BCE, wall paintings, pottery, seals and Linear B tablets depict date palms, suggesting an awareness of the species. However, these artistic representations often lack the hanging clusters of ripened fruit seen in Egyptian and Western Asian art, which might indicate that *P. theophrasti*, rather than *P. dactylifera*, was more common in this region (Taiz and Taiz, 2017, p. 142). There is also an absence of macro-archaeobotanical evidence for the consumption or storage of *P. theophrasti* or any other palm species in prehistoric Crete. This gap is particularly striking given that the largest population of *P. theophrasti* exists on Crete today (Livarda and Kotzamani, 2013). It raises questions about whether the palm species depicted in Minoan and Mycenaean art was cultivated for aesthetic or ceremonial purposes rather than for fruit production or trade.

Overall, the interplay between ecological suitability (e.g., proximity to water, ability to grow in regions with limited rainfall and poor soil) and trade potential (e.g., access to trade routes) shaped the cultivation and trade of date palms in this period. The consistent presence of date palms in settlement contexts, their increased prominence in the Iron Age and the enigmatic

absence in Crete and Cyprus contribute to a complex picture of date palm use in the ancient world. The evidence suggests that date palms were not only a dietary staple but also played a role in trade and possibly in ceremonial or medicinal contexts, depending on the region.

6.6 Discussion and Conclusion

The archaeobotanical data presented in this chapter indicates a broad yet discernible trajectory from the use of raw tree fruits to the more systematic development of value-added products (e.g., wine, vinegar, olive oil, raisins, dried figs and possibly date wine). Although specific historical and environmental contexts vary between regions, three major conclusions stand out.

Overall, grapes, olives and figs appear very early in the Pre-Pottery Neolithic in the southern Levant and northern Fertile Crescent, frequently outside their natural distribution zones. Initially, these fruits were likely gathered for immediate consumption. Archaeobotanical contexts such as refuse pits and domestic hearths show small-scale use, often with a limited number of seeds or stones. By the time of the Early Bronze Age and especially moving into the Middle and Late Bronze Ages, data increasingly pointed to larger-scale, intentional gathering or cultivation and more complex processing. Concentrated caches of seeds, crushed stones and the co-occurrence of specialised equipment (e.g., treading floors, fermentation vats and simple lever and weights press) mark a pivotal shift toward producing wine, vinegar, raisins and olive oil.

Less ubiquitous pomegranates and dates also follow a broad progression from minimal, possibly imported use (when found well outside their wild range) to more frequent local cultivation and eventual integration into regional trade systems. Pomegranates appear relatively late, no earlier than the Early Bronze Age in Syria, Palestine and Cyprus, often in wealthy or ritual contexts (e.g., tombs, temples or elite residences). Date palms, especially in the Levant and Egypt, remain strongly tied to areas with high salinity or marginal lands near water sources; by the Iron Age, certain sites (e.g., those in Palestine) yield large numbers of date seeds, hinting at significant, possibly commercial-scale exploitation. Collectively, these patterns confirm a discernible trend from small-scale consumption toward systematic processing of tree fruits into value-added products.

Despite the overarching shift, regional trajectories vary significantly, reflecting differences in ecology and trade connections. In the Southern Levant (Palestine and Jordan), some of the earliest evidence for fruit processing, especially wild grape treading (possible early wine) and early olive oil production, appears here in the Pre-Pottery Neolithic and Neolithic. By the Early Bronze Age, sites such as Tel Yarmouth, Jericho and Tell esh-Shuna show extensive archaeobotanical remains tied to specialised installations, suggesting a well-developed fruit-processing tradition.

In the Northern Levant (Lebanon and Syria), olives, grapes and figs also appear early but clear evidence for large-scale value-added processing (e.g., specialised presses) emerges prominently by the Middle and Late Bronze Ages. Pomegranates become visible in the Middle Bronze Age, often associated with elite or ritual contexts, indicating a comparatively later adoption or local cultivation.

In the Aegean (Greece, Crete and Turkey) grapes, figs and olives are first documented in the Neolithic but large-scale wine and oil production truly intensified in the Early to Middle Bronze Age, aligning with the rise of early complex societies and maritime trade. Olive oil in particular became central on Crete by the Middle and Late Bronze Ages, evidenced by simple lever and weight presses, large storage vessels and significant seed caches.

In Egypt, fig and dates are present from the Chalcolithic or earlier but unequivocal pomegranate finds date only to the Middle Bronze Age and later, mainly in elite tombs and palatial complexes. Evidence of date palms and their by-products became especially prominent in the Middle and Late Bronze Ages. Wine production is also well-attested (e.g., residues in jars), though archaeobotanical links between specialised grape presses and site remains are not evidenced.

Although Armenia is frequently considered a center of early grape domestication (as shown by Areni-1 cave in the Chalcolithic), other fruit evidence, particularly pomegranates, remains conspicuously sparse in the macro-botanical record. Finds of grapes in purpose-built installations support an early and sophisticated wine or vinegar tradition despite fewer domesticated grape remains in the earliest phases. These regional differences highlight that while fresh fruit consumption is widespread from the outset, the emergence of fruit processing and thus the transition to value-added product economies, does not follow a single timeline.

The progression from fresh fruit consumption to processed commodities, such as wine, olive oil, raisins, dried figs and possibly date wine, reflects market variability, as it suggests choices in cultivation priorities and the necessary processing equipment and economic differentiation across the eastern Mediterranean and Armenia. For instance, in terms of quantity and scale, in regions like the southern Levant (for olives) and Armenia or Greece (for wine), large caches of seeds and processing residues point to surplus production beyond basic household needs, implying a robust local or interregional trade. In areas where fruit remains appear sporadically (e.g., certain parts of Turkey or Lebanon), the evidence may represent either smaller-scale local consumption or incomplete archaeobotanical sampling.

Morphological studies occasionally differentiate wild from domesticated varieties (as with grapes and olives) but often both forms seem to have been processed similarly. This underscores that domestication was not a strict prerequisite for turning fruits into oil, wine or dried goods, wild stocks were utilised effectively long before full domestication. Over time, however, regionally preferred cultivars developed, possibly selected for higher sugar or oil content. This could have impacted the quality and types of value-added products being produced and possibly the ease of production. Pomegranates and certain figs often appear in tombs or elite residences, reflecting their perceived value as prestige goods or ritual offerings. The frequent discovery of raisins, grape pressings or olive press residues in everyday domestic contexts suggests a steady demand in ordinary diets and local economies, not merely high-status consumption, at least by the later time periods. Together, these patterns indicate that while all regions experienced some degree of fruit processing, the scale, intensity and market integration varied widely depending on ecological potential, cultural preferences and access to trade. By the Iron Age, many areas show robust evidence of surplus production and specialised equipment. The combined archaeobotanical record thus demonstrates a clear, albeit regionally varied, non linear-evolution from small-scale local fruit gathering to systematic processing and value-added production.

Chapter 7 - Pressing Concerns: The Archaeology of Processing Equipment

This chapter examines archaeological evidence of oil and wine production equipment from the Neolithic to the Iron Age in the eastern Mediterranean and Armenia. Armenian production

equipment is discussed in detail in Chapter 8. Physical installations are the best evidence for olive oil and wine production, especially when there are traces of botanical data attached (Pratt, 2021, p. 47). The primary goals are to investigate: (1) whether such equipment became larger and more specialised over time, as is commonly assumed; (2) whether the rate of development varied between regions and micro-regions; (3) whether simpler, less specialised tools and facilities continued to be used alongside more advanced equipment and in which economic contexts; and (4) the effectiveness of each processing method and equipment. By analysing when and where processing equipment first appeared; what types of semi-specialised or specialised equipment was available and where; the changes in processing equipment, technological advancements (in terms of impact on quantity, quality and type of product); its geographical spread; its context in the wider economy and the effectiveness and benefits of each processing method for each fruit under study, we can gain crucial, albeit limited, insights into the variability of ancient markets for olive oil and wine from the times and areas under study. This is particularly significant as such equipment provides some of the most tangible evidence for the wine and oil processing industries. However, this area of study during the time periods indicated remains underexplored compared to the more extensive analysis of ceramics and other storage vessels, leaving gaps in our understanding of production technologies.

Another important objective that this chapter seeks to address is to understand how different architectural features of the processing equipment can actually impact the process of turning fruits into value-added products (e.g., movements of liquids and timing) since this is a generally missed or neglected focus within the study of processing equipment. Scholars like Frankel (1999), Hadjisavvas (1996, 2020), Foxhall (2007) and van W Scheepers (2006) have traditionally focused on architectural features of processing equipment, creating detailed typologies and descriptions based on characteristics like the shape of a press bed or the number of bores in a weights. This chapter seeks to shift the focus towards more functional and practical aspects, moving beyond typological distinctions that are frequently presented without sufficient explanation of their practical implications.

The analysis begins by examining changes in processing equipment over time, comparing designs, scales of production and technologies across the Neolithic, Chalcolithic, Bronze Age and Iron Age. This can reveal shifts in production capacity, specialisation and market expansion.

Production scale and capacity can indicate market variability. The size of processing equipment can be used to estimate production volumes and shifts toward surplus production, often tied to trade and general market demand. Changes in equipment size, from small household tools to large, industrial-scale installations, likely reflect market expansion and increased demand. Additionally, standardisation of tools, especially during the Bronze and Iron Ages, suggests the development of uniform production practices associated with wider markets. However, the achievement of these aims is somewhat problematic due to issues surrounding processing equipment (see Chapter 2 for more details)

Different Tree Fruit Pressure

When processing these fruits into value-added products, the amount of pressure needed varies based on the structural characteristics of fruits (e.g., fruit's texture, water content and internal structure) to ensure the quality of the wine and oil, as well as the ease of the process (Shanshiashvili et al., 2024; Del Fresno et al., 2022). Olives have a firm, fibrous structure and a hard pit, making them more resistant to pressure. The process involves not only breaking the flesh and the oil cells but also applying enough force to extract the oil from the pulp. Dates are dense and fibrous with relatively low water content. Processing them into a paste would require more pressure than softer fruits, like figs and grapes, due to their toughness. Figs are softer than dates and contain more natural moisture. They require moderate pressure to extract juice but their internal structure is less resistant than that of dates or pomegranates. While grapes are the softest among these fruits with a high water content, flesh-to-seed ratio, small pips and thin skin. Minimal pressure is needed to crush or press grapes for wine production and in fact, too much pressure can negatively affect the quality of the wine by releasing undesirable tannins from seeds and skins (Shanshiashvili et al., 2024). Even though pomegranates are the smallest tree fruit, they have tough, leathery outer skin and tightly packed seeds (arils) surrounded by juice-filled sacs. Extracting juice from pomegranates requires enough pressure to break the arils without crushing the seeds too much (to avoid bitterness), usually less than grapes though.

When processing fruits into value-added products, the amount of pressure needed varies based on their structural characteristics, such as texture, water content and internal structure, to ensure product quality and processing efficiency (Shanshiashvili et al., 2024; Del Fresno et al., 2022).

Olives have a firm, fibrous structure and a hard pit, making them highly resistant to pressure. The process involves breaking down the flesh and oil cells while applying sufficient force to extract oil from the pulp. Dates are dense and fibrous with low water content. Their toughness requires more pressure to process into a paste compared to softer fruits like figs and grapes. Figs, being softer and more moisture-rich than dates, need moderate pressure to extract juice. Their internal structure is less resistant than that of dates or pomegranates. Grapes are the softest among these fruits, with high water content, a favorable flesh-to-seed ratio, small pips and thin skin. Minimal pressure is required for wine production, as excessive pressure can release undesirable tannins from seeds and skins, negatively affecting wine quality (Shanshiashvili et al., 2024). Though pomegranates are the smallest tree fruit, their tough, leathery skin and tightly packed seeds (arils) present a challenge. Extracting juice requires enough pressure to break the arils without excessively crushing the seeds to avoid bitterness. If the pressure is too low, the fruits may not be pressed sufficiently to extract all of the juice or achieve adequate maceration, leading to underutilisation of the fruit and potential waste. On the other hand, if the pressure is too high, quality may be compromised. Excessive pressure can introduce bitterness, astringency or unwanted compounds and over-crushing the pits could slow down the process or negatively affect the taste.

Breakdown of Chapter

Non-specialised equipment is considered non-diagnostic because it can be associated with various processes, typically linked to small-scale household economies. These are briefly described in Section 7.1. Both non-specialised and specialised types of crushing equipment are examined in Section 7.2. Small, simple installations, which are basic forms of technology, are ubiquitous production tools suited to household or village-level economies. Depending on their size, they could also support larger-scale operations (see Section 7.3). Thousands of these simple installations are found across the landscape, providing clear evidence of production activity but not necessarily tied to the manufacture of specific value-added products. Consequently, they are not a major focus of this chapter. Simple Lever and Weight Presses (SLWPs), however, are more explicitly associated with specific products, such as olive oil or fruit wine and are therefore given detailed attention in Section 7.4. These presses were purposefully designed to process particular raw materials, distinguishing them from more generalised equipment. Oil separators,

fermentation vessels and storage vessels are briefly discussed in Sections 7.5 and 7.6. Since this study considers tree fruits beyond just grapes and olives, Section 7.7 explores the possibility of alternative processing equipment for producing value-added products from other fruits, supported by iconographic and textual sources alongside limited archaeological evidence.

It should be emphasised that the decision not to categorise this chapter based on the specific value-added products associated with processing equipment was deliberate. This approach recognises that much of the equipment was multipurpose and could achieve similar outcomes. Additionally, the effectiveness and benefits of different processing tools often depended on a variety of factors, which are explored in Section 7.8. This section includes innovative calculations, sensitivity analyses, pivot tables and graphs that evaluate key processing methods and the archaeological evidence discussed in Sections 7.2 through 7.7. Finally, Sections 7.9 and 7.10 focus on what the processing equipment reveals about the types, quality and quantity of value-added products produced, offering further insights into ancient production technologies and their economic implications.

7.1 Non-specialised Equipment

Similar to the simple, non-specialised equipment briefly discussed in Chapter 4, any tool or apparatus capable of breaking down tree fruits from their solid form into liquid or semi liquid form (maceration) could have been employed by workers. Contrary to what some scholars (e.g., Cahill, 2001, pp. 238-239) suggest, processing modest quantities of olive oil or wine does not require dedicated, permanent equipment. However, producing oil in amounts larger than very small batches without a press would be both inefficient and wasteful, even more so than wine production (Foxhall, 2007).

Ancient peoples used various items such as bags, mortars and pestles, grinding stones, rollers and weights with some form of pressing stone (see below), typically at the household or village level, small-scale economies. These were traditionally used for processing small quantities intended for local consumption, since the manual labour required to produce larger sums would be difficult given time constraints and the harvesting season. It is beyond the scope of this study to identify every type of non-specialised equipment across all site-phases in the regions under

examination. As these non specialised pieces of equipment are non-diagnostic, unable to provide specific evidence of the exact product being produced and have not been detailed in this study.

7.1.1 Case of Cup Marks

Cup marks found in high concentrations, typically rock-cut, like those found at Magharet Jeymel, Har Okhman, 'Amqa North, Kızbacı Tepesi, Koca Der, Gedevre Tepesi and Lachish, clearly served a specific purpose since they appear so commonly throughout various regions. They may also have functioned as areas for agricultural and horticultural production or for libations, not specifically wine or oil (Eitam et al., 2015; Van den Brink et al., 2001; Luke and Roosevelt, 2017, pp. 130-138). It is probable that either the instant production of a value-added product or the pouring of such a product into the cup marks served as a libation for the ritual of blessing the processing equipment before the processing season commences, blessing the wine or oil being produced and satisfying the gods' thirst (Luke and Roosevelt, 2017). This is supported by the discovery of cup marks outside of funerary reliefs, sanctuaries and citadels, all linked to ritual ceremonies and liquid offerings to deities (Lloyd and Mellaart, 1965; Korfmann, 1998). As well, there are Hittite texts that emphasise rites and ceremonies designed to ensure that particular deities remained favourably disposed, thereby assuring a productive harvest and production (Hundley, 2014). Summoning rituals involving libations and other offerings, involving liquids poured into small pits, are also found elsewhere in the Near East and Aegean (Ussishkin, 1975; Hofner, 1967; McMahon, 2002).

The liquid produced could have also been the additives (e.g., other tree fruits such as pomegranates, storax resin, terebinth resin, cedar oil, juniper, mint and cyperus) that were used in conjunction with the wine/oil being produced in the installation to develop different types of value-added products (Koh et al., 2014) or where they were stored during production. All of those additives are mentioned in the Mari texts (18th century BCE) and the Ebers Papyrus (15th century BCE) (Yasur-Landau et al., 2008). Furthermore, the majority of the holes were not square and were too small and shallow to hold a wooden beam or a pole to support a roof (Kaba, 2018; Ahlström, 1978), as for a SLWP. They reflect small-scale production associated with personal use/the household economy due to the small amounts of liquid that could be produced at one single time. This is shown by the examples of average cup marks from the 2nd millennium

BCE in the Mamara Lake Basin Survey which indicated that the average amount of wine/oil that could be produced was 0.38 litres (Luke and Roosevelt, 2017, pg. 130-138) (see Table 7.1).

	Radius (r)	Height (h)	Volume ($V = \frac{1}{3}\pi r^2 h$)	Litres (L)	# Bottles of Modern Wine*
Smallest	3.50cm	3cm	38.48cm ³	0.038L	0.05
Average	6.75cm	8cm	381.70cm ³	0.38L	0.5
Largest	10cm	13cm	1361.35cm ³	1.36L	1.8

*Table 7.1: Amount of liquid that could be created based on the size of the cup marks from the 2nd millennium BCE Mamara Lake Basin survey (Luke and Roosevelt, 2017). They measure between 3.50-10 cm in radius and 3-13 cm in height. *Based on the average 0.75L bottle of modern wine to give perspective.*

Evidence of cup marks are also found attached to simple installations (see section 7.3) normally either saucer/bowl shape or conical shape, on Crete, Cyprus, the Levant and Turkey (Hillbom, 2003; Hood, 1995; Eitam et al., 2015; Denel, 2007).

7.2 Crushing Equipment

7.2.1 Non-Specialised Crushing Equipment

During the periods under study, various non-specialised pieces of crushing equipment were employed for processing a range of tree fruits, including pestle and mortars (Sabatini, 2019, p. 249; Onozuka, 2012, p. 71; Salavert, 2008, p.7; Foxhall, 2007; Reynier, 1910), weights, boards and bags (Sabatini, 2019, pp. 250–251; Galili et al., 1997; Mitchell et al., 2012), stone rollers (Van Limbergen, 2017; Baruch, 2007; Decker, 2001; Netzer, 2002, pp. 73–75; Foxhall, 1993, pp. 193, 179–180; Trainor, 2021; Carrington Smith, 1994, p. 373; Callot, 2003, 2013) and possibly torsion devices (Frankel, 1999, Appendix A; Blackman, 1958, p. 28; Newberry, 1893, 1894-53; Davies, 1907, 1922). However, identifying and categorising these tools presents significant interpretive challenges, given their non-specialised nature and potential for reuse in other contexts.

The major difficulty lies in the multifunctionality of these tools, which were not exclusively designed for crushing activities linked to wine and oil processing. This ambiguity complicates

their interpretation as diagnostic evidence for specific fruit processing activities. For instance, while stone rollers are often associated with crushing or grinding tasks, they may have also been repurposed for unrelated industrial processes, such as textile dyeing or leather production (Dar, 1999, p. 94). Similarly, weights and pestle and mortars, though common in fruit processing, could have been integrated into more advanced equipment or employed in entirely different industries, given their versatility and lack of specialisation. An added layer of complexity comes from the uneven preservation of different materials within the archaeological record. Objects made of organic substances, such as wooden boards, woven bags and torsion devices, are especially prone to decay and thus rarely endure. The absence of these materials creates a significant gap in our understanding of ancient processing technologies, as it limits our understanding of complete production systems.

By the Iron Age I, stone rollers began to appear in greater numbers and became more predominant across the areas under study (Onozuka, 2012, p. 71, Eitam, 1986; Dothan and Gitin, 1984; Frankel, 1984, 1985; Foxhall, 2007; Hadjisavvas, 1987, 1988). The increased prevalence of stone rollers may suggest a move towards more standardised and efficient production processes. Stone rollers, with their robust and durable construction, likely offered greater ease of use and higher output compared to smaller, manually intensive tools like pestle and mortars. This technological shift could reflect growing demand for wine and oil products, necessitating tools capable of handling larger volumes of raw materials more efficiently. The adoption of stone rollers may thus signify a response to market expansion, as producers sought to meet the needs of increasingly complex trade networks and consumer bases

In terms of labour input, the use of stone rollers could indicate a move towards semi-mechanised production, reducing the reliance on manual effort and potentially allowing for the employment of less specialised labour. The efficiency of stone rollers would have reduced the time required for crushing, thereby increasing overall productivity. This transition may have also influenced the organisation of labour within workshops, with the potential for larger, more centralised processing facilities that could accommodate higher-capacity equipment.

However, the dominance of stone rollers also raises questions about market variability. While they may have been more efficient for medium-large-scale production, the shift away from

smaller, multipurpose tools such as pestle and mortars could indicate a decline in the production of niche or small-batch products. The standardisation implied by the use of stone rollers might have prioritised high-volume production for trade over the diversity of goods, potentially marginalising smaller producers or those catering to local markets. The rise of stone rollers may have reduced that balance, making markets less variable and more homogenous.

Another consideration is the economic and technological implications of this shift. Stone rollers would have required significant investment in materials and production compared to simpler tools like boards or bags. Their prevalence could reflect broader changes in resource availability, technological innovation or the socio-economic structures that supported more capital-intensive production methods. The ability to invest in such equipment might also point to increasing social stratification within these industries, where wealthier producers or elites could dominate production and control larger shares of the market.

The continued use of simple crushing technologies, such as mortars, weights and rollers, until the end of the Iron Age (c. 6th century BCE) highlights their versatility and accessibility across areas. The similarity of these tools suggests that communities prioritised functionality and ease of use, reflecting a shared understanding of olive oil and wine production based on common traditions. These tools were effective and efficient for the initial extraction of smaller amounts of oil and juice, with mortars made from locally available materials, making them economical (Callot, 1984, pp. 72-73, 90-91, 122-127). Weights and rollers enhanced the crushing process, allowing broader participation in oil and wine production among households and small-medium scale producers (possibly larger). This adaptability likely paved the way for more specialised systems in the Hellenistic period (332 BCE-37 BCE), demonstrating a continuous response to agricultural demands and market changes. The collective engagement in olive oil and wine production may have fostered shared practices and rituals, strengthening community bonds and contributing to a shared cultural identity rooted in agricultural heritage and economic activities.

7.2.2 Later Developments: Specialised Crushing Equipment

The introduction of the round olive crusher represents the most significant development in olive crushing because it revolutionised the process by employing rotary movement, which greatly improved efficiency and precision. Unlike earlier methods (using non-specialised equipment

which relied on manual labour and provided limited control). The round olive crusher allowed for continuous, even pressure. One of the advantages of rotary as opposed to reciprocal movement is that it is one direction only and therefore is continuous. This would eventually enable the use of animal power and later that of water, wind and machine. This rotary motion enabled a more consistent and thorough crushing of olives, extracting more oil with less effort. Additionally, this innovation reduced energy waste and manual strain, making the process faster and more productive. This ultimately enhanced the overall quality and yield of olive oil production.

Three main types of basins have been identified as likely used for crushing on the basis of their association with large stones of a shape that could fit inside the basin to crush tree-fruits (Table 7.2). These date from the Hellenistic Period and onwards, approximately 4th century BCE (Ayalon et al., 2009; Kloner and Sagiv, 1989, pp. 57-64; Hadjisavvas, 1992, 1999; Tuna, 2020, p. 49). Other evidence to suggest crushing as the main function of these basins is the presence of an occasional beam niche found in association with the basin and the sockets of the basin in which there is a place for a beam/pole (Kloner and Sigev, 1989, p. 72; Eitam, 1986; Frankel, 1999, 68-74). These suggest some form of movement over the top of the basin itself, as confirmed by pre-industrial rotary olive crushers (e.g. at Fassuta in Palestine in 1980) (Frankel, 1999, p. 69). It is clear that these represent round crushing basins in which a round crushing stone or stone would revolve. A horizontal shaft would pass through a hole in the centre of the round crushing stone and was usually attached to a vertical pivot which rotated in a socket in the centre of the basin, while the distal end of the shaft usually served as a handle to turn the crushing stone. Therefore, the crushing stone rotated both on its own axis and around the crushing basin. These basins have been classified according to Frankel (1999), as being a round crushing basin having: (1) a flat crushing surface and a sunken socket; (2) a flat crushing surface with a raised socket; and (3) a concave crushing surface and a raised socket.

In addition, two types of crushing stones have been categorised. The first type is wheel-shaped with a square socket. The second type has a concave semi-circular shape (Table 7.2).

Basin Type	Crushing Stone	Areas*	Advantages	Disadvantages
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	Type			
Type 1	Type 1	Cyprus, Lebanon, Palestine, Syria	The sunken socket design offers some stability to the crushing stone.	The basin's surface can unevenly spread olives, causing an inconsistent crush that requires manual redistribution.
Type 2	Type 1	Cyprus, Greece, Lebanon, Palestine, Syria	The raised socket likely improves stone alignment and control, making it slightly more efficient than Basin 1.	Type 2 also has a flat surface and could potentially lead to scattering of the olives.
Type 3	Type 2	Greece, Palestine	Type 3 funnels olives toward the centre, keeping the stone in consistent contact for faster, more thorough crushing. The raised socket adds stability, improving the stone's motion.	Olives at the outer edges may not be crushed as efficiently, potentially leaving some under-processed.

*Table 7.2: Comparative Analysis of Olive Crushing Mechanisms by Basin Type. *Locations based on analysis done by Frankel (1999, Appendix A and B).*

A Type 1 basin was often associated with the wheel-shaped crushing stone since the stone fit perfectly on top of the flat crushing surface and the hole of the stone fit directly over top of the basin's sunken socket. Likewise, the Type 2 basin was often associated with the wheel-shaped stone since the stone fit perfectly on top of the flat crushing surface of the basin while the hole of the stone fit around the protruding socket of the basin. The Type 3 basin was often found alongside a convex stone that was designed to fit inside the concave shape of the basin and rotate easily. Type 3's concave shape naturally funnels the olives toward the centre, ensuring that the olives are evenly distributed under the crushing stone. This design minimises scattering, which can slow down the process. With a more consistent contact surface due to the concave design, Type 3 can crush olives more thoroughly and efficiently, potentially increasing the overall quantity of olives crushed in a given time frame. The raised socket design provides added stability during the crushing process, enhancing the motion of the stone and improving the effectiveness of the crushing action. Overall, Type 3's design features contribute to a more efficient and effective olive crushing process, providing better results in both speed and quantity.

The exact date and place of origin remain uncertain, primarily due to the challenges associated with dating the stone material, establishing a clear stratigraphic association and relying on relative dating methods. However, by the beginning of the Hellenistic period, these tools were in general use based on their abundance in the archaeological record. All three types are found in the Hellenistic Period, although this is outside of the time periods under study. This overlap suggests that, regardless of specific regional variations, all the areas under investigation shared a common technological advancement in olive oil production. The presence of all three types of crushing mechanisms during the Hellenistic period reflects cultural exchange and continuity in agricultural practices across regions. Their widespread adoption indicates that communities recognised the efficiency of these methods for oil extraction, leading to their integration into local production systems. This shared technology likely facilitated trade and interaction, as communities with similar methods could engage in commerce and share knowledge. Additionally, the discovery of these tools at various archaeological sites suggests that olive oil production became increasingly standardised, driven by growing demand and expanding trade networks. Understanding this commonality sheds light on the economic and social structures of the time, revealing how agricultural practices influenced community development and interactions among neighbouring cultures.

7.3 Simple Installations

7.3.1 How it Works

Olive oil and wine production using simple installations dates back to as early as the Chalcolithic period. These installations could be either rock-cut or freestanding, in both fixed and mobile forms. Despite variations, all simple installations followed a similar basic process. The fruits, such as olives or grapes, were placed on a typically sloping treading/crushing area (TCA) and crushed or pressed using methods like torsion, treading or stone rollers. The extracted juices would then flow, aided by gravity, through a channel mechanism (CM) into a lower collection area (CA), which could be a large collection vat, small vat or pithoi (see Figure 7.1). From these collection points, the juice would undergo fermentation in the case of wine or oil separation for olive production. This system allowed for a more efficient extraction and collection of liquids in greater quantities, compared to the use of non-specialised equipment. This was a crucial development in early wine and oil production methods.

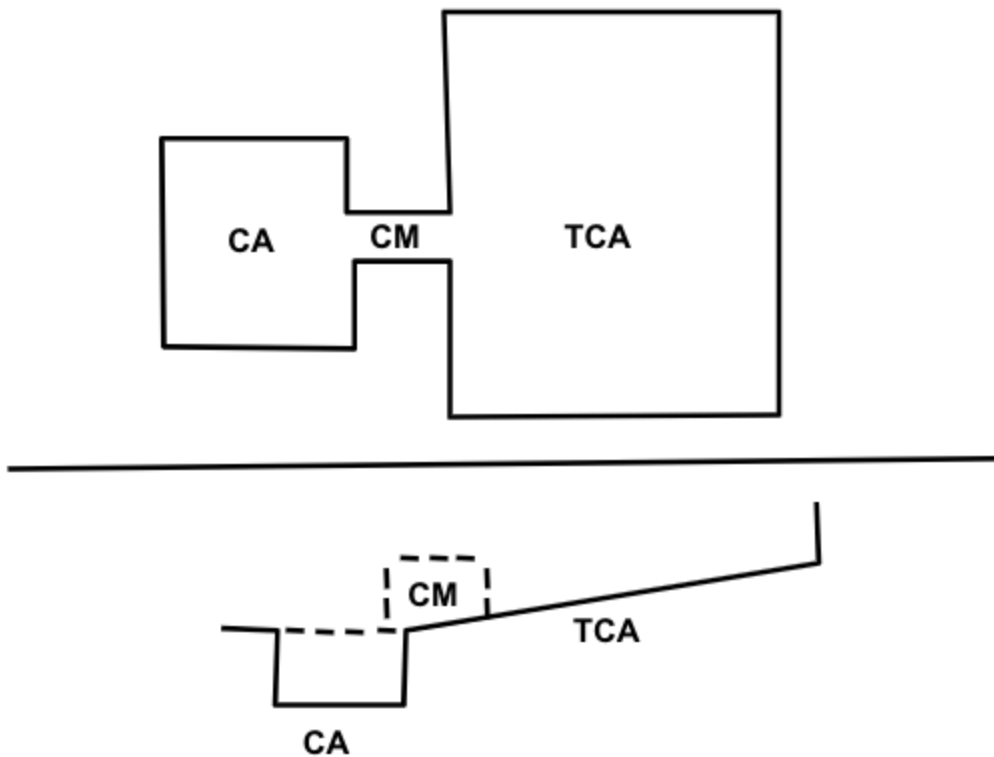


Figure 7.1: Demonstrates the different pieces of equipment (TCA,CA,CM) that make up a simple installation.
TCA=treading/crushing area; CA=collection area; CM=channel mechanism.

7.3.2 Typologies

There are so many simple installations that documenting and categorising all of them in the landscape and at sites is beyond the scope of this study. It would constitute a project in its own right and would be a valuable future undertaking. The total number of installations across the entire study area reaches thousands, likely tens of thousands. For example, over 162 rock-cut simple installations were recorded within a 10 km² radius in Palestine alone (Frankel, 1984, 1985) and an archaeological survey of Western Galilee documented hundreds of wine presses within a few kilometres, the majority being rock-cut simple installations (Ayalon et al., 2009). Given that many of these installations are located in hinterlands or peri-urban areas and other rural locations, where research has been less extensive, a significant number may have been overlooked in publications, associated with a different function or simply remain undiscovered. Therefore, simple installations will be discussed in broader, general terms as they play a role in the development history of oil and wine processing equipment, specifically the equipment and

methods used within the TCA. The focus here is the differences in installation size as a possible indicator of the growth in production scale, as well as the shape and materials of the TCA as possible indicators of the type of value-added product being produced. This analysis will also consider what equipment could be used and which methods could be applied. The study will center on general typologies and distinctions between various systems.

- Type 1.1 - SI (Rock-Cut)
 - Type 1.1.1 - Treading Crushing Area (TCA)- Square Shape
 - Type 1.1.1.1 Collection Area (CA)- Square Shape
 - Type 1.1.1.2 Collection Area (CA) - Circular Shape
 - Type 1.1.1.3 Collection Area (CA) - Ambiguous Shape
 - Type 1.1.2 - Treading Crushing Area (TCA) - Circular Shape
 - Type 1.1.2.1 Collection Area (CA)- Square Shape
 - Type 1.1.2.2 Collection Area (CA) - Circular Shape
 - Type 1.1.2.3 Collection Area (CA) - Ambiguous Shape
 - Type 1.1.3 - Treading Crushing Area (TCA) - Ambiguous Shape
 - Type 1.1.3.1 Collection Area (CA)- Square Shape
 - Type 1.1.3.2 Collection Area (CA) - Circular Shape
 - Type 1.1.3.3 Collection Area (CA) - Ambiguous Shape
- Type 1.2 - SI (Free-Standing Fixed)
 - Type 1.2.1 Stone Treading Crushing Area (TCA)- Square Shape
 - Type 1.2.1.1 Stone Collection Area (CA)- Square Shape
 - Type 1.2.1.2 Stone Collection Area (CA) - Circular Shape
 - Type 1.2.1.3 Stone Collection Area (CA) - Ambiguous Shape
 - Type 1.2.1.4 *Pithoi*
 - Type 1.2.2 Stone Treading Crushing Area (TCA)- Circular Shape
 - Type 1.2.2.1 Stone Collection Area (CA)- Square Shape
 - Type 1.2.2.2 Stone Collection Area (CA) - Circular Shape
 - Type 1.2.2.3 Stone Collection Area (CA) - Ambiguous Shape
 - Type 1.2.2.4 *Pithoi - Collection Receptacle*
 - Type 1.2.3 Ceramic Treading Crushing Area (TCA)- Square Shape
 - Type 1.2.3.1 Stone Collection Area (CA)- Square Shape
 - Type 1.2.3.2 Stone Collection Area (CA) - Circular Shape
 - Type 1.2.3.3 Stone Collection Area (CA) - Ambiguous Shape
 - Type 1.2.3.4 *Pithoi - Collection Receptacle*
 - Type 1.2.4 Ceramic Treading Crushing Area (TCA)- Circular Shape
 - Type 1.2.3.1 Stone Collection Area (CA)- Square Shape
 - Type 1.2.3.2 Stone Collection Area (CA) - Circular Shape
 - Type 1.2.3.3 Stone Collection Area (CA) - Ambiguous Shape

- Type 1.2.3.4 *Pithoi - Collection Receptacle*
- Type 1.3 - SI (Free-Standing Mobile)
 - Type 1.3.1 Ceramic Treading Crushing Area (TCA)- Square Shape
 - Type 1.3.1.1 *Pithoi - Collection Receptacle*
 - Type 1.3.2 Ceramic Treading Crushing Area (TCA)- Circular Shape
 - Type 1.3.2.1 *Pithoi - Collection Receptacle*
 - Type 1.3.3 Organic Treading Crushing Area (TCA)
 - Type 1.3.3.1 *Pithoi - Collection Receptacle*

The typologies presented can be categorised into two primary classifications: rock-cut simple installations (Type 1.1) and free-standing simple installations (Types 1.2 and 1.3), each representing different factors like construction methods, structural characteristics, portability, durability and locations/usage context (see Table 7.3).

Rock-cut installations are carved directly into bedrock, typically in hilly or mountainous areas where natural rock surfaces are available. Their structures usually consist of depressions, basins or troughs carved into the rock, forming permanent fixtures in the landscape. Being part of the rock, they are completely immovable, which ties them to specific locations. They are highly durable and resilient against environmental factors, contributing to their long lifespan. These installations are common in regions with abundant rock outcrops and were often used for processing products like wine or oil, where permanence and stability were advantageous.

In contrast, free-standing installations are constructed above ground from materials such as stone, mudbrick or wood, allowing them to be built in areas without natural rock formations. They are independent, self-supporting structures that may include basins, press beds or troughs, serving similar functions to rock-cut installations. Free-standing installations are more portable, depending on their size and construction materials, but they are generally less durable, being more susceptible to erosion and decay, especially if made from perishable materials. These installations are often found in flatter terrains or regions lacking suitable rock, offering flexibility in location and adaptation to specific needs across diverse landscapes.

Both types are further divided into specific subcategories based on their material, the shape of their treading crushing area (TCA) and their collection area (CA) or collection receptacle. This systematic breakdown allows for a detailed understanding of the structural variations present

within the typological framework. It should be noted that some of the simple installations, like Type 1.3, could have been used for oil separation as well since their shape and structure could suit multiple purposes (see section 7.5).

	Rock-cut	Free-standing
Construction	Carved directly into bedrock in hilly or rocky terrain.	Built above ground from stone, mudbrick or wood. Usable when rock is absent.
Structure	Fixed basin, troughs or depression carved into rock.	Independent basins or troughs constructed to serve similar functions.
Portability	Immovable, fixed to location.	Movable to some extent, depending on size and material.
Durability	Very durable; resistant to weathering due to solid rock.	Less durable; vulnerable to erosion or decay, especially with perishable materials.
Usage Context	Common where rock is abundant; suited for permanent processing.	Used in flatter or rock-poor areas; offers flexibility in placement and adaptation.

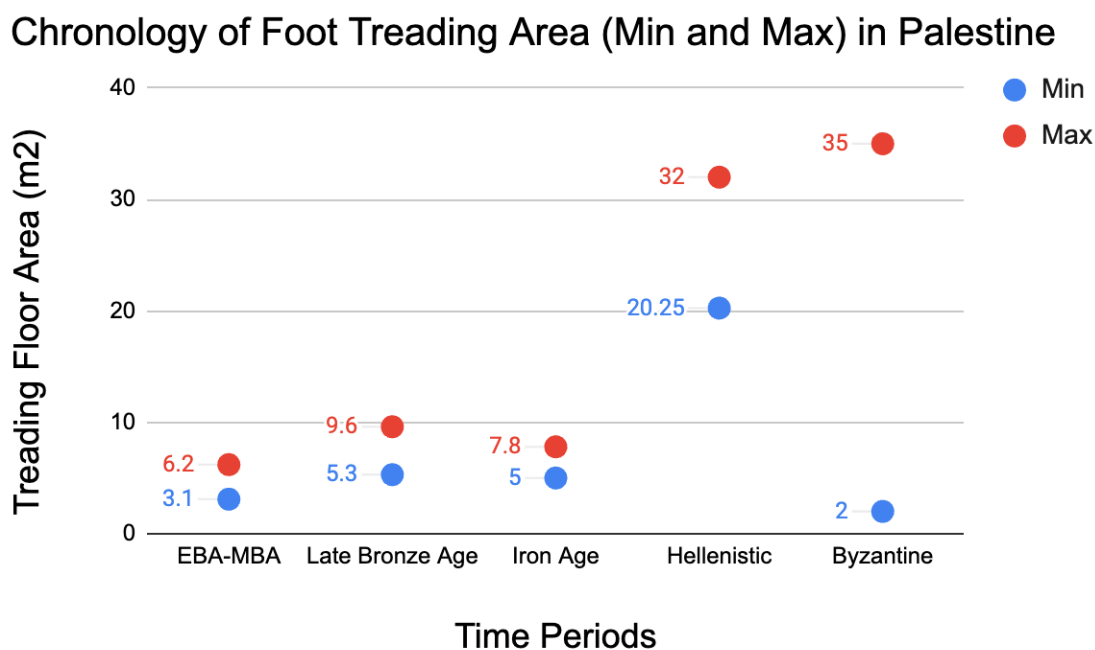
Table 7.3: Comparison of rock-cut and free-standing processing installations based on construction, structure, portability, durability and usage of context.

7.3.3 Treading Crushing Area Size

The size of the TCA plays a possible role in determining the scale of production and the efficiency of large-scale production (e.g., in producing value-added products more easily and quickly), depending on the labour force. A larger TCA typically involves more workers over a shorter period, allowing for greater output. For instance, a large TCA might require three workers to operate for four hours to produce a certain amount of juice or oil. In contrast, a smaller TCA could see one worker working for nine hours to produce the same quantity. While the size can serve as an indicator of the scale of operation, suggesting that a larger TCA generally reflects larger-scale production, there are other possibilities. For example, a site might feature multiple smaller TCAs with simple installations, which could collectively produce a larger overall output than a single large TCA.

Based on the treading floor area data collected by Frankel (1999) from sites across Palestine, (e.g., Nahal West Yatir, Horevot South Shivta, Avedat, Kh. Rehovot-Dueran, Tel Michal, Afeq,

Kh. Judur, Tel el-Nasba and Taanach) it is clear that small treading floors persisted over time, suggesting smaller household or village production continued. However, the data also reveal a gradual increase in floor size, suggesting that as production demands grew or communities invested in larger-scale operations, facilities were expanded to accommodate greater volumes of grapes and more treaders. This trend, illustrated in Graph 7.1, demonstrates the balance between maintaining small-scale, local production methods and gradually adopting larger installations to increase output. Larger treading floors enabled higher liquid yields, both in terms of maximum and minimum production but also required additional labour, as more workers were necessary to operate the expanded spaces efficiently. The increase in floor size thus reflects a strategic adaptation, enhancing production capacity while highlighting the trade-off between efficiency, labour input and operational scale in historical winemaking practices.



Graph

7.1: Chronology of foot treading area (min and max) in Palestine according to data from Frankel (1999).

7.3.4 Treading Crushing Area Shape

The shape of the TCA floor, whether circular, square or irregular, can impact the use of certain methods and how effective those methods are within the TCA. This could have an impact on the quantity and quality of the value-added product being produced. For instance, using large stone

rollers in a square TCA may be easier to maneuver compared to a circular TCA, particularly in terms of physical labour and the time required to produce a value-added product. The flat, straight edges of a square installation could allow for more efficient movement of the rollers, providing greater control over the process and potentially reducing the effort needed to complete each cycle. In contrast, a circular TCA may present more challenges in terms of maneuverability, as the rollers would need to cover a curved surface, requiring additional physical effort and time to complete the same task. Additionally, rock-cut simple installations would have benefited more from the TCA being square since the cut away stone could have been reused for building purposes, plus it is much easier to cut a square into rock than a circle.

On the other hand, a circular floor would be ideal for treading since it allows for a continuous and fluid motion, enabling workers to move without the interruptions caused by corners. This design not only enhances processing speed but also reduces fatigue, creating a more efficient workflow. Additionally, the circular motion promotes even distribution and mixing of grapes, leading to more consistent juice extraction and improved quality. However, circular floors may limit usable space, restricting the volume of grapes that can be processed at one time. In contrast, a square floor maximises floor space, making it better suited for handling larger quantities of grapes in a single batch. Nonetheless, its corners can disrupt the rhythm of treading and trap grapes, requiring extra effort to ensure even processing and potentially compromising quality. Torsion methods, which rely on twisting or pressing mechanisms, tend to be more effective along linear paths or edges, making circular floors less compatible with such processes. Additionally, structural design issues may arise, as devices that depend on fixed points for leverage may not align well with a circular layout, potentially hindering their efficiency. However, from a labour perspective, the movement of people required to physically twist the bag suggests that a circular design might be more advantageous, as it allows for greater freedom of movement and accessibility.

7.3.5 Treading/Crushing Area Materials

The materials used for the TCA can provide some possible insights into the types of value-added products being produced, as well as the scale of production. For instance, a ceramic TCA would most likely be associated with wine production due to the limitations of such material with the use of heavy stone rollers. Such rollers are more typically used in olive oil processing. The

weight and pressure from these rollers could easily crack the bottom of a ceramic TCA, making it unsuitable for oil extraction. Furthermore, large ceramic TCAs, in which multiple people could work simultaneously, would likely suffer structural damage as well due to the weight of the fruit and the pressure applied during the treading or torsion process. As a result, ceramic TCAs were probably more commonly used for small-scale, mobile wine processing, where fewer people were involved and the need for heavy crushing equipment was less critical. In contrast, a large stone TCA capable of accommodating multiple individuals, such as four people standing and working at once, indicates that significant quantities of product could be processed. Stone is a much more durable material, able to withstand the pressure exerted during crushing, making it suitable for larger-scale operations. Such a TCA would be versatile enough to process both wine and olive oil, depending on the specific needs of the producer and the equipment and methods chosen.

7.3.6 Collection Area and Receptacles

The size/type of collection receptacle (ceramic jars or stone collection vats) and material (stone or ceramic) do not provide significant insight into the quantity or quality of the value-added products, since the product would have been transferred to separate fermentation or storage vessels after the juice or oil had been extracted (see section 7.6). For example, collection vats at Tel Michal ranged from 1.2 to 2.5m³ (Herzog, Rapp and Negbi, 1988, pp. 73–75), while those at Tel Nasba measured between 0.5 and 0.6m³ (McCown, 1947, pp. 250–257). This difference suggests that larger vats allowed for more product to be processed at once without the need to pause for transferring liquids. However, this mainly reflects the efficiency (in terms of speed, ease and possibly labour input) of the process rather than any direct correlation to product quantity, quality or types of valued-added products being produced.

Frankel (1999), Beeri (2008) and Onozuka (2012) argue that stone collection vats in olive oil installations were smaller than those used in wine production, suggesting that vat size indicates the type of value-added product being processed. While this interpretation is plausible, it overlooks the adaptability of human behaviour and the potential for multipurpose equipment (see section 7.8.4). Written evidence from Ugarit texts indicates that olives and vines were cultivated together as early as the Late Bronze Age (LBA), implying that the same installations might have been used for both wine and olive oil production (Heltzer, 1999; McGeough, 2005). The

multipurpose use of installations also explains why people would invest in large-scale permanent structures, given that both wine and olive oil production lasted only a few months each year. Archaeological evidence, such as the use of lime and plaster to adapt presses between production seasons, supports the feasibility of such practices (e.g., Tell el-Burak, Kouklia-Styllarka, Nevallat and Tel Bethel) (Orsingher et al., 2020; Orendi and Decker, 2018; Kelso, 1968; Frankel, 1999; Walsh, 2002; Van den Brink et al., 2001). These adaptations would have mitigated concerns about contamination between products. Smaller collection vats, typically associated with oil production, may also have been used in wine processing, particularly for capturing the best-quality juice, pre-fermentation or decanting before the wine was transferred to fermentation vessels (Ahlström, 1978). Furthermore, evidence from sites like Tel Ekron and Zayit shows that collection vats and TCA installations could serve other functions, such as grain storage or fabric dyeing, challenging the assumption that vats were exclusively dedicated to a single product (Dothan and Gitin, 1984, 1986; Eitam, 1986; Eitam and Shomromi, 1987; Gal and Frankel, 1993). Consequently, the assumption that small vats were used solely for olive oil production is flawed. The evidence instead supports the conclusion that such equipment was designed for flexibility, enabling the possible production of multiple products without the risk of contamination.

7.3.7 Organic Materials

Iconographic evidence supports the concept of freestanding, mobile and simple grape-crushing installations, constructed from organic materials such as rope and wood, that were transported directly into the vineyards. For instance, an attic black-figure vase depicts figures vigorously stomping grapes with their feet in wooden presses, with a separate vessel positioned to collect the resulting must (see Photo 7.1, Archaeological Museum of Syracuse). However, the TCA is depicted as being made of the same material as the baskets filled with grapes carried by the workers, which would indicate a rope material. Other examples appear throughout the Greek world (Boulay, 2015; Sparkes and Talcott, 1974 p.14).

Although these iconographic depictions primarily date to the 6th and 5th centuries BCE, it is reasonable to propose that similar materials and techniques may have been in use much earlier, though they have not survived archaeologically. The simplicity of these installations, in terms of

materials, construction and portability, suggests that they could have been utilised since the earliest phases of oil and wine production.

Additionally, written evidence from the Roman period (c. 1st century CE) provided by Hero of Alexandria and Columella indicates that wooden boards were used to create transportable, simple installations called a *regula* and *galaegra* (Columella 12.52.19, 12.54.2; Roby, 2023; Drachman, 1932, pp. 60–62). This evidence supports the idea that organic materials could have been used for such simple installations, even if these examples date to later periods.



Photo 7.1: Black figure amphora, probably dating to 530-500 BCE, of Dionysos and satyrs pressing grapes (Archaeological Museum of Syracuse).

7.3.8 First Evidence and Geographical Developments

Archaeological evidence of early simple installations for value-added processing is documented across several regions and time periods. In Palestine, the earliest evidence dates back to the Chalcolithic period at the site of Megiddo (Frankel, 1999, p. 55). In Syria, simple installations from the Early Bronze Age (3000–2700 BCE) have been identified at Ras Shamra (Ugarit) (Courtois, 1962; Callot, 1987). Crete also shows evidence from the Early Bronze Age (3300–2500 BCE), with installations discovered at Myrtos, Malia and Gournia (Platon and

Kipaka, 1993; Hutchinson, 1962; Scott Gallimore, personal communication, 2013). In Lebanon, similar installations are dated to the Iron Age (700–600 BCE) at Tel el-Burak (Orsingher et al., 2020; Orendi and Decker, 2018). While installations from Jordan, Greece, Turkey and Egypt were not included in this analysis due to falling outside the specified periods, Egypt offers compelling iconographic evidence of their use during the Late Bronze Age (c. 1543–1292 BCE). For instance, a tomb depiction from Thebes illustrates workers treading grapes using ropes and a pole to maintain balance (Oxford Expedition to Egypt: Scene-details Database, 2007). Cyprus, on the other hand, shows no evidence of datable simple installations, as the SLWP was directly adapted without any clear precedent in undateable rock-cut features (Hadjisavvas, 1996, 2020). It is important to note that the absence of discoveries does not preclude the possibility of earlier examples, as gaps in the archaeological record often reflect the limitations of excavation and preservation.

Location	Dates	Site(s)	Sources
Palestine	Chalcolithic	Megiddo	Frankel, 1999, p. 55
Syria	EBA (3000-2700 BCE)	Ras Shamra (Ugarit)	Courtois, 1962, pp. 420-431; Callot, 1987, pp. 197-202.
Crete	EBA (3300-2500 BCE)	Myrtos, Malia, Gournia	Hutchinson, 1961, p. 242; Scott Gallimore, personal communication, 2013
Lebanon	Iron Age (700-600 BCE)	Tel el- Burak	Orsingher et al., 2020; Orendi and Decker, 2018.

Table 7.4: Archaeological sites and dates of the earliest evidence of simple installations in the areas under study.

Archaeological evidence suggests that simple installations continued to be used across these regions, excluding Cyprus, well into the Byzantine period and beyond. This persistence is particularly evident at sites such as Nahal Yait West and Montfort (Frankel, 1999; Pinkerfeld, 1961). Despite the availability and implementation of more sophisticated installations, these simpler forms remained functional and relevant, likely due to factors such as ease of construction, lower maintenance requirements and suitability for local environmental and economic conditions. Their continued presence in later periods suggests that technological advancements did not necessarily render older methods obsolete but rather introduced a spectrum of solutions tailored to different environmental and societal needs. The primary distinction lies in

the spatial extent of the TCA and CA (see table 7.5) (Ayalon et al., 2009; Kouraku-Dragōna, 2016; Hovhannisyan et al, 2015; Hadjisavvas, 1996, 2020; Brun, 1993, 2004; Pratt, 2014; Amouretti et al., 1991; Dodd, 2022; Frankel, 1999).

The timing of the introduction of wine and oil production facilities can create profound differences between regions, influencing their economic development, social structure, technological progress and cultural identity. Early adopters often gain a significant advantage, becoming innovators and market leaders, while latecomers may struggle to compete or rely on the innovations of others to catch up. However, late adopters can also benefit from observing and learning from the successes and failures of earlier producers, potentially implementing more refined systems from the outset.

7.3.9 Economic Impact

Regions with earlier wine and oil production installations likely gained significant economic advantages by establishing trade networks and integrating agricultural production with manufacturing and commerce. This early adoption allowed them to dominate both regional and long-distance markets and accumulate wealth, which in turn supported infrastructure investment and technological advancements. In contrast, later-adopting regions struggled to compete against established producers, especially as market dominance and trade opportunities were already secured.

The early adoption of specialised equipment reflects a market demanding higher volumes for local consumption and/or trade. Simple installations, designed to process larger quantities efficiently, catered to these demands better than non-specialised household tools which were limited in capacity. Features such as sloping treading areas and gravity-fed collection mechanisms enhanced efficiency by reducing labour while maximising output.

Simple installations also improved product quality. Their controlled crushing and pressing processes, through methods like torsion or stone rollers, prevented over-crushing and ensured higher-quality wine and oil. Dedicated collection areas further refined the product by separating liquids from fruit matter more effectively than non-specialised tools.

The later adoption of specialised equipment likely signals the maturation of production systems driven by urbanisation and growing markets. Initially reliant on non-specialised tools, these regions transitioned to efficient setups as demand for higher volumes and quality increased. This shift reflects economic growth, where the cost and complexity of specialised installations became justifiable for larger-scale production and trade expansion.

7.3.10 Technological Diffusion and Innovation Impact

Regions with early installations often take on a pioneering role, becoming centres of innovation where techniques are refined and knowledge is disseminated to neighbouring areas. This early leadership solidified their status as hubs of production technology, fostering further advancements and influence earlier on, as shown by Crete. In contrast, later-adopting regions may benefit from observing and adopting these innovations, enabling them to bypass the trial-and-error phase of technological development, such as in Cyprus (see section 7.4.6). However, this advantage for late adopters may come at the cost of reliance on external sources for technological expertise, potentially limiting their independence in innovation and adaptation.

7.3.11 Social and Cultural Implications

The early adoption of wine and oil production facilities often shaped societal structures, particularly through the emergence of social stratification. The wealth generated by these industries allowed elites to consolidate control over production and trade, thereby solidifying their economic and political dominance. This, in turn, influenced the broader societal framework, fostering the development of an elite class with significant power. In areas where such installations appeared later, these socio-economic changes were delayed, impacting the pace and nature of social development. The timing of these transitions could result in differing societal trajectories between early and late adopters.

Cultural identity was also profoundly influenced by the timing of adoption. Regions with early installations often deeply integrated wine and oil production into their traditions, festivals and social practices, making these industries central to their cultural heritage. By contrast, regions with later installations may not have achieved the same level of centralised cultural integration.

7.3.12 Environmental and Agricultural Impacts

In terms of environmental and agricultural development, early adoption had significant implications for land use and management. Regions with earlier installations were likely to invest in the cultivation of vineyards and olive groves sooner, resulting in more mature and productive agricultural systems over time. However, this could also lead to earlier environmental impacts, such as deforestation and soil depletion, driven by the expansion of these industries. In contrast, later-adopting regions may have benefited from improved land management practices developed elsewhere but faced challenges in securing prime agricultural land already in use.

7.3.13 Regional Power Dynamics

Regional power dynamics were also shaped by the timing of adoption. Early-adopting regions often gained dominance in trade and resource control, exerting influence over neighbouring areas. These regions could establish themselves as economic and political centres, leveraging their early technological and agricultural advancements to control key trade routes and markets. In contrast, areas with later installations might become economically dependent on these dominant regions, struggling to achieve parity. This disparity could result in long-term imbalances in regional development, with later adopters often lagging behind their counterparts.

7.3.14 Later Developments

As wine and oil methods and equipment started to diversify, simple installations tended to be used more for wine processing since simple lever and weight presses (SLWP) were more ideally suited for the pressing of olives (see section 7.4). However, wine could have still been made using a SLWP, as long as the weights were smaller and lighter than the ones for olive oil pressing, like at the site of Kh Hudash (Eitam, 1980, pp. 7, 40) in the Iron Age in Palestine and later in the Byzantine period at sites like Kh Judur (Baramki, 1934-1935) and Bet Ha-Shitta (Aharoni, 1953; Gal, 1985-86, fig. 2,3). As the making of wine developed, the simple installations discussed above changed and diversified. They grew in both size (TCA and CA) and number of TCA and CA per installation (Fukhs et al., 2021). As well, different installations and devices were added to the two basic elements. Examples would be compartments in the sun for grapes or raisins to make sweet or raisin wine (e.g., Qalandiya, Halusa and Bamuqqa) (Baramki, 1933; Mazor, 1981, pp. 54,60; Callot 1984, pp.70-94) and small, intermediate collecting vats

that could collect the first must (Columella 12,27; Frankel, 1999, pp. 41,140). Such adaptations supported the creation of different types and qualities of value-added products.

However, there are two unique instances of intermediate collection vats appearing at Iron Age sites, centuries earlier than when they become more common: at Tel Michal (Herzog, Rapp and Negbi, 1988, pp. 73–75) and Qal'a (Eitam, 1980, pp. 8–15). These examples suggest that the technology for intermediate collection vats was known and available during this period but was not widely adopted. One possible explanation for this limited use is a focus on producing a specific type of wine that required the concentrated collection of the first must, prioritising flavour and composition. This method would have allowed winemakers to control the quality of the initial must, which is often richer in sugars and tannins, resulting in a more desirable product. Alternatively, the selective adoption of this technology may reflect regional or cultural preferences, economic constraints or variations in the scale of production. For instance, smaller-scale producers might not have seen the need for intermediate vats, relying instead on simpler installations that were easier to construct and maintain. The presence of intermediate vats at these two sites could also indicate experimental or innovative practices, where certain producers sought to refine their techniques to create distinctive products.

The presence of intermediate vats provides the first physical evidence suggesting the possibility of red wine production using processing equipment. Simple installations are typically associated with white wine production based on the design and function of their equipment. However, the type of wine produced could be altered during the fermentation stage. For example, the macerated material from the initial press could be transferred into a fermentation vessel along with the juice, allowing the wine to develop its red colour and flavour before being strained prior to consumption. The introduction of the intermediate vat therefore marked a significant development in wine production. By providing a dedicated space for fermentation, intermediate vats enhanced the efficiency and control of red wine production, distinguishing them from the simpler systems used solely for white wine.

More sophisticated wineries tended to have larger TCAs and CAs, which suggests greater efficiency of production and the ability to produce larger quantities of product. For instance, at the site of Tel Michal, there is a noticeable increase in size between the Iron Age and Hellenistic

periods, while from the Hellenistic to Roman periods, the increase in size is only marginal (Table 7.5). During the Iron Age, winemaking practices were likely evolving to meet the needs of growing populations, increased trade and expanding regional networks (Falconer and Redman, 2022). Wine began to emerge not only as a local commodity but also as a valuable trade good, integral to social and ritual practices. This would have spurred greater investment in winemaking infrastructure (Dodd, 2020, 2022). By the Hellenistic and Roman periods, however, wine production had likely become a more established industry with refined practices and stable markets (Cimadomo, 2019; Atrash, Overman and Gendelman, 2022). The marginal increase in size during these later periods may indicate that the scale of production was already optimised for existing demand and infrastructure. This suggests that producers had reached an equilibrium where larger installations were no longer necessary to meet demand or that technological innovations were instead focused on improving quality and efficiency rather than scale. Furthermore, in these later periods, the development of trade networks and access to imported wine might have reduced the pressure to dramatically expand local production.

Time Period	TCA (m²)	CA (m³)	Size Rank)
Iron Age	6.6 - 7.9	1.2 - 3.94	3
Hellenistic	20.25 - 32(mean 26.5m ²)	5.2 - 7 (mean 6.1)	2
Roman	27.5	6	1

Table 7.5: Size of Tel Michal TCAs and CAs across different time periods (Herzog, Rapp and Negbu, 1988, pp. 168-176).

A comparison of size of TCAs and CAs from Frankel (1999), further indicates that the size of TCAs and CAs tended to grow throughout the Iron Age, Hellenistic and Roman periods. By the Byzantine period, the TCAs were smaller while the CAs remained similarly large. For example, at the sites of Galilee Hasolelim South East (Frankel, 1999, pp. 150-151) the TCA was 12.4m² and 13 m² at Mispè Resh Laqish South (Frankel, 1999, List A), while the CAs (6.4m³ and 6.8m³) remained similar in size to Roman and Hellenistic examples (see Table 7.5). This is not always the case (i.e., the size of the TCA does not directly correlate with the time period required for production). However, it highlights a particular pattern that is relatively common, at least in the Levant where we have more information and recorded measurements of size.

The numbers of TCAs and CAs started to vary from the Hellenistic period onwards. For instance, at Jericho there were two TCAs, two intermediate vats and one CA in an installation dating to the Hellenistic (Netzer, 1989, p. 276) and at Shivta there were three different installations with a variety of storage places, one TCA, one intermediate vat and two/three CAs dating to the Byzantine (Mazor, 1981, pp. 55-60). These are just some examples that highlight the differences found in various areas. The increased numbers of each piece of equipment indicate an increase in scale compared to simple installations and the move to create different types and qualities of wine.

The most significant thing to note is that simple installations consisting of only TCAs and CAs continued in use beside more sophisticated installations until modern times (Herzog, Rapp and Negbi, 1988, pp. 168-175; Foxhall, 2007; Frankel, 1999; Hovhannisyan et al., 2015; Pratt, 2021; Amouretti and Brun, 1993; Amouretti et al., 1991). Even in cases where a particular type of improved winery becomes typical of a certain region, it will almost certainly not be the only type found in that region but will be accompanied by less sophisticated wineries that were functioning at the same time (Frankel, 1999, pp. 149-151). There are numerous possible explanations for this. First, the choice of equipment often depends on the desired quantity of production and/or availability of the required amounts of tree fruits. Simple installations might be perfectly suited for small-scale or medium-scale production, eliminating the need for investment in more advanced systems. Simpler methods required fewer resources, making them more accessible to small-scale producers or those with limited capital. Second, older equipment, especially if constructed from durable materials like stone, often had a long functional lifespan, leading to its continuous use over time. Third, functional simplicity suggests that simple installations were often easier to set up, maintain and transport, particularly for smaller or temporary operations, such as seasonal harvests in remote areas. Fourth, there was likely a continuation of traditional practices, where familiar and proven methods were preferred over adopting new technologies (i.e., traditional methods were deeply ingrained and continued to be practised due to familiarity, cultural significance or a preference for the specific qualities they imparted to the wine). Fifth, simple installations could serve as supplementary facilities even in regions with advanced wineries, particularly during times of high demand, such as peak harvest periods, when existing infrastructure may have been insufficient to handle the volume of production. Finally, variations

in production processes, including the use of different fermentation vessels or other less visible practices, allowed producers to achieve different qualities and types of wine or oil, regardless of the sophistication of the equipment used.

7.3.15 Conclusions

The most significant thing to note is that simple installations consisting of only TCAs and CAs continued in use beside more sophisticated installations until modern times. Furthermore, the specific value-added product manufactured within a TCA cannot always be clearly identified unless supported by botanical data to provide direct evidence of the materials processed. Overall, these features are not highly diagnostic on their own. However, they can suggest an increase in the scale of processing activities (see section 7.8), particularly when compared to non-specialised equipment. Specialised installations usually reflect higher production volumes and greater economic investment.

The value-added product would vary in terms of quality and quantity depending on the process used in the TCA. Methods such as torsion pressing, treading or using weights and planks yield different results. The size and structure of the TCA and the associated CA could further indicate the processes it was used for. For example, a small ceramic TCA found at Malia and Zakros in LBA Crete would be more suited for treading than for large stone rollers (Platon and Kopaka, 1993). The dimensions and weight of the rollers would make them impractical for smaller installations, suggesting that wine was the likely product, as treading is not well-suited for olive oil extraction. Additionally, the size of the TCA might reflect the scale of production. A small ceramic TCA on Crete would probably yield a lower volume of wine compared to a larger rock-cut installation in Palestine from the same period. The larger installation could accommodate more workers simultaneously, increasing productivity. However, the efficiency of manual processes would probably be relatively consistent across regions. The variation in TCA size and design not only highlights regional differences in production techniques but also offers insights into the scale of economic activities and resource availability in different areas.

7.4 Simple Lever and Weight Press

7.4.1 How it Works

The Simple Lever and Weights Press (SLWP) was an early form of processing equipment that leveraged the principles of mechanical advantage. Unlike simpler installations, the SLWP was a more advanced and specialised piece of technology, particularly suited for crushing and pressing. Both of these simpler systems shared common components, like a TCA and CA, but the SLWP's use of a lever made it significantly more efficient. The SLWP worked by inserting a long beam (the lever) into a fixed anchoring point, known as the beam niche. At the other end of the beam, force was applied by attaching simple weights. Human labour was required to lift and secure the weights beneath the beam using ropes. Lighter weights are often applied for the first pressing to get the highest quality oil or wine, followed by additional heavier pressings to extract more liquid of lower quality. For this sequential process, the amount of pressure can be adjusted through the weights. Fruits intended for pressing were placed beneath the pressing point in baskets or bags and a flat stone or wooden piece was used to apply pressure. As the weights were lowered by gravity, with their size varying depending on the fruit being pressed (e.g, lighter weights for grapes compared to olives), force was exerted on the pressing point, crushing the fruits and extracting their juice. The juice then flowed into collection vessels through lateral or central channels (see Figure 7.2). Interpreting how SLWPs function is based on understanding of later, more complex versions, such as improved lever and weight presses, lever and screw presses, single rotating screw presses and double screw presses, that were thought to be adapted from the original, simpler SLWP (Gutman and Wagner, 1986; Argoud et al., 1980, pp. 7, 39, pl. 3; Dorpfeld, 1895, pp. 168-169; Dalman, 1928-1942, pp. 4,20, pl. 62; Sordinas, 1971, pp. 13-25). This interpretation is further supported by ethnographic and historical evidence from the Mediterranean, as well as Roman and Byzantine texts (Hamilton, 1934-1935, pl. 66.2; Hadjisavvas, 1987, fig. 3; Avitsur, 1986, p. 34). Only certain components of the SLWP, such as the press bed, CA and weights, are commonly preserved in the archaeological record due to their durable materials. Niches, whether built into walls or in monoliths, may occasionally survive but are rare. Wooden beams and ropes, being organic, have not survived.

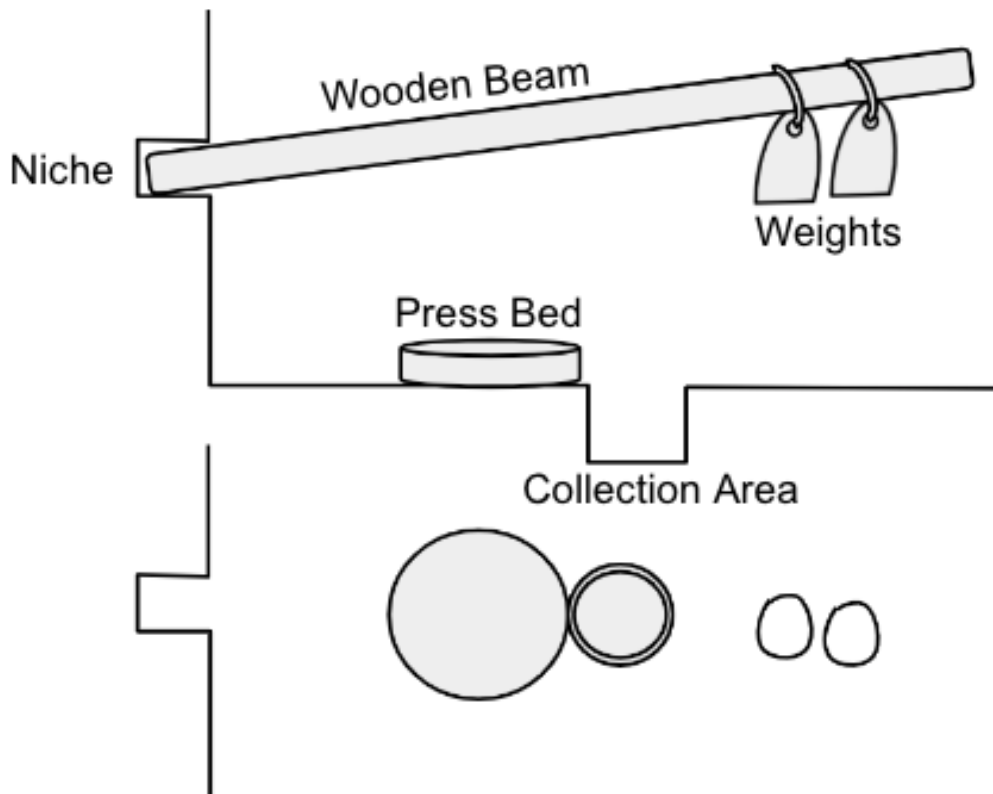


Figure 7.2: The different pieces of equipment (niche, wooden beam, press bed, collection area and weights) needed to create a simple lever and weights press. This design is based on the SLWPs from Iron Age sites in Palestines, like Kh Banat Barr; Kh Hudash, Tel Yoqneam and H Rosh Zayit (Ben Tor et al., 1987; Gal and Frankel, 1993; Eitam, 1979, p.146; Frankel, 1999, Appendix A). The SLWP features a simple niche (Type 1.1), weights (Type 2), simple circular press bed (Type 1.1) and lateral collection.

7.4.2 Typologies

These typologies are developed based on the four primary types of archaeological remains associated with a SLWP. They are organised in a sequence that reflects the relative impact each type of remains had on the production process and the resulting value-added product in terms of quality, quantity and type. Niches play a critical role in controlling both the positioning and the amount of weight that can be used to press the remains, directly affecting the efficiency of the pressing process. In contrast, the weights themselves determine the magnitude of force applied to the fruit, influencing the extraction process. The shape of the press bed and the type of collection system employed appear to have no real impact on the process or the type of the resulting value-added product. The method of collecting the value-added product for fermentation, separation and storage had no impact on its quality, quantity or type. This is because the product

would ultimately have to undergo fermentation, separation and storage in any case, to achieve the desired type and quality. For further details on these relationships, see the sections below.

- **Niches**

- Type 1: Simple Niche
 - Type 1.1 - Fixed
 - Type 1.2 - Monolith
- Type 2: Reverse U Shape Niche
 - Type 2.1 - Fixed
 - Type 2.2 - Monolith

- **Weights**

- Type 1: Horizontal Bore
 - Type 1.1 - Irregular
 - Type 1.2 - Bell-shaped
- Type 2: Vertical Bore
 - Type 2.1 - Irregular
 - Type 2.2 - Cylinder
- Type 3: Unspecified in Publications

- **Press Bed**

- Type 1: Simple
 - Type 1.1 - Circular-Shape
 - Type 1.2 - Cylindrical Round-Shape
 - Type 1.3 - Rectangular/Square-Shape
 - Type 1.4 - Pear-Shape
- Type 2: Groove(s)
 - Type 2.1 - One Groove
 - Type 2.1.1 - Rectangular/Square-Shape
 - Type 2.1.2 - Pear-Shape
 - Type 2.2 - Two Grooves
 - Type 2.2.1 - Pear-Shape
- Type 3: Spout
 - Type 3.1 - Circular-Shape
 - Type 3.2 - Cylindrical Round-Shape
 - Type 3.3 - Rectangular/Square-Shape
 - Type 3.4 - Pear-Shape

7.4.2.1 Niches

Based on the location and shape of the purposefully cut mortise holes in walls and monoliths, two types of anchoring points or niches have been classified (see [Appendix 9a](#) for more details). Their association with press bed and weights also confirm this as their purpose (Hadjisavvas et al., 1991, pp.69-80). These niches were categorised based on their ability to provide control and support of greater weights, both of which were determined by the shape of the niche rather than its location. Type 1 is a simple niche form made of stone and cut into the shape of a square or rectangle to fit a wooden beam. Within this category, Type 1.1 was found within walls, while Type 1.2 was found in monoliths. Evidence of simple niches has been discovered in Cyprus and Syria during the Late Bronze Age (LBA), marking the first known use of this type. Additionally, Type 1 niches were identified in Palestine during Iron Age II, representing their first recorded appearance in that region.

Type 2, on the other hand, is a niche with a capstone-like shape resembling a reverse ‘U’ that was integrated into the stone cut. Type 2.1 niches were found within walls, while Type 2.2 niches were identified in monoliths. These niches first appeared in Cyprus, Syria and Palestine during the Iron Age. In Palestine, both Types 1 and 2 niches emerged at the exact same time. The simultaneous appearance of these types may suggest a shift in technological practices or the adoption of a new standardised design for anchoring mechanisms. This could imply the diffusion of similar technological innovations across neighbouring regions during the Iron Age, possibly due to trade or shared cultural practices. At the site of Tel Mique, the most comprehensive olive oil production center excavated to date, mass production was carried out for both local and non-local consumption (Dothan and Gitin, 1986; Eitam, 1996). At this site, almost every installation had a niche, of which 9% were Type 1 and 91% were Type 2 (Eitam, 1986). This discrepancy could indicate that Type 2 was gradually replacing Type 1 and became the predominant niche type during Iron Age II.

Both types of niches operated similarly, acting as devices that physically controlled the extent and speed with which the beam was raised or lowered by the weights attached to its opposite end. However, Type 2 had significant advantages due to its reverse U-shaped design. Its curved structure allowed for a stronger stopping mechanism that could better withstand the upward pressure exerted by the beam during the pressing process. This added resistance reduced the

likelihood of slippage or breakage, thus providing more effective control over the force applied to the fruits. This enhanced control enabled the operator to finely regulate the pressing process, likely improving the efficiency of juice extraction. Furthermore, the wall in which a niche was embedded would have provided greater structural stability than a monolith. This is because the wall served as a fixed and immovable anchor, supported by the overall structure of the building or installation. In contrast, freestanding monoliths lacked this additional lateral support, making them less stable and more prone to shifting or tilting under pressure. Consequently, Type 2.1 niches, with their advantageous shape and location in a structurally reinforced wall, were likely the most effective option. This stability would have facilitated the use of heavier weights and allowed for more physical force during pressing, thereby extracting more juices with greater efficiency.

There is no clear evidence for niches in Greece or Crete as of yet, which is puzzling given that Crete had some of the earliest examples of SLWP presses and made sophisticated modifications to pressing beds early on. This absence raises questions about regional variations in pressing technology and whether niches were unnecessary in these regions due to alternative designs or material preferences. However, this lack of evidence may be due to several factors affecting the archaeological record. Issues with preservation and identification of niches could be significant. For instance, walls containing niches would need to be preserved to an adequate height for the niches to remain visible and identifiable. Similarly, freestanding niches may have been dismantled, with their stones repurposed for other construction projects over time. Additionally, dating niches poses challenges since definitive examples with precise dates are rare. The majority of known niches have been dated to the Iron Age based on the stratigraphic association of ceramics found in the same layers, rather than through more specific chronological evidence.

7.4.2.2 Weights

The weights were categorised into two subgroups based on the placement of the bore, through which a rope would have passed: Type 1 (horizontal bore) and Type 2 (vertical bore). A horizontally positioned bore is a hole drilled horizontally near the top of the weight, allowing it to align parallel to the ground when suspended. This positioning ensures that force is evenly distributed across the pressing mechanism, reducing tilting, improving stability and maintaining consistent downward pressure. In contrast, a vertically positioned bore is a hole drilled through

the top of the weight, causing it to hang perpendicular to the ground. In this position, the weight swings more freely, which can lead to shifting pressure and a more concentrated force application at a single point. This type of bore might be preferred when variable pressure is required, making it ideal for processes that benefit from adjustable force distribution. They were further subdivided by their shape which could have influenced weight distribution and show complexity. They are identified as weights associated with a SLWP due to their proximity to press beds and storage or fermentation ceramics, indicating a deliberate functional link.

Types 1.1 and 2.1, are horizontal bore and vertical bore weights that do not conform to a standard or uniform shape or size and are typically made from stone. The irregularity in their shapes could suggest that these weights were likely repurposed materials, such as rocks from nearby sources or discarded objects or hastily crafted items designed primarily for practical use rather than aesthetic appeal or uniformity. They are found in the areas under study, as early as the LBA.

Type 1.2, horizontal bore small bell-shaped weights, by contrast, were designed with a distinct shape that provided efficient and targeted pressure application. These weights were roughly bell-shaped, tapering to a narrow point, with a horizontal round perforation located at the upper narrow side. Examples have been documented as early as the LBA in Cyprus and Syria, while in Palestine they appear in the Iron Age II (Hadjisavvas, 1996; Eitam, 1996; Callot, 1987; Frankel, 1999) (see [Appendix 9b](#) for more details on a few site-phases with the presence of weights). These weights varied in their dimensions, weight and the type of stone used, reflecting local practices, resources and the specific needs of different regions – a true lack of uniformity. The absence of any standardisation meant that bell-shaped weights could differ significantly from one area to another, depending on the size of the pressing operation and the scale of production. While some may have been large and heavy for industrial-scale pressing, others could have been smaller and lighter for more domestic or small-scale use.

Those are similar to Type 2.2, which are cylinder-shape vertical bore weights. The cylindrical shape provides stability and even weight distribution, preventing tilting and ensuring uniform force application. Additionally, this design reduces structural stress on the press bed and wooden beam, extending equipment lifespan. Its symmetrical form and simplified suspension also make it easier to handle and install, improving operational efficiency. Evidence for these were found in

Palestine in the Iron Age from c. 800 BCE and later (Tufnell, 1953; Frankel, 1999; Albright, 1942-43; Fantalkin, 2004; Bunmovitz and Lederman, 2008).

Type 3, are unspecified weights that refer to those that lack detailed descriptions or photographic documentation in available texts or archaeological records. They are often mentioned in passing but are not characterised in terms of their shape, weight, type of stone or other specific features. The materials chosen for these weights (Types 1, 2 and 3) also varied, with different types of stone being used based on availability, durability and suitability for the task.

7.4.2.3 Press Beds

Three main types of beds have been identified as likely used for pressing based on their association with collection receptacles and weights. This is supported by finds of complete presses with niches and weights (Hadjisavvas, 1996; Frankel, 1999). The press bed, made from various types of stone, served as the foundation for the simple lever and weight press, similar to the treading and crushing floors of simple installations dating to the Bronze Age. Press beds have been classified into three categories: simple (Type 1), grooves (Type 2) and spout (Type 3) based on the functionality of liquid extraction and the liquid movement (see [Appendix 9c](#) for some site-phases with details). They are further subdivided based on their shapes, circular, cylindrical round, rectangular/square and pear-shaped, which are not critical factors in terms of pressing and production but rather aesthetic. What matters most is the weight-to-surface-area ratio and stone type, not the shape of the surface itself (see [Appendix 10](#)). Circular or pear-shaped beds are often preferred for ease of positioning circular fruit bags. In historic Cypriot villages, basket diameters averaged 60 cm (Hadjisavvas, 1996, p. 75), making press beds of at least this size essential for even force distribution. While smaller surfaces concentrate pressure and boost extraction efficiency, they risk fruit damage or uneven extraction if not carefully managed (see SLWP sensitivity analysis). The fit of baskets to press bed area size is important, while the shape is not.

Type 1 presses featured a simple, groove-free design in which the extracted liquid pooled in the press bed and was either collected manually or allowed to drain by gravity, depending on the system. The absence of grooves slowed drainage, reducing efficiency and production speed, while also increasing the risk of contamination and complicating the collection of pure liquid.

This design likely reflects an earlier stage of technological development. Type 1 presses have been identified in Crete, Syria and Palestine but have not yet been found in Cyprus or Greece (Tufnell, 1953; Frankel, 1999; Albright, 1942-43; Fantalkin, 2004; Bunmovitz and Lederman, 2008; Hadjisavvas, 1992, 2020).

Type 2 designs, featuring one or more grooves, enhance efficiency by channeling extracted liquid away from the pressing surface to a designated collection area. This innovation reduces liquid pooling, speeds up drainage and keeps the press surface cleaner. Additional grooves can guide liquid to specific collection points, optimising the collection system's efficiency. The grooves may strengthen the press surface, distribute pressure more evenly and improve durability. Grooves can also aid in separating different liquid components (such as oil from water), thus enhancing the quality of the final product. Evidence of this type of press bed has been found in Cyprus, Syria and Palestine but not yet in Crete or Greece (Frankel, 1999; Bunmovitz and Lederman, 2008; Hadjisavvas, 1992, 2020; Foxhall, 2007).

Type 3 examples are equipped with a spout that directs extracted liquid from the pressing bed into a designated collection area, improving drainage and relying on gravity for efficient flow. This design ensures a continuous liquid flow, accelerates the pressing process and minimises contamination risks by keeping solids separate from the liquid. Compared to Type 2 presses, Type 3 is even more effective in facilitating the movement of liquids. These presses have been identified in Crete, Cyprus and Palestine (Hadjisavvas, 1992; Frankel, 1999).

7.4.3 First Known Evidence

The earliest evidence of SLWP in the regions under study dates to the 16th century BCE in Crete and Syria, followed by Cyprus around 1300 BCE, Armenia and Palestine in the 9th century BCE and Greece in the 6th century BCE (see Table 7.6). Armenia's SLWP use was associated with sesame oil rather than olive oil or wine (Bedigian and Harlan, 1986, pp. 146-147) and will not be discussed further. Although SLWP evidence in Turkey appears only in the Hellenistic period and in Jordan and Lebanon in the Roman period (Foxhall, 2007, p. 139), it is possible the technology was known in these areas, as well as in Palestine and Greece, as early as the Late Bronze Age. The proximity of these regions, coupled with active trade routes, shared agricultural practices and cultural exchange, likely facilitated the spread of SLWP technology well before current

archaeological evidence confirms it. The interconnected nature of Mediterranean and Near Eastern civilizations during this period further supports the likelihood of earlier adoption of SLWPs in these regions (Hall and Osborne, 2022).

Area	Earliest Location(s)	Earliest Time Period	Earliest Date	Source
Crete	Vathypetro and Kommos	Late Bronze Age	c.1550 century BCE	Renfrew, 1972, plt. 15.2; Branigan, 1970, pl 8; Marinatos and Hirmer, 1960, 140; Blitzter, 1991, p. 93.
Syria	Ugarit	Late Bronze Age	c.1500-1300 BCE	Callot, 1987 pp. 197-202.
Cyprus	Alassa Paliotaverna, Alassa-Pano Mandilaris, Maroni-Vournes, Kalavassos-Ayios Dhimitrios	Late Bronze Age	c.1300 BCE	Hadjisavvas, 2020, pg. 38-42; Hadjisavvas, 1992.
Palestine	Tel Dan	Iron Age	c. 840 BCE	Arie, 2008, pp. 6-7, 32-35; Onozuka, 2012, pp. 76-77; Biran, 1980.
Greece	Klazomenai	Iron Age	6th century BCE*	Foxhall, 2017, p. 134-136.

*Table 7.6 Early adoption of SLWP systems across regions: locations, chronology and sources. Evidence of SLWPs from Turkey, Jordan and Lebanon falls outside the time periods under study and was therefore excluded from this analysis. * Chosen to keep within the table since it is somewhat close to the time periods under study.*

There were several potential advantages for early adoption of SLWP technology. For example, they may have achieved higher production volumes more quickly and easily, positioning themselves as reliable suppliers ,capable of meeting large-scale demand. This early advantage could potentially allow them to dominate regional and international markets by saturating them with value-added products before competitors entered. Enhanced production quality was likely another benefit, as early access to advanced pressing techniques enabled the refinement of processes to produce superior products that could command higher market prices. Consistently

high-quality products could have helped these regions establish a reputation for excellence, making them preferred suppliers in competitive markets.

Regarding labour inputs, early adoption could have facilitated gradual adaptation to new technologies, minimising disruptions and fostering the development of skilled workers over time. This probably led to the development of a proficient workforce adept at operating SLWP systems efficiently. Later adopters may have faced steeper learning curves and required more intensive training to catch up. With greater experience, early adopters were likely able to reduce labour costs per unit over time, achieving economies of scale.

In terms of market dynamics, early adopters probably had the opportunity to establish their reputation and penetrate diverse markets before competitors, securing positions in both premium and mass-market segments. They may have been better positioned to serve large urban centres and export markets, diversifying their customer base, while later adopters might have been limited to more localised markets. Aligning supply with existing demand likely allowed early adopters to stabilise their market presence, while later adopters often had to carve out niche markets or find other ways to compete (e.g. cost).

Additionally, early adopters were probably instrumental in shaping supply chains and setting standards for product quantities and types demanded by various markets. This head start may have enabled them to consolidate economic and market power by introducing higher-quality, abundant products and creating demand that was challenging for later adopters to match. Early adopters might also have led technological innovations, further enhancing SLWP systems to maximise efficiency and output, keeping them ahead of competitors. This dominance would have helped stabilise supply and pricing, establishing benchmarks that later adopters had to follow or try to undercut.

7.4.4 Geographical and Archaeological Distribution

There is currently no evidence of SLWPs in Syria and Crete from the 1000-600 BCE period. There is evidence of SLWPs being constructed between 1300 to 950 BCE in Cyprus. The presence of presses during this period appears more continuous than in other regions. A small gap in the archaeological evidence exists between 950 and 700 BCE (Hadjisavvas, 1996, 2020;

Chaniotis and Hadjisavvas, 2012). This gap could be attributed to the presence of Phoenicians on the island (Hadjisavvas, 2013), who dominated wine production in the larger region, along with evidence of strong oil production. Given the Phoenicians extensive production of wine and oil elsewhere, it is possible they did not require additional processing equipment because they were focused on other industries, such as copper production.

In Palestine, however, there is an absence of SLWP evidence in the archaeological record until the 8th/7th century BCE, when they appear suddenly and in large, concentrated numbers. This abrupt and widespread emergence suggests a rapid, significant and deliberate transformation rather than a gradual development (see section 7.4.5 for further explanation). It is possible that this shift was influenced by the large-scale wine production already established in regions such as Syria, Cyprus and Crete, prompting the adoption of similar practices in Palestine.

While the comparative timelines across these areas suggest a possible eastward diffusion of SLWP technology, the limited evidence available makes this trajectory difficult to confirm with certainty, especially when one considers some odd phenomena (section 7.4.5).

7.4.5 Cyprus and Palestine: Exceptions to Regional SLWP Trends

Notably, a couple of unique phenomena stand out: Cyprus adopted SLWP without evidence of prior use of simple installations and Palestine shows a significant time gap in using SLWP compared to other surrounding areas.

7.4.5.1 Cyprus' Adoption of SLWP Without Preceding Simple Installations

The earliest confirmed evidence of oil and wine production equipment on Cyprus excluding undateable rock-cut simple installations at sites like Amathus, Karion and Paphos, are the SLWPs found at sites like Alassa Paliotaverna, Alassa-Pano Mandilaris, Maroni-Vournes and Kalavastos-Ayios Dhimitrios during the Late Bronze Age, around 1300 BCE (Hadjisavvas, 2020, pp. 38-42, 71-73; Hadjisavvas, 1992; Frankel, 1999, Appendix A and B).

This evidence suggests that Cyprus likely adopted advanced pressing technology through external influence and trade, bypassing earlier technological stages such as the simple

installations seen in Crete and Syria. This direct adoption suggests a sudden shift to large-scale production. The early use of SLWPs indicates that Cyprus was part of a sophisticated, interconnected trade network, benefiting from its strategic location to produce high-quality oil and wine for both local consumption and export. The absence of confirmed simple installations prior to the introduction of SLWPs suggests that Cyprus did not develop pressing technology in isolation but was heavily influenced by foreign innovations. The island was a significant economic hub in the Late Bronze Age Mediterranean and was already a key supplier of copper and other goods (Papavasavas and Kassianidou, 2012; Kassianidou, 2013). The adoption of more advanced pressing technology supports the idea that Cyprus' economy was centrally driven and organised around large-scale production sites designed to produce significant quantities of oil and wine for trade. This advanced technology would have helped diversify the island's economic activity and gave Cyprus an even stronger economic position in the region.

The immediate transition to SLWP allowed Cyprus to quickly achieve a production quality comparable to regions that had been using SLWP for centuries. This enabled the Cypriots to create products competitive in both quality and quantity. The ability to rapidly increase output would have supported market expansion by integrating these products into existing trade networks they already had for other products. However, this direct transition also introduced immediate demands for skilled labour to operate and maintain SLWP. This likely required training and adaptation in the early stages. Over time, as skills became more widespread, labour could be more efficiently organised around SLWPs, enabling Cyprus to capitalise on lower labour costs per unit of product.

7.4.5.2 A Regional Outlier: SLWP Adoption in Palestine

The late emergence of SLWP technology in Palestine, with the earliest potential evidence dating to around 840 BCE, is particularly striking compared to nearby regions where SLWPs were in use as early as the 16th century BCE, a gap of at least 400 to 600 years. Two proposed examples of SLWPs in Palestine, dating to between 1000 and 800 BCE, include one at Tel Dan (Biran, 1980) and another at Megiddo (Frankel, 2016). Stager and Wolf (1981) suggest that a SLWP was constructed in the cultic complex at Tel Dan, dating to the 11th or 10th century BCE. However,

Arie (2008, pp. 6-7, 32-35) demonstrates that the stratum containing this SLWP actually dates to the late 9th or early 8th century BCE, based on absolute dating and ceramic typology. Onozuka (2012, pp. 76-77) further supports this, dating the SLWP to around 840 BCE. Moreover, the shape of the crushing basin, initially thought to indicate its use for olives, may suggest otherwise. The depth of the vats and the angle of the walls make it unsuitable for olive crushing, potentially indicating a simpler installation for wine processing.

A free-standing rectangular central vat with bores and peripheral grooves was found at Megiddo (Frankel, 1999, 2016) but its dating remains uncertain. According to Frankel (1999, Appendix A), the vat was not included in the original report by Lamon and Shipton (1939, fig. 123), though Frankel observed it during a site visit. The vat apparently appears in an aerial photograph (fig. 123) located in the northwest corner of square R6. It remains *in situ* within one of the buildings later disturbed by the construction of stables or storehouses from Stratum IV (c. 1000-800 BCE) (Lamon and Shipton, 1939, pp. 90, 105). However, issues persist with its dating and categorisation. The photograph in Lamon and Shipton's report (1939) is blurry, making it difficult to clearly discern the vat's structure, function or even if it is a central vat. Additionally, the limited surrounding space challenges the idea that it functioned as a press, as does the lack of a niche, foundations on all three sides or evidence of weights, elements typically associated with SLWP technology. Onozuka (2012, pp. 76-77) took a photo of the Megiddo vat that contrasts from Frankel's drawing. While Frankel's illustration (Frankel, 1999, Appendix A) shows the vat with bores, Onozuka's photo does not. Instead, the vat in Onozuka's image resembles vats from later periods of the Iron Age (8th/7th centuries BCE) found at sites such as En Hagit (Frankel, 1999, Appendix A), Tel Gezer (Eitam, 1986), Timnah (Kelm and Mazar, 1987) and Ekron (Dothan and Gitin, 1984, 1985; Gitin, 1987), suggesting the Megiddo vat should be dated to around c. 800 BCE. If Frankel's drawing is accurate, however and the vat indeed has bores, this could indicate a more sophisticated example of the technology, potentially dating to a period later than the 8th/7th centuries BCE, as technological advancements based on simpler designs emerge in later periods.

This gap is particularly striking given that Palestine is one of the most extensively researched areas in terms of processing equipment, with a well-documented history of processing

technologies, especially from the early periods. Numerous studies, excavations and surveys have been conducted in this region, emphasising its longstanding tradition of oil and wine processing (e.g., Frankel, 1999; Van W Scheepers, 2006; Eitam et al., 2024; Onozuka, 2012; Salavert, 2008; Sabatini, 2019;). Moreover, given Palestine's proximity to Syria, Cyprus, Crete and other regions that had presses from earlier periods plus the trade and interactions with those areas, the technology should have been easily available. Consequently, this raises the question of whether the absence of earlier evidence for SLWP in Palestine reflects a genuine lag in adopting this technology.

If this was the case, several factors might explain the delayed adoption of SLWP technology in Palestine. One possibility is that traditional methods of oil and wine production remained reliable and effective, meeting both local consumption and trade demands. These methods were deeply embedded in cultural practices, agricultural cycles and economic structures, making significant deviations or rapid technological advancements unnecessary or even undesirable. Over generations, these established techniques had been refined to ensure consistent product quality and predictable yields, fostering cultural and technological conservatism that may have slowed the acceptance of new innovations. This conservatism could have been further reinforced by the cost and accessibility of new technologies. For example, SLWPs may have required greater or at least different, investments in materials, labour and infrastructure, making them impractical for some producers, particularly those operating within subsistence or regional trade economies.

This delay may have lasted until the 9th century BCE, as the development and spread of technologies like the SLWP often corresponded to economic demand. During the Late Bronze Age and early Iron Age, the region faced instability, with the collapse of city-states and the withdrawal of Egyptian control in the 12th century BCE (Schipper, 2012; Steel, 2018; Sherratt and Sherratt, 1993). This led to a more rural, village-based society where self-sufficient communities depended on terrace farming and limited trade, reducing the need for technological advancements like the SLWP (Masalha, 2016; Sherratt and Sherratt, 1993). By the 10th century BCE, however, significant economic changes, including population growth, urbanisation and increased trade, particularly in the north (Fritz, 1987; Broshi and Finkelstein, 1992; Bloch-Smith and Nakhai, 1999; Sherratt and Sherratt, 1993), likely created the conditions for adopting more efficient technologies like the SLWP. A favourable climate and expanded agricultural production

further supported this shift (Finkelstein and Langgut, 2018; Langgut et al., 2016). The adoption of the SLWP likely aligned with these developments as the population grew leading to increased demand for products. Therefore, increased production capacity was required.

This period of agricultural and economic transformations (10th/9th century BCE) aligns with the initial use of SLWP in Palestine, particularly in the northern regions, where they became widespread. By 800 BCE in northern Palestine, SLWPs had largely replaced the older round and rectangular oil presses (Onozuka, 2012, pp. 81-83). In contrast, round oil presses continued to be used in the southern regions during this period, as seen in discoveries at Tel Beth Shemesh (Bunimovitz and Lederman, 2008, 2011). SLWPs were instrumental in advancing olive oil production during the later Iron Age (Finkelstein and Langgut, 2018).

7.4.6 Later Developments Based on SLWPs

The next development was the Improved Lever and Weight Press (ILWP), from around the 4th century BCE across all of the areas under study (Frankel, 1999, pp. 77–98; Foxhall, 2007; Hadjisavvas 1996, 2020). The ILWPs were similar to the SLWPs but were larger with the addition of anchoring pier bases, beam supports (guide bases) and beam and drum supports to help stabilise the anchoring and pressing points and the point of applied force. The ILWPs were further improved by the use of sophisticated beam weights. Sophisticated beam weights are significantly more effective for oil and wine production as their advanced features enhance precision, efficiency and control during the pressing process. These weights, in various shapes, cylindrical, rectangular, bell-shaped, octagonal, oval and irregular and equipped with diverse grooves (e.g., upper grooves, crossed grooves, vertical bores and combinations of upper, lower and lateral grooves) (Frankel, 1999, pp. 99–106), offer superior stability, higher weight capacity and precise adjustments. The grooves and additional features ensure the weights are securely fastened to the beam, minimising slippage and enabling consistent pressure application. This stability not only improves extraction efficiency but also allows for larger, heavier stones to be used, increasing total pressure. Furthermore, the diverse groove configurations and bores allow for precise adjustments and better pressure distribution across the press, ensuring optimal extraction while preserving the quality of the final product.

The next major technical advancement in press technology was the development of the lever and screw press, as well as the single or double screw press (ethnographic examples are discussed in Chapter 4). These innovations not only improved workforce safety, as noted by Hero of Alexandria (*Mechanica* 3.15) but also provided a significant mechanical advantage. The screw mechanism generated much higher pressure, allowing for greater liquid extraction from the same amount of raw material and enabling larger batches to be processed efficiently. It also ensured consistent results even with variability in output. Furthermore, lever and screw presses offered precise pressure control, preventing over-pressing and minimising the extraction of undesirable elements like bitter tannins or seed impurities.

The evolution of processing equipment reflects not only the expansion of tree fruit cultivation but also the growing demands for large-scale wine and oil industries to produce sufficient quantities for both interregional and intraregional trade. This heightened demand was likely driven by growing populations and the rise of larger, more powerful empires (e.g., during the Hellenistic, Roman and Byzantine periods), all of which required substantial supplies of wine and oil for consumption, trade and taxation. This, in turn, would have led to the expansion of agricultural lands, providing the necessary space to cultivate more raw materials for processing (Ayalon et al., 2009; Tuna, 2020; Zuiderhoek, 2013; Kourakou-Dragona, 2016, pp. 106-108). The increased demand for these commodities fostered a thriving market that extended beyond local consumption to encompass extensive trade networks (Temin, 2006; Bintliff, 2013). This rising demand helped drive the development of more sophisticated processing equipment to enable producers to increase output and provide an improved and consistent quality of product. In essence, the advancement of processing equipment was likely both a response and symptom rather than a cause or catalyst for economic and cultural developments (Foxhall, 1993, 2007).

7.5 Oil Separators

7.5.1 Typologies

For any given volume of olives to be pressed, on average 60% of the weight was liquid based with approximately 40% water and other substances but only 20% oil (Åströms, 1992; Callot, 1984, p. 71). The three main types of separating methods for retrieving the oil used the principle

of gravitation: since oil and water are different on a molecular level, oil will float. These separators are mainly based on written records (Epstein, 1992; Pratt, 2014; Van W Scheepers, 2006) and the use of ethnographic and historical examples (Bel, 2017, figs 1-3; Forbes and Foxhall, 1978, p. 39; Frankel, 1999, Appendix A; Petrakis, 2006). Separators were first divided on how they used the principles of gravity: Type 1 is skimming, Type 2 is overflow and Type 3 is underflow separators. They were then subdivided based on their materials and in the case of Type 2 and 3 where the liquid would flow from. These separators were circular and round in shape.

- Type 1 - Skimming
 - Type 1.1 - Ceramic
 - Type 1.2 - Stone
- Type 2 - Overflow
 - Type 2.1 - Ceramic
 - Type 2.1.1 - Small Opening
 - Type 2.1.2 - Spout
 - Type 2.2 - Stone
 - Type 2.2.1 - Small Opening
 - Type 2.2.2 - Spout
- Type 3 - Underflow
 - Type 3.1 - Ceramic
 - Type 3.1.1 - Small Opening
 - Type 3.1.2 - Spout
 - Type 3.2 - Stone
 - Type 3.2.1 - Small Opening
 - Type 3.2.2 - Spout

Type 1 is the simplest method and involves skimming the floating oil from the lees using a ladle or a similar utensil with small holes. The oil would be separated as soon as possible since contact with the air soon leads to fermentation and impacts the quality of the oil. This method is indicated in the archaeological record by the presence of single-receptacle tanks (non-specialised) and the absence of ‘sophisticated’ separators found within oil processing facilities (Frankel, 1999, p. 174-176; Hadjisavvas, 1992, p. 72). Realistically, any type of equipment, made of ceramic or stone, with a large enough upper mouth and holding capacity could have been used for this process. These can be easily confused with ceramic simple installations (see Section 7.3).

Type 2 overflow separators are considered the most useful for oil processing due to their simplicity, efficiency and ability to handle larger quantities with minimal effort. Their design, featuring an opening or spout just below the rim of the vessel, allows the natural separation of oil from watery lees through a passive process that relies on the differences in density between the two liquids. As oil floats above the water, it can easily flow out through the spout without requiring additional manual intervention, making the process efficient and less labour-intensive. The convenience of Type 2 separators lies in their ability to streamline the separation process, reducing the need for repeated handling or the use of additional tools. By enabling the continuous flow of oil, these vessels are particularly advantageous when processing larger quantities of oil, as they can operate without constant monitoring or manual adjustments. This design would have been highly beneficial in contexts where speed and efficiency were critical, such as in larger-scale oil production facilities or during peak harvest periods. Furthermore, the passive nature of the separation process means that less skilled labour is required to operate these separators compared to more complex systems. The ease of use and effectiveness in managing large quantities of oil makes Type 2 overflow separators a practical and efficient choice for ancient oil production, likely contributing to their widespread use in historical processing contexts. There are challenges in identifying such separators archaeologically due to the fragility of their defining spout.

Type 3, underflow separators, have openings or spouts at the bottom of the vessel or vat for the separated liquids to flow out (Frankel, 1999, p.175). Again, they are challenging to identify archaeologically due to their structural fragility. The spout, often the thinnest and most vulnerable part, is prone to breakage or damage, leaving incomplete artefacts that are harder to classify. Identification also requires preservation of the vessel's lower section and several inches above the spout. Such features are rarely intact due to post-depositional damage such as soil pressure or human activity. Compounding this difficulty is the multifunctional nature of ancient vessels. A spout could suggest varied uses (example: as a small crushing and extraction vessel for grapes) (see section 7.4), thus making identification uncertain without contextual evidence. Additionally, these portable vessels were often repurposed, moved or discarded, further reducing the chance they would be discovered in a production setting.

All the above methods involve a second stage of purification that was accomplished in settling vats. The freshly pressed oil was muddy and time was needed for the impurities to settle to the bottom of the vat. However, almost any ceramic or stone vessel could be used for this process as long as there was a large mouth to allow the final product to be removed. (Hadjisavvas, 1992, p. 76).

7.5.2 Other Value-Added Products

Evidently, oil separating installations and equipment could be used for other value-added products, like wine and in other ways. Therefore, the context in which they are found, the size of the spouts and any archaeobotanical evidence are crucial in determining their actual function. For example, a freestanding overflow separator, round with deep walls and a small ‘U’-shaped hole at the top/rum, was found at H. Rosh Zayit, dating to the Iron Age. It was discovered alongside a level-and-weights press, a press bed, a crushing mortar and pottery vessels used for collection (Gal and Frankel, 1993), which allowed for its convincing classification as an oil separator. At Vathypetro, a small square press bed was found in conjunction with an overflow separator in a household. It was initially described as a winepress by Renfrew (1972), likely due to the height of the walls (around 30 cm), which suggested treading (Frankel, 1999). However, the high walls may have been intended to keep the bags or wooden boards with fruit in place while they were being crushed by the simple level-and-weights press, which was in use at the time. A narrow spout could indicate that it was meant to facilitate the pouring of small quantities of something like olive oil (especially given the presence of olive stones) rather than the abundant liquid produced by grape pressings, including solid substances from the must.

7.5.3 Geographical Distribution

Type 1 is non-specialised and was likely found in all areas and periods under study, from the Neolithic onwards. In contrast, Type 2 was predominantly located in the Levant, with evidence dating back to the Chalcolithic period. These simple pottery overflow separators were used continuously until the pre-industrial era. Key sites associated with Type 2 include Rasm Harbus, Rasm el-Kabesh and Ein el-Hariri, with notable usage in Crete from the 16th century BCE onwards (Epstein, 1978, p. 29; Epstein, 1992; Stager, 1990, p. 97; Gal and Frankel, 1993; Frankel, 1999; Renfrew, 1972, pl. 15.2; Branigan, 1970, pl. 8). Type 3 is found primarily on

Cyprus, with evidence dating back to the Neolithic at sites such as Sotira, Dhali-Agridhi and Ayios Epiktitos Vrysi (Peltenberg, 1978, pp. 72–73; Lehigh, 1974, p. 85). Its use continued until the pre-industrial era, with additional examples from the Early Bronze Age in Greece, Palestine and Crete. Key Aegean sites include Myrtos, Mallia, Kommos and Vathypetro, highlighting a focus on the Aegean world and Cyprus (Forbes and Foxhall, 1978, p. 46; Branigan, 1970, p. 71; Hutchinson, 1962, p. 242; Shaw, 1977, p. 208).

7.5.4 Conclusions

There was no significant evolution in oil separation equipment from its first appearance in the Neolithic through the time periods under study. The lack of evolution over millennia reflects the sufficiency of these tools to meet the practical, economic and cultural needs of ancient communities. The simple yet effective design principles, combined with the adaptability of the equipment and the stability of production methods, meant that the equipment as initially developed required little to no refinement to sustain production across diverse contexts and historical periods.

The fundamental principle of oil separation, gravity, relies on the natural buoyancy of oil, which separates from water and other substances due to its lower density. This straightforward mechanism does not necessitate complex machinery or significant technological advancement, meaning that it would not require new or additional resources. The basic designs of oil separation equipment were both cost-effective and versatile. Single-receptacle tanks allowed for skimming, while overflow and underflow separators were simple yet functional solutions that worked efficiently across varying production scales. These tools were adaptable to the requirements of small-scale household production and larger industrial operations. The multifunctional nature of oil separators further contributed to their enduring use. These devices could be employed not only for oil separation but also for processing other value-added product liquids. The simplicity of the existing equipment ensured it could be produced and maintained at minimal cost. The widespread availability of raw materials (clay and stone) and the ability to create these tools locally further reduced the incentive for innovation.

The archaeological record shows continuity in the use of these techniques and equipment across regions and diverse cultures, from the Levant to the Aegean. For instance, underflow separators

in the Aegean and overflow separators in the Levant were used consistently from the Neolithic through to the pre-industrial era. The difficulties in the definitive identification of separators in the archaeological record further highlights their multipurpose nature. This ambiguity underscores the adaptability and widespread functionality of these tools.

7.6 Fermentation and Storage Vessels

Fermentation and storage vessels fall beyond the scope of this study due to their sheer number and variety, spanning different contexts, forms, sizes and functions, which make them a broad and distinct area of research in their own right (see explanation in Chapter 1). Any type of vessel with a lid could have been used for both fermentation and storage processes, further complicating their specific role in production. Nevertheless, while these vessels provide valuable insights into the scale, logistics and preservation strategies of oil and wine production, they are limited in their ability to shed light on the more detailed aspects of production processes, labour organisation or the subjective quality of the final products.

Fermentation and storage vessels can reveal much about the scale and organisation of production: their size, volume and quantity indicate storage capacity, surplus and potential trade, while their manufacture reflects labour investment and coordinated efforts. Features such as seals, linings, handles and inscriptions provide evidence for preservation methods, transport and supply chains and organic residues or vessel design can even hint at the type of liquid stored and the value placed on quality control. However, vessels alone cannot show the precise techniques used in pressing, fermentation or separation, nor can they reveal how labour was organised, whether within households, workshops or under centralised control. They also offer little certainty about the cultural or ritual significance of production and while residues suggest general product types, they cannot determine exact quality or specialised production methods without complementary archaeological or chemical evidence.

7.7 Other Tree Fruit and Processing Equipment

Mesopotamian inscriptions indicate that date wine was a prominent alcoholic beverage during the Iron Age, suggesting its central role in the region's cultural and social practices (Broshi,

2007, p. 56). This prominence may account for the increased evidence of date palms and figs across site-phases from this period. Additionally, Babylonian and Assyrian records from the 1st millennium BCE frequently reference the production and resale of date wine, indicating its established role in the economy and daily life (Stol, 1994, pp. 155-183). Although most literary sources that discuss date and fig wine production fall outside the primary time scope of this study, they suggest that the winemaking process was already well known by the periods described and may have been practised for centuries, if not millennia. As shown in Table 7.7, the available literature, dating from the 1st century CE onwards, indicates that no specialised equipment was typically used in the production of date and fig wines. Instead, large storage vessels, likely made from local materials, were employed for macerating the fruit in water and allowing fermentation to occur.

Literature Sources	Key Information Regarding Date/Fig Wine Production	Time Periods
Dioscorides	Water and dates fermented 5-10 days in a storage vessel; strained on day 11; no other technology noted (Stohl, 1994, pp. 155-183).	1st century CE
Pliny the Elder	Similar to Dioscorides; only a storage vessel used (Historia Naturalis XIV, 102) (Stohl, 1994, p. 158).	1st century CE
Levi ben Sisi	Dates reused in multiple fermentation “rounds” until yeast stopped; high sugar content (up to 70% sugar) allowed repeated fermentation (Broshi, 2007, p. 57).	2nd century CE
Babylonian Talmud	Water and dates fermented less than a week in a large container (Stohl, 1994, pg. 158–161).	c. 500 CE
Iraqi farmers	Dates fermented 2 days for malt ($\approx 9\%$ alcohol) for distillation (Barreweld, 1993, pp. 2-3).	20th century CE
Armenian ‘fermenters’/Վնդար-իչնէր	Figs (status symbol) fermented 10–13 days; similar to Roman date wine. Approx. 1 L water + 0.5 L mashed dates per litre of wine. (Participant 22, personal communications, 2022; Participant 45, personal communication, 2022).	19th century CE - present

Table 7.7: Chronological overview of date and fig wine production techniques and equipment based on literature (1st Century CE – Present).

The exact origins of date or fig wine production remain unclear, largely because the equipment used was non diagnostic and lacks distinctive features to date it precisely (Broshi, 2007, p. 56). Date and fig wine production likely relied on non-specialised, non diagnostic fermentation

vessels, which were typically used for storing various food sources. These vessels enabled the maceration of the fruit within (probably using a wooden masher, similar to a pestle and mortar), as part of the winemaking process. Unlike other fruits such as olives, grapes and pomegranates which release juices through pressing, dates and figs have a high concentration of soluble solids that cannot be extracted by pressing alone. To produce juice from dates or figs, water must be added to dissolve and dilute these concentrated solids, after which the insoluble solids can be separated out (Barreveld, 1993). This process requires vessels with the capacity to hold substantial amounts of water during fermentation, which aligns with the use of large-scale storage containers as suggested by historical sources. The reliance on general-purpose storage vessels, rather than specialised winemaking equipment, indicates that the production of date and fig wines was both widespread and accessible, seamlessly integrated into the everyday lives of ancient communities. This simplicity in equipment allowed for the broad adoption of winemaking practices across different social and economic classes.

Evidence of five date wine production installations have been found in Palestine, with four located in Jericho (Netzer, 1989, p. 276; Netzer, 2001, pp. 127–128; Netzer, 2002) and one at Ein Feshkha (Hirschfield, 2004, pp. 54–55; Humbert and Chambon, 1994), all dating to the late Hellenistic or early Roman period (1st–2nd centuries BCE). Each installation included a treading floor, an intermediate vat and a large collection area, all strategically positioned near water conduits. Four installations were directly supplied by water from these conduits, while one Jericho winepress relied on manual filling. The winemaking process began with removing pits from dates or cutting the figs (Barreveld, 1993, p. 59), after which the fruit was taken to the treading floor. A small amount of water was added at this stage to lubricate the fruit and aid in the maceration process. Cylindrical stone rollers, present at each installation, were used to crush the date and water mixture on the treading floor (Brun, 2004, p. 211). These rollers, one of which was found in situ, were sizable and likely required a team of two or three individuals to operate. The intact roller, measuring 1.48 meters in length and 0.8 meters in diameter, weighed approximately 900 kg. It was likely operated by two to three people and would have been sufficient to easily crush dates and figs into a paste or maceration to which water could be added (Humbert and Chambon, 1994, p. 252). Once the fruit was adequately crushed, the resulting maceration could either be left to ferment in the collection pool, where ample water was added to

aid fermentation and sunlight facilitated the process or it could be transferred to a storage vessel for fermentation. In the latter case, additional water would be added to achieve the desired consistency and sugar balance. In practice, any simple installation that could support sufficiently heavy stone rollers and provide enough space for fruit maceration could have been used for production.

Although these installations date to the 1st–2nd centuries BCE, it is likely that the practice of date wine production began much earlier, potentially coinciding with the introduction of date palms to the region. Evidence suggests that date palms may have been cultivated as early as the Neolithic period in Palestine and Jordan, the Chalcolithic in Egypt and the Early Bronze Age in Lebanon (see Chapter 6, Table 13). During these early periods, non-specialised equipment, such as simple ceramic storage containers similar to those used in ancient beer production, may have been utilised for fermentation.

Archaeobotanical evidence shows a marked increase in date palm remnants in Late Bronze Age Egypt and Iron Age Palestine, suggesting a possible shift in preference or need to date consumption and date wine over time (Chapter 6). This shift appears to have led to a change in date wine production - a move from basic, non-diagnostic vessels where dates were likely macerated using a wooden bat or spoon (similar to a mortar and pestle), to larger, more specialised installations equipped with stone rollers (Callot, 2003, 2013). This transition likely influenced the quantity and quality of production, as well as the amount and intensity of labour required to enable larger-scale, more efficient production (Table 7.8). Wooden bat/spoon crushing is simpler but requires significant physical labour, with less control over mash consistency and quantity. This approach is best for small-to-moderate batches where ease of setup is a priority. Stone rollers yield a finer mash more efficiently, with better quality control and reduced labour intensity, making them ideal for larger-scale production even though they require additional handling to transfer the macerated dates into fermentation vessels (van Limbergen, 2017; Callot, 2003,2013).

Impacts	Wooden Bat/Spoon	Stone Rollers
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Quantity	Crushes directly in the vessel, enabling immediate fermentation but limited by labour strength and uneven mashing.	Handle larger batches outside the vessel, with extra transfer steps but greater bulk capacity.
Quality	Produces a coarser, less uniform mash that retains more sugars/fibre, giving thicker, less controlled fermentation.	Create a finer, uniform mash, releasing more sugars for efficient, consistent fermentation.
Ease	Simple setup but physically demanding and repetitive.	Require setup and transfer but reduce physical strain for large volumes.
Labour Force	Labour-intensive, often needing multiple workers for larger vessels.	Less manual effort once set up, improving efficiency and reducing worker strain.

Table 7.8: Review of the different impacts of the wooden bat/spoon and the stone rollers in terms of quantity, quality, ease and labour force.

There is evidence of date wine processing depicted in Egyptian tomb paintings as early as the 16th century BCE. These paintings specifically highlight the transportation of dates to the TCA and workers treading the dates (i.e., some workers holding the upper framework of a vat and some workers actively treading the dates in the vats using one or both feet). The workers are arranged in groups, often facing different directions, indicating coordinated labour (Oxford Expedition to Egypt: Scene-details Database, 2007). This evidence suggests that relatively simple installations of varying sizes may have been used to crush the dates. Since dates were harvested from spring to autumn, this suggests that the installations in question were likely used for multiple purposes throughout the year (see section 7.8.4). Treading activities for dates may have taken place in the TCA from spring through to autumn, prior to the harvesting and processing of grapes or olives. This could help explain why the infrastructure in this area involved large-scale, permanent structures, despite their limited usage for only a few months each year to produce date wine.

7.8 Effectiveness and Benefits of Each Type of Processing Equipment: A Summary

7.8.1 Structure: Simple Installation vs. Non Specialised Equipment

Simple installation (section 7.3) structures offer a more effective solution than non-specialised household equipment (section 7.1) for olive oil and grape wine production. The sloping treading/crushing area of simple installations allows for the processing of larger volumes of olives or grapes compared to non-specialised equipment, which is limited in capacity. The channel mechanism efficiently directs the extracted juice or oil to a lower collection area using gravity, minimising the need for manual handling and enabling larger quantities to be processed with less effort. In addition, simple installations can apply torsion, treading or stone rollers, ensuring more consistent pressure during crushing and pressing. This prevents damage to grape seeds and avoids over-crushing olive pulp, both of which can compromise flavour. In contrast, household tools often lack the ability to apply uniform pressure, resulting in lower-quality output. The use of designated collection areas, such as vats or pithoi, helps separate the juice or oil from the fruit matter more effectively, leading to purer, higher-quality liquids.

Non-specialised equipment, by comparison, often lacks this separation process, yielding less refined results and possibly less quantities. The efficient design of simple installations, particularly their gravity-fed systems, reduces the manual labour typically required in smaller setups, where liquids might need to be transferred manually. Overall, simple installations are well-suited for larger-scale production, processing greater volumes with ease and offering scalability without the need for complex machinery.

7.8.2 All Processing Equipment: Advantages and Disadvantages

Each method, pestle and round mortars, weight, boards and bag, stone rollers, rotary crushing basin and weights, differs in terms of ease of use, labour force required and the quality and quantity of the output (see [Appendix 11](#) for a more detailed breakdown). For calculations and formulas, sensitivity analyses, pivot tables and graphs focusing on each method refer to [Appendix 10](#).

The equations developed and the sensitivity analysis examples provide a solid foundation for further research into the pressures generated by various oil and wine pressing equipment. The methodologies in this research offer a replicable framework that future researchers can adapt to study other pressing equipment or variables, such as raw material differences, environmental conditions or labour inputs, expanding our understanding of ancient agricultural practices. By utilising these equations and sensitivity analyses, researchers can better understand the operational mechanics of ancient processing equipment. This understanding can lead to more accurate reconstructions of historical olive oil and wine production processes, providing insights into how ancient societies maximised their yields and improved product quality. The developed models also allow for a comparative analysis of different pressing technologies over time.

These calculations are innovative. According to this author, no detailed analysis or calculations have been conducted for torsion, pestle and mortar, weights, boards and bags, treading, stone rollers, nor in such detail for SLWPs. While Rojas-Sola and Ramirez-Arrazola, 2011, pp. 2380–2382) discuss specialised olive oil crushing equipment like the *Galerie Gouttière* and *Trapetum*, dating from the Roman period onwards (beyond the timeframe and equipment under review, here) their focus is on the evolution of engineering aspects rather than pressure calculations or practical applications in the olive oil process. Consequently, the calculations and analyses presented here are uniquely comprehensive. Frankel (1999, p. 61) briefly mentions beam length, beam weights and a basic equation but provides no evidence or detailed explanation. No previous work has addressed the effects of beam positioning, whether closer to or farther from the press bed or weights, on pressure and weight distribution. Nor have prior studies considered factors beyond mechanical advantage, such as force, crushing force, variable force, actuation force, control over pressing, complexity, investment, labour and the quality and quantity of output. This analysis fills those gaps, offering novel insights into these pressing systems.

The pestle and mortar method offered a simple, flexible approach where pressure varied with user-applied force and contact area. While effective for breaking down small quantities of harder materials or initiating extraction, it was labour-intensive and inefficient for larger operations. This method's reliance on repetitive manual labour and limited scalability made it more suitable for localised or preliminary processing rather than comprehensive production.

Weights, boards and bags provided consistent pressure through static weights, with limited adjustments possible via changes to weight or surface area. This method was cost-effective and sustainable, favoring gentle processing of softer materials. However, its reliance on static force reduced adaptability for diverse materials or higher-pressure needs. Best suited for small- to medium-scale production, it lacked efficiency for intensive operations.

The torsion method relies on manually applied force, with pressure determined by operator weight and effort. While suitable for small-scale production, it requires optimisation of leverage and contact area for better efficiency. High-pressure output demands extra manpower or modifications, limiting its practicality for large-scale operations. Simple and resource-efficient, it is well-suited for artisanal use but remains labour-intensive and unsuitable for industrial purposes. The method lacks pressure adjustability during operation. It produces moderate yields, exceeding treading but at greater physical effort. Accessible and cost-effective for resource-limited communities, it is sparsely evidenced archaeologically but well-documented in iconographic and ethnographic sources. Key optimisation factors include user weight, lever arm length and contact area, with smaller areas generating higher pressure.

The treading method relied on human weight to generate pressure, offering low, fixed force with no flexibility for adjustment. This technique excelled in delicate applications, such as grape juice extraction, where moderate pressure preserved fruit quality. It was cost-effective, labour-intensive and more efficient than torsion, with a straightforward setup and low resource requirements, ensuring accessibility and sustainability. However, its inability to achieve higher pressures or process large volumes effectively limited its use in intensive oil extraction or large-scale operations. While treading worked well for breaking grape skins without damaging seeds, it was less effective for tougher materials like olives. Pressure varied with user mass and foot area and although archaeological evidence is limited, ethnographic and iconographic examples support its historical use.

Stone rollers, utilising gravity and the mass of the roller, exert crushing forces significantly higher than manual methods such as treading or torsion, making them highly effective for large-scale operations. Their mass and rolling mechanics provide more consistent pressure, which is essential for processing large quantities and achieving consistent results. Adjustable

roller mass and contact area offer some control over pressure but excessive force can damage delicate materials, limiting versatility. Additionally, stone rollers demand substantial investment in materials, infrastructure and labour and their construction and maintenance require expertise, making them less accessible to smaller producers. Archaeological evidence supports their historical use and factors like roller size, material and surface conditions can optimise their efficiency.

Rotary crushing basins, combined with weights, integrated rotational dynamics with static pressure, effectively process harder fruits. Adjustments in rotational speed, basin radius and weights enhanced flexibility, making this method efficient for scaling operations. Its ability to adjust pressure and leverage rotational force makes it an optimal choice for high-quality oil and wine production, outperforming simpler methods in both quantity and quality. While more complex and costly, the benefits justify its use in large-scale production contexts. However, its complexity and reliance on skilled labour or animal power restricted its adoption in less resource-intensive settings.

The simple lever and weight press (SLWP) emerged as the most versatile and powerful method, utilising mechanical advantage to generate consistent, high pressure. Its design allowed for precise adjustments to beam length, press bed area and applied weights, supporting a broad range of pressures and making it highly efficient and controllable. This versatility enabled high-yield and controlled-quality outputs, making the SLWP ideal for large-scale olive oil and wine production. While it requires significant investment in skilled labour and materials for construction and maintenance, its minimal manual input and ability to adapt to diverse material types greatly enhance efficiency. However, the investment and periodic adjustments required for optimal performance make it less practical for smaller-scale activity.

Mechanical tools like stone rollers, rotary crushing basins and the SLWP reduce the amount of manual labour required per volume of output. These systems, especially the rotary ones, provide higher mechanical advantage and greater precision, which translates to more consistent results and less repetitive effort for workers. Tools like the rotary crushing basin and SLWP offer significant control over the pressing process, allowing adjustments in rotational speed, direction

and applied weight. This level of control is much higher than that offered by simpler manual systems.

In conclusion, the choice between manual and mechanical tools depends on the scale and needs of the production process. Manual tools are simple, less expensive and best suited for small-scale operations while requiring significant labour input per volume of output. Mechanical tools offer superior efficiency, greater control over the crushing process and higher-quality outputs, making them ideal for larger-scale production. Labour costs are lower per volume of output for large-scale operations.

7.8.3 Large-Scale Production: Most Effective Equipment for Each Tree Fruit and their Value-Added Products

Although it is challenging to identify economic and labour-related factors in the archaeological record, this framework provides valuable insight into the continued use of simpler and less sophisticated equipment alongside advanced installations throughout history. Simpler tools, while lacking the efficiency and mechanical advantages of more complex systems, were generally more affordable, required fewer resources to construct and demanded less specialised knowledge to operate. These factors made them accessible to a wider range of users, particularly in communities with limited economic means or where skilled labour was unavailable. Moreover, the adaptability of simpler equipment allowed it to be used in diverse contexts, including smaller-scale or domestic settings, where advanced machinery might have been impractical or unnecessary.

For large-scale production aimed at achieving the best combination of quantity, quality and efficiency, different types of equipment would have been optimal depending on the specific product being processed (e.g. olives, grapes, figs, dates or pomegranates) (Table 7.9). Each product required specialised methods to maximise yield and quality but the underlying choices were shaped by economic, social and trade priorities.

Value-Added Product	Most Effective Piece of Equipment*
Oil (Olive)	Stone Rollers and SLWPs

Wine (Grapes)	Treading and SLWPs
Wine (Figs)	Stone Rollers and SLWPs
Wine (Dates)	Stone Rollers and SLWPs
Wine (Pomegranates)	Weights, boards and bags and torsion bag

Table 7.9: Most effective/useful piece of equipment for large-scale production based on the type of fruit and value-added product according to the analysis in section 7.8.2.

The structural characteristics of fruits play a crucial role in determining the most effective processing methods for transforming them into value-added products since they require varying pressures (Shanshiashvili et al., 2024; Del Fresno et al., 2022). For example, olives, figs and dates, are best suited to processing with stone rollers and SLWPs (larger and weightier weights), as this method effectively breaks down their tough exteriors while preserving their inner quality compared to grapes and pomegranates. Grapes are ideal candidates for processing methods such as treading and SLWPs, particularly when using small and lightweight weights. These techniques are effective at preserving the delicate texture of the grapes while efficiently extracting their abundant juice. Additionally, tools like weights, boards, bags and even pestle and mortar are the least well-suited for processing grapes due to unique grape structure. Grapes are round, with a sturdy yet thin outer layer and a somewhat dense, fleshy interior, making them particularly amenable to gentle yet efficient pressing methods. On the other hand, pomegranates present unique challenges due to their comparatively larger seeds, lower flesh-to-seed ratio, thick skin and the difficulty (i.e., timing and physical labour) of extracting the fruit from their tough exocarp, rind and inner membrane to then press. Additionally, the small amount of juice yielded per seed makes their processing more complex than that of other fruits. The reduced liquid yield per fruit likely necessitates processing pomegranates in smaller batches to maintain efficiency and minimise waste. In this context, methods involving weights, boards, bags or torsion bags are the most suitable, as they apply controlled pressure without damaging the seeds or wasting juice. Treading and SLWPs would exert excessive force, while a pestle-and-mortar approach would not effectively press the pomegranate's unique structure and texture.

7.8.4 *Multiuse*

As discussed, most pieces of equipment could be used to process most, if not all, tree fruits. Therefore, there is a strong possibility that processing equipment in simple installations and SLWPs were multi-use in nature. There is evidence of wine and oil being produced using the same pieces of equipment (e.g., in LBA Cyprus SLWPs were used for both wine and oil production).

Storable fruits, such as dates, dried figs and pomegranates, offer greater flexibility during their spoilage-sensitive period since they can be stored for extended durations before being processed, typically a longer processing window of 4 to 6 months, even after their harvest seasons (e.g., dates from August to December, pomegranates from September to October and figs from June to October) (see Chapters 3 and 4). This contrasts with highly perishable crops like grapes and olives, which must be processed immediately after harvest to prevent spoilage. As a result, multipurpose equipment makes economic sense for producers, particularly those operating large-scale, permanent installations that would otherwise remain idle for much of the year. For instance, wine production typically occurs from mid-August to October, while olive oil production takes place from September to November, both only lasting three months (see Chapter 3). If processing facilities were designed exclusively for one product, they would only be operational for a few months each year. However, by using the same equipment to process both perishable and storable fruits, especially when their spoilage-sensitive periods have little to no overlap, producers can maximise efficiency and ensure more continuous use of their infrastructure, making production far more economical. For example, dates and olives could have been processed using the same stone rollers or SLWP, as their harvest seasons do not significantly overlap.

Archaeological evidence reflects the state in which presses were last used or abandoned, rather than how they may have been adapted or repurposed throughout their active lifespans. It is quite plausible that these installations were built with the flexibility to accommodate multiple forms of production throughout the year. Human innovation and agricultural adaptability often defy rigid interpretations of production equipment. Even if the equipment were initially designed for a single function, they could have been modified or adapted for other purposes. For example, sites

like Tel Ekron and Zayit demonstrate that collection vats and TCAs could serve different functions, such as grain storage or dyeing, further challenging the view that TCAs and CAs must be used exclusively for one product (Dothan and Gitin, 1986; Eitam, 1986; Heltzer and Eitam, 1987, pp. 37-56; Gal and Frankel, 1993).

The adaptability of the installations plays a pivotal role in understanding their design and functionality and the importance of such equipment in catering to diverse production needs. The height, shape and dimensions of the TCA were carefully constructed to provide significant flexibility in the methods employed within them. This versatility would have allowed producers to seamlessly switch between various extraction techniques, such as traditional treading, the use of stone rollers or even torsion bags, depending on the desired value-added product, season and the type of fruit being processed. For SLWPs, this adaptability extended to the replaceable storage bags used for holding the fruit. These bags could be swapped out based on the type of fruit being processed, whether it was grapes for wine production or olives for oil extraction and the season. For example, switching from a bag containing grapes to one with olives was made possible, provided the press bed and other components of the press were thoroughly cleaned to prevent cross-contamination. By enabling quick adjustments to the materials used and the processes employed, SLWPs could accommodate a wide range of production scenarios.

Academics such as Frankel (1999), Beeri (2008) and Onozuka (2012) have claimed that the potential for contamination between olive oil and wine, should multi-use equipment have been employed, would have rendered such shared use impractical or undesirable. However, technological solutions likely mitigated the risk of cross-contamination. For instance, plaster or lime coatings on treading floors, press beds and collection vats allowed for thorough cleaning between production cycles, as evidenced by installations from the Jenin-Megiddo Survey and Kouklia-Styllarka, Cyprus (Ahlström 1978; Frankel 1999; Hadjisavvas, 1996). Plaster-lined ceramic vessels from the Middle Bronze II period at Acre and Tel Nami also demonstrate techniques to preserve both wine and oil (Artzy and Gitin, 1995). Similarly, stone-slab treading floors, such as those at Bet Mirsham, Bet Shemesh, Tel Nasba and Ugarit (Albright, 1938; Grant and Wright, 1938, pp. 256-258; Callot, 1987, pp. 197-202), enabled deep cleaning to prevent residue build-up, ensuring equipment remained versatile and not contaminated. Further evidence suggests oil may have been intentionally used in wine storage to enhance product quality.

Historical accounts from the 19th and 20th centuries describe the application of oil to corks or as a sealing layer atop wine in ceramic vessels, preventing oxidation and minimising contamination (Frankel, 1999). This practice could plausibly extend to ancient processing equipment, where oil might have served a similar protective function.

7.9 Types and Quality of Value-Added Products Based on Processing Equipment

This chapter explores various types of ancient equipment used for producing wine and oil. However, it is important to note that these tools do not provide direct evidence of the specific products being made, such as red, white or sweet wines or first versus third pressings of olive oil. Instead, they reflect the potential ease, or likely success of producing certain types and qualities of value-added products and the replicability to do so. The same tools could be used to produce a wide variety of products depending on factors such as grape processing methods, grape variety, fermentation duration and additional techniques that influenced sweetness, acidity or colour (see Section 7.6). Similarly, basic equipment, separators and storage vessels offer limited insight into the specific type of olive oil produced. Ancient olive oils varied significantly in flavour, acidity and intended use but these characteristics are not inherently evident in the tools themselves. The versatility of this equipment means that the same tools could produce vastly different styles or types of products, leaving little trace in the archaeological record.

Additionally, some equipment made from organic materials may have decomposed over time, while other tools may have been relocated, reused or simply not associated with the specific production stages uncovered in archaeological investigations. Ultimately, the manner in which liquids, botanical remains and must were left or stored during fermentation is more likely to provide insight into the type and quality of the product than the processing equipment itself.

Modern winemaking illustrates the importance of pressure control in creating diverse products. For example, Eric Baugher (personal communication, 2023) notes that white wines require 100 kPa and reds 200 kPa, while Dawson Raspuzzi (personal communication, 2024) explains that red wines often use 80-100 kPa with a 20 kPa increase and white wines are produced at pressures between 40-60 kPa. This flexibility in pressure was critical for efficiently producing various wine types and likely had a similar impact on olive oil production. Advanced equipment like the

SLWP and rotary crushing basins further enhanced production by providing superior control over pressing, adjustable force and actuation force (see [Appendix 10](#)). These innovations improved the ease and replicability of producing product quality and consistency through precise and even processing. Additionally, they facilitated larger-scale production, higher yields and better preservation of raw materials, resulting in more uniform and refined products compared to simpler methods.

In contrast, less sophisticated equipment was often unable to fully and evenly crush or press tree fruits, which could either directly affect the ease and replicability in which different types and quality of oil and wine were produced or the final product. Uneven pressing could lead to inferior extraction and a less consistent final product, highlighting the limitations of early manual methods. Furthermore, as demonstrated by Mattingly (1988), variations in product quality and geographic sources became closely associated with different social classes, underscoring the importance of diverse production capabilities. The ability to produce various types of oil and wine efficiently and with precision was essential in meeting the demands of different markets and social strata, demonstrating the critical role of advanced equipment in shaping ancient economies and consumption patterns.

The type and ripeness of the fruits are crucial in terms of type and quality of finished products. Different varieties of fruit have unique flavour profiles, acidity levels and characteristics (Chambon, 2018). The equipment does not change these intrinsic properties but rather, it facilitates the extraction process. Techniques vary significantly depending on the desired outcome. For example, different maceration techniques in winemaking can lead to different styles (e.g., white wine vs. red wine) even if the same equipment is used.

Chemical analysis of samples from processing, fermentation, separators and storage equipment can provide insights into various aspects of the product, such as the type of fruit, additives and the level of fermentation (Drieu et al., 2020) when the processing equipment cannot. However, these analyses do not necessarily indicate the specific type or quality of the product. For example, malvidin, the anthocyanin responsible for the red colour of grapes and their value-added products, is a strong chemical indicator for the presence of red wine (Cheynier et al., 2006). Malvidin is found in few plants other than grapes, including pomegranate (Alighourchi et

al., 2007; Whelton, et al., 2021), which has sometimes been added to wine (Ward, 2003) or used in a mixture of half grapes and half pomegranate to make wine (Participant 7, personal communication, 2021). While tartaric acid and syringic acid can help determine that some type of fruit or vegetable was processed, they cannot provide certainty about the specific foodstuff involved (Winter and Hermann, 1986; DeBolt et al., 2006; Barnard et al., 2011).

Written sources provide information about the types of wine and oil produced that cannot be inferred from the processing, fermentation, separators and storage equipment. For instance, Diocletian's list describes three types of oil classified by the number of times the olives were pressed, with evidence from the Roman period through pre-industrial times (Dalman, 1928–1942; Pliny 20.6.23). While water was added to the pressed grape skins and pressed again creating a poor type of wine to create after-wine. This wine was probably supplied to the poor/working class (Caton 25, Columell 12.4.40 and Pliny 14.12.86). Some other examples of different types of wine and oil are provided below (see Tables 7.10 and 7.11). It should be noted that these extra stages of the production process were created as the technology of processing equipment developed and were most likely not present during earlier production with non specialised equipment.

Types	Explanations	Sources
First Oil	Pulp rests briefly after crushing; oil naturally released by its own weight.	(<i>Men</i> .8.4)
Floating Oil	Hot water added or olives boiled; oil skimmed from the surface. Used from Chalcolithic to pre-industrial times.	Dalman, 1928-1942; Avistur, 1986
Oil Lees	Black residue after pressing; used as manure, insecticide, wood protector and for infertile trees.	Cato (99,100,118), Varro (1.40.7) and Columella (4.24.6)

Table 7.10: Types of oil and oil production along with historical sources.

Other	Explanations	Sources
Pre-Treatment of Grapes	Grapes left in the sun 3 days before treading; first must kept separate for sweet wine	Columella (12.27)

First Must	Naturally flowing grape juice before crushing; considered finest quality	Pliny (14.12.85), Columella (12.41)
Second Must	Juice obtained by pressing crushed grapes again; outer mass pressed last	Varro (1.54.3)
Lees - Wine	Made by pressing the dregs of the wine.	Cato (43), Pliny (14.12.86)
Boiled Down Must	Fresh must boiled down to concentrate sugar; used to sweeten other wines	Pliny (14.9.80), Columella (12.20.2)

Table 7.11: Types of wine and wine production, along with historical sources.

Historically, sweet wine has been documented as far back as the Late Bronze Age in Egypt (c. 1323 BCE), with references to its production found in written records (Lesko, 2000, p. 225). During this period, the presses used in Egypt were large versions of simple installations according to iconographic evidence (Oxford Expedition to Egypt: Scene-details Database, 2007), suggesting that various wine types could be made with basic equipment/processes, like treading. The emphasis at the time was less on complex machinery and more on the types of grapes (such as raisins) and additives like honey, which were used to create sweet wine. This reflects the importance of ingredient selection in shaping the flavour and style of wine, even when production tools were relatively simple. However, these ingredient choices and production decisions are not directly visible in the archaeological remains of the equipment itself, as the material evidence focuses more on the mechanical aspects of production, such as the design of the presses. Instead, our understanding of these decisions comes from texts in ancient records and, more recently, from chemical analyses of residues found at archaeological sites. Thus, while the tools and machinery used in wine production were relatively straightforward, the selection of ingredients was crucial and dictated the flavour profiles of the wines produced.

The diversity of wine preferences among consumers, including those who enjoy salted and bitter wines (e.g., wines influenced by crushed seeds that impact tannin flavours), highlights the broad acceptance of various wine profiles (Harutyunyan, 2023; Chambon, 2018). This widespread acceptance underscores the need for more advanced and controlled processing equipment capable of easily adjusting pressure to create different but consistent wine types and flavours. To accommodate such diverse consumer preferences, production equipment must be flexible and

able to adapt to varying demands for pressure and ingredient manipulation. As a result, sophisticated equipment, such as SLWPs and rotary crushers, is better suited to producing a greater variety of wines. Flavour additives would more likely be introduced during the storage and fermentation stages, directly within the storage and fermentation vessels or right before being served.

7.10 Processing Equipment Scale and Capacity

Processing equipment varies in terms of scale, influencing both the production process and potential output. A small winery may produce high-quality wine on a smaller scale, while a larger winery might focus on mass-producing lower-quality wine, even with similar equipment. Quantity is typically estimated from the TCA or press bed size, collection receptacles or storage/fermentation vessels (see Chapter 8), rather than being directly measurable.

As demonstrated in Section 7.8, advanced processing equipment, such as the SLWP and rotary crushing basins with weights, significantly improve the efficiency and speed of producing large quantities of oil and wine. The connection between engineering advancements and production quantity is evident, with the widespread adoption of SLWPs by the 9th century BCE. This highlights their importance in improving ease, efficiency and possibly quality. However, labour intensity and time invested in production leave no direct physical traces. Unlike monumental architecture, where phases of construction and labour investment can sometimes be inferred from unfinished structures or quarry marks, processing activities such as pressing or fermenting rarely leave discernible signs of time spent. Researchers can attempt to infer labour organisation by studying spatial layouts and wear patterns in workshops or production areas. For instance, the arrangement of equipment and proximity to storage areas can suggest workflows or efficiency measures, as explored in Chapters 5 and 8. However, these inferences remain indirect and cannot fully substitute for direct evidence of labour.

The processing equipment primarily indicates potential production scale and processing capacity but interpreting these aspects is challenging due to the limited information on labour inputs. The same quantity of a value-added product can be produced using different processing methods but each requires varying levels of labour, investment, time and efficiency, factors not always

evident in the archaeological record. For example, wine production methods such as torsion presses, manual treading or SLWP demand different resources, including physical effort, technological investment and time but could theoretically yield the same quantity of product. There is a similar issue with the use of wild, cultivated or domesticated tree fruits, since their quantities are comparable. These differences, while significant, often leave minimal trace, making it difficult to identify specific techniques or quantities.

The equipment left behind reflect only the material side of production, largely omitting the essential human element, specifically, the workers who operated, maintained and laboured within these facilities. Without direct evidence of the workforce's involvement or records of their decisions, reconstructing the roles, choices and strategies behind production is difficult, as is understanding the skill and time required. Written sources, when available, sometimes supplement archaeological evidence but often focus on the economic value or output rather than on labour practices and the labourers themselves.

7.11 Conclusion

This chapter has addressed the key objectives of exploring the development, distribution and significance of value-added processing equipment from the Neolithic to the Iron Age in the eastern Mediterranean. By analysing archaeological evidence, it has been possible to investigate the extent to which processing equipment became larger and more specialised over time, the regional and chronological variability in technological development and the persistence of simpler, multipurpose tools alongside advanced installations. The evolution of pressing technology is not simply a linear narrative of gradual process.

While the physical evidence confirms the presence of wine and oil production, it offers limited insights into market dynamics, consumer preferences and regional specialisations. The multifunctionality of many installations complicates the identification of specific value-added products, underscoring the challenges in reconstructing ancient production processes. However, the findings illustrate clear trends in the evolution of processing technologies, including the gradual shift from small, household-scale tools to larger, more standardised equipment. This

trend reflects not only technological innovation but also the growing demands of trade and market expansion.

A general trajectory can be discerned: initially, basic household tools enabled the small-scale extraction of juice or oil for local use. Gradually, more specialised and larger-scale installations, such as simple lever and weight presses, appear in the archaeological record. While the timeline of adoption differs by region, these changes collectively indicate a systematic shift toward pressing technologies designed to produce larger quantities of oil and wine that could be stored or traded. Even highly specialised, larger-scale presses continued to coexist alongside simpler methods. Such coexistence suggests that local consumption and surplus production both had roles in ancient economies, depending on regional needs, resources and consumer demand. For instance, simpler installations were often preferred for their accessibility, ease of use and suitability for small-scale production, while advanced systems required significant investment and were typically tied to larger-scale or elite-driven production systems.

Significant regional and chronological differences emerge when comparing the eastern Mediterranean. Regions like Cyprus and parts of Syria show relatively early adoption of SLWP technology during the Late Bronze Age, likely due to strong interregional networks and established trade routes. Cyprus, in particular, appears to have introduced advanced pressing methods with minimal evidence for preceding simple installations. Crete likewise features sophisticated installations (e.g., Vathypetro, Kommos) from the Late Bronze Age onward, although the archaeological emphasis is more on wine than on oil. Palestine presents a conspicuous gap: although simple rock-cut installations are attested from the Chalcolithic onward, clear evidence for the widespread use of SLWPs appears only around the 8th–7th century BCE. The sudden profusion of presses at this point implies rapid, large-scale adoption, perhaps driven by changing economic demands, population growth or evolving trade networks. Evidence from Armenia likewise signals a relatively late uptake of lever-and-weight press technology, often initially geared to sesame oil rather than olive oil. This illustrates differing agricultural resources and priorities, further shaping how production equipment was adopted. Despite these divergences, a striking continuity emerges across all regions: simple installations and low-technology tools persist right into the Byzantine period (and often beyond), operating in

parallel with more advanced presses. Local tradition, small-scale household economies and the desire for simpler, low-investment methods appear to have ensured their continued use.

This chapter also emphasised the practical implications of architectural features and processing methods, moving beyond typological analysis to consider how equipment functioned in different economic contexts. By doing so, it has contributed to a more nuanced understanding of the variability in production systems, providing insights into the technological sophistication, scale and economic significance of ancient wine and oil industries. Ultimately, this study demonstrates that while gaps in the archaeological record pose challenges, even limited datasets can yield valuable insights into ancient economies. This analysis also lays a critical foundation for understanding Chapter 8 by providing a framework for analysing and interpreting processing equipment in terms of its technological, material and contextual significance related to the *missing* processing equipment of Urartu.

Chapter 8 - Gone with the Wine: The Curious Van-ishing of Urartu's Wine Presses

The ancient state of Urartu, flourishing between the 9th and 6th centuries BCE in the Armenian Highlands, is known for its extensive fortifications, intricate metal work and impressive networks of irrigation architecture (Turker and Alaeddinoglu, 2015; Gökce, 2016). At its height in 743 BCE, Urartu encompassed modern-day Armenia, eastern Turkey (primarily around Lake Van) and northwestern Iran. Among its notable economic achievements was the production of high-quality wine, which played a crucial role in its trade and tribute systems, especially with their neighbours, like Assyria, with whom they were in constant conflict (Smith and Kafadarian, 1996; Gevorgyan and Bobokhyan, 2014).

Extensive archaeological and archaeobotanical evidence demonstrates the scale of the Urartian wine industry and Urartu's prominence in winemaking. This evidence includes: Urartian and Assyrian inscriptions emphasising the quantity and importance of wine and the wine trade (Batmaz, 2013, p.74; Turker and Alaeddinoglu, 2015); irrigation architecture (Oganessian, 1955; Melkonyan et al., 2010); grape iconography depicted on ceramics and metalwork (Harutyunyan et al., 2005); archaeobotanical data, including remains of fruits and honeycomb; chemical analysis inside ceramics indicating fruit juices (Hovhannisyan et al., 2015, pp. 236-297; Piotrovsky, 1959; Bdoyan, 1972) and ceramics indicative of large-scale storage (Barnard et al., 2011). These *karases* have been historically and are still currently used to ferment and store wine.

Urartian sites with significant evidence of both wine consumption and dedicated wine fermentation and storage areas (Piotrovsky and Janpoladyan, 1956, Arutyunyan, 2005) include: Aratsani Valley (stored 220 000 L of wine) (Arutyunyan, 1964), Teishebaini (stored 400 000 L of wine) (Khalpakhcyan, 1961) and Getap 1 (stored 20 000 L of wine) (Melkonyan et al., 2010). Collectively, this evidence suggests that the Uratians produced substantial wine output. They likely traded with regions like Assyria and Babylonia, which lacked the potential for grape wine production and therefore highly valued this commodity (Tsetskhladze, 2021). Despite the abundance of evidence indicating a thriving wine industry, there is a conspicuous lack of

physical evidence for specialised wine production equipment from the Urartian period, as well as from the centuries before and after – amounting to an approximate 1,300-year gap (1700 BCE - 4th century BCE). This absence raises critical questions about the nature of wine production equipment in Urartu, particularly regarding its form, what it was made from and where and how it was used.

The main purpose of this chapter is to address such a significant gap in the archaeological record by analysing available data to reconstruct the characteristics and functionality of specialised wine processing equipment. This analysis will also seek to identify regions with a higher likelihood of yielding physical evidence of such equipment. To achieve this, the chronology of wine production equipment in Armenia (and surrounding Urartian peripheries), from the Chalcolithic era (c. 4800 BCE) to the early Modern Period (c. 18th century CE), will be examined. This analysis will be compared with contemporary equipment from the Iron Age, as well as materials and discovery sites in neighbouring regions, including the eastern Mediterranean. In addition, this chapter will incorporate insights from Chapters 4 and 5, using it as a heuristic tool to explore potential functionality, scale of production, labour and, less possibly, the locations of these ancient tools. Rather than serving as a substitute for archaeological evidence, Chapter 5 is used as a guide for researchers on what to look for and where to focus their efforts. This approach is especially pertinent given the scarcity of physical evidence for specialised wine production in the area in general. Additionally, Chapters 3, 4, 5, 6 and 7 serve as the foundation for a specialised case study presented in this chapter. The information from these chapters, which has been critically analysed and thoroughly examined, is applied in a practical manner to demonstrate its relevance and utility. This case study not only integrates the theoretical insights and evidence discussed earlier but also illustrates how these findings can be synthesised and applied within research and practical contexts. This highlights the need for alternative methods, possibly interdisciplinary methods, to address gaps in the archaeological record, particularly when faced with limitations such as funding, geography and resources. By reconstructing potential wine press designs and pinpointing regions likely to yield evidence, it offers a roadmap for future excavations and sheds light on the technological and economic capabilities of the Urartian state.

Structurally, the chapter begins by explaining the reasons behind the absence of wine press evidence, considering factors such as archaeological biases, misattribution of artefacts and destruction over time. It then moves into a chronological study of wine processing equipment, categorising various installations across different historical periods. The chapter further incorporates evidence from neighbouring regions to contextualise Urartian practices and explore potential sites for future excavation. Finally, theoretical and methodological discussions provide a framework for understanding Urartian wine technology, bridging the gap between archaeological data and historical expectations.

8.1 Explanations for the Absence of Wine Presses

Given the large-scale nature of the Urartian wine industry, as inferred from ancient and historical sources, specialised equipment would have been necessary. Such equipment was likely constructed from durable materials like stone or fired clay, making it more likely to survive archaeologically and easier to interpret functionally, similar to contemporary equipment from Bronze and Iron Age cultures of the Eastern Mediterranean (Platon and Kopaka, 1993; Hadjisavvas, 2020; Frankel 1999). However, no such equipment has been definitively dated to the Urartian period. One highly valuable insight from recent analogues (above and Chapter 5) is their suggestion that grape processing likely occurred off-site, near the vineyards. If this is the case, the lack of concrete evidence for such facilities is unsurprising.

The "missing winepress" problem is not unique to Urartu. For example, despite clear evidence of Phoenician involvement in wine trade and vine cultivation from the 1st millennium BCE, the first Phoenician winepress was only discovered recently, in 2019, at Tell el-Burak (Orsingher et al., 2020). The site also yielded storage amphorae and significant grape remains (Orendi and Deckers, 2018). Similarly, the flourishing Late Antique wine industry in the Negev Highlands, known from storage vessels and textual data, has yielded limited evidence of winepresses (Fuks et al., 2021). Likewise, despite the Hittites being well known for their wine culture, as evidenced by inscriptions (e.g., laws on grapes and vineyards and land records) and drinking-related material culture, there is no clear or confirmed documentation of wine presses (White and Miller, 2018; Hmayakyan, 2010).

The most likely explanation for this absence is that the equipment simply has not yet been found. Traditionally, archaeological research has focused on state-owned buildings, specifically palaces and fortresses and associated luxury items, possibly due to a political and nationalistic bias in regional archaeology (Barnett, 1959). Hinterland areas, in which presses are commonly found (Frankel, 1999) are often either ignored or neglected and more comprehensive surveys are lacking, creating a probable bias in our understanding of ancient material culture.

Another challenge is the historical confusion with neighbouring cultures. Since at least the 19th century, scholars have mistakenly attributed Urartian artefacts to Assyrian or Anatolian cultures (Hovhannisyan et al., 2015), likely due to the difficulty in distinguishing the artistic styles and material culture of these geographically close civilisations. For instance, in the British Museum, the maps of the various exhibits do not distinguish between Anatolian and Urartian artefacts, despite their being from different geographical regions. This has all further complicated the identification and understanding of Urartian material culture.

Incomplete documentation of archaeological finds has also hampered our understanding of Urartian material culture. In the past, limited documentation, particularly for finds deemed "less significant" at the time of excavation, has led to the loss of valuable information. Once such materials are destroyed or lost, they cannot be re-excavated or catalogued for further study (Badalyan et al., 2007, pp. 7-9; Hovhannisyan et al., 2015).

Linguistic barriers have also posed a challenge. Much of the research on Urartian culture is published in Russian, Turkish or Armenian, hindering access to crucial information for archaeologists who are unfamiliar with these languages (Badalyan et al., 2007, p. 7; Barnett, 1959). To address this issue, this project involved contacting six Urartian specialists and three linguists who are proficient in these languages, ensuring a comprehensive review of relevant materials.

Archaeobotanical recovery and analysis is a relatively new addition to Armenian archaeology, especially compared to the era of large-scale excavations (Badalyan et al., 2007, pp. 7-8). Consequently, artefacts (like an *aragast* or *grub*) that might have yielded valuable archaeobotanical evidence, such as organic remains associated with processing equipment, may not have received the same level of scrutiny and observation in the past.

Deliberate destruction has also contributed to the loss of Urartian archaeological evidence. Evidence suggests widespread burning and looting during the decline of the Urartian kingdom (Ristvet, 2018; Daryaei, 2018, pp. 38-44). Additionally, the Armenian pogroms of the 19th and 20th centuries and the Armenian Genocide and subsequent political turmoil in the 19th, 20th and 21st centuries also resulted in the destruction, defacement or repurposing of many historical and archaeological sites in Armenia, Artsakh and eastern Turkey (Balakian, 2013; Üngör, 2015, pp. 241-254).

Finally, the reuse of materials throughout history has further complicated the identification and dating of certain artefacts. Building materials like wood and stone, as well as processing equipment, may have been repurposed or have not withstood the test of time, obscuring their original context and function (Frangipane, 2016, pp. 26-30; Underwood, 2012). This reuse makes it challenging to interpret the archaeological record accurately and fully understand the material culture of the Urartians.

8.2 Chronology of Armenian Wine Processing Equipment

This study represents the first comprehensive compilation of specialised Armenian wine processing equipment, with a focus on functionality and typology according to the methods of wine production. To this author's knowledge, the only comparable work is by Hovhannisyan et al. (2015), who provides a brief timeline of archaeological evidence related to wine but with a focus predominantly on the material culture of wine consumption and storage, rather than on the equipment involved in wine processing.

A total of 41 sites and 56 site-phases within the former area of Urartu have been identified with evidence of grape processing or wine production installations dating back to before the early Modern period (see [Appendix 12](#)). There is a scarcity of evidence for both eastern Turkey and northwestern Iran, regions that were once part of Urartu, particularly from periods predating the late Medieval period. Consequently, greater emphasis was placed on Armenia, including some regions that were not historically part of Urartu but lay on its periphery, to provide a more comprehensive understanding of the historical context.

Sites with wine pressing facilities are clustered in Armenia's modern regions known for both historical and contemporary grape growing. These sites are predominantly located in the regions of Aragatsotn, Armavir, Ararat, Kotayk and Vayots Dzor. These areas, excluding Kotayk, are renowned for producing some of the best wine grapes historically and continue to be the primary locations for wine production in both pre-industrial and modern Armenia (Hovhannisyan et al., 2015).

The presses originate from five distinct periods: (1) the Chalcolithic; (2) the Bronze Age ; (3) the Classical period; (4) the Medieval period; and (5) the early Modern period. The number of site-phases and their construction periods are presented below (Table 8.1). The chronology of wine pressing facilities reveals a significant gap from 1700 BCE to the 4th century BCE. This nearly 1,300-year gap spans the entire Urartian period, as well as several centuries before and after.

	Periods	Dates*	#of Site-Phases
Chalcolithic	Chalcolithic	4500-3300 BCE	2
Bronze Age	Early Bronze Age	3300-2200 BCE	4
	Middle Bronze Age	2200-1500 BCE	4
	Late Bronze Age	1500-1000 BCE	1
Classical Period	Classical Period	4th century BCE-4th century CE	13
Medieval Period	Early Medieval	4th-7th centuries CE	6
	Middle Medieval	7th-11th centuries CE	2
	Late Medieval	11th-15th centuries CE	17
Early Modern Period	Early Modern	15th century CE-18th century CE	7

Table 8.1: Chronology of site-phases by historical periods and dates. *These periods are defined according to the Armenian archaeological chronology established by Hovhannisyan et al., 2015.

Notably, several sites, including Agarak, the Areni-1 cave, Armavir, Artashat, Aruch, Ashtarak,

Dvin, Etchmiadzin, Garni, Haghpat, Khojabagher, Yeghvard and Zvartnots, exhibit evidence of wine processing across multiple periods. Some sites show the presence of two different types of wine installations over time: Agarak (Types 2 and 3), Armavir (Types 3 and 4), Etchmiadzin (Types 3 and 5), Garni (Types 3 and 5), Haghpat (Types 4 and 5), Khojabagher (Types 3 and 4) and Yeghvard (Types 3 and 4). Conversely, the Areni-1 cave (Type 2), Artashat (Type 3), Aruch (Type 4), Ashtarak (Type 3), Dvin (Type 3) and Zvartnots (Type 3) have a continuous history of using the same type of installation for wine production, spanning 400 to 1600 years.

The evolution of processing equipment typologies in Armenia can be broadly categorised into five distinct stages. This classification follows a framework similar to that proposed by Frankel (1999), which provides a structured approach to understanding technological development over time. It should be noted that the shape of the treading floors and collection vessels was not a factor in creating any subdivisions, as these features do not greatly affect the actual functionality of the presses or the final value added product (for more information, see Chapter 7, sections 7.3 and 7.8). To better visualise this progression and the overlaps between various equipment types, a timeline has been created (see Figure 8.1), which demonstrates the periods during which these typologies were in use simultaneously as well as sequentially:

- Type 1: Non-Specialised Equipment
- Type 2: Simple Installation
- Type 3: Improved Installation with a *Tarapan*
- Type 4: Complex Installation
- Type 5: Complete Installation

Timeline Showing the Co-existence of Types 1-5 in Armenia.

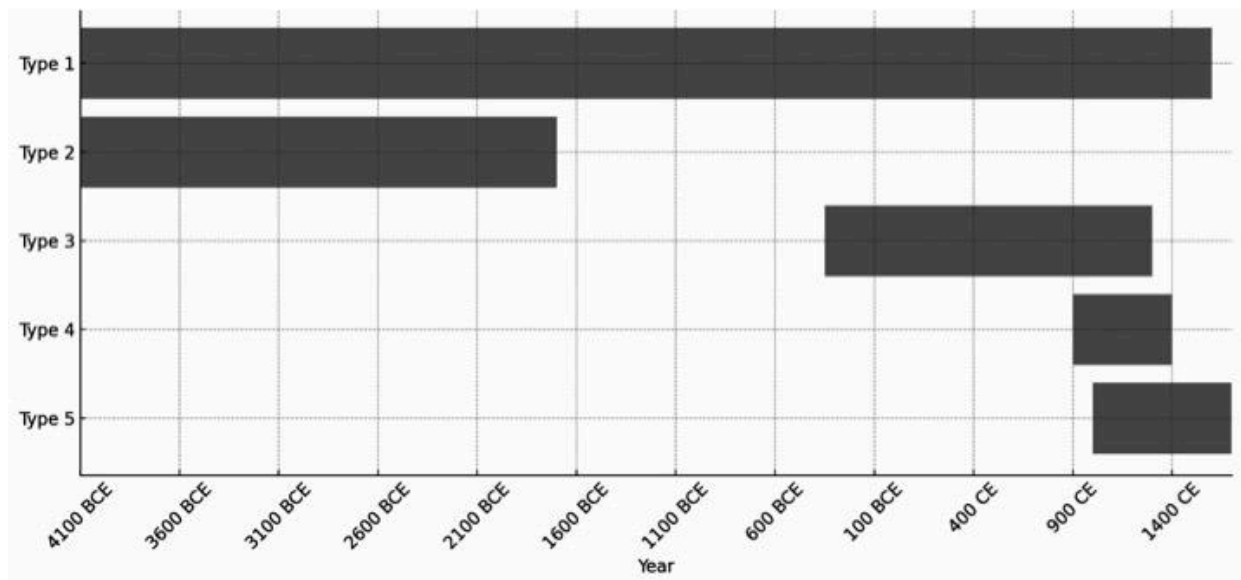


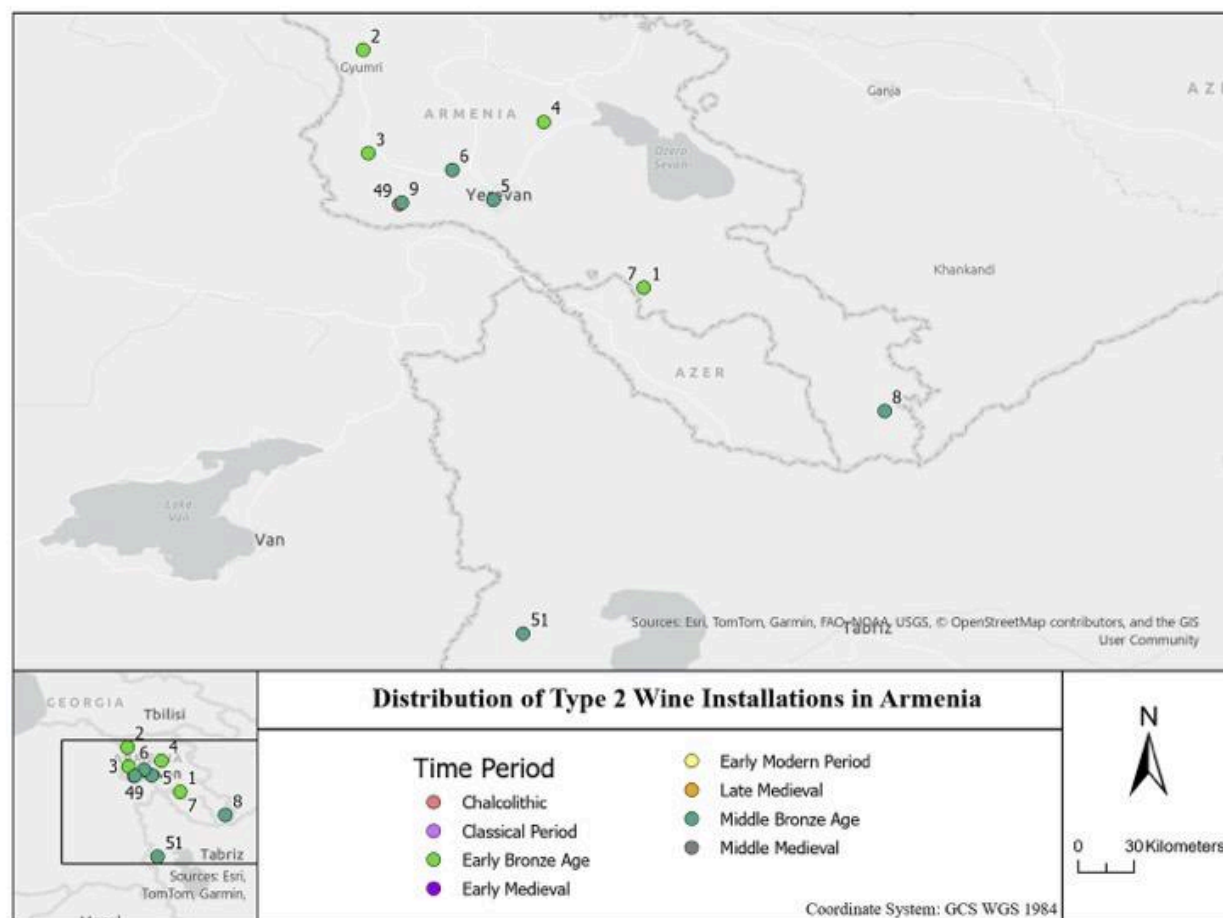
Figure 8.1: Timeline showing the co-existence of types 1-5 in Armenia.

8.2.1: Type 1: Non specialised Equipment

The earliest forms of pressing equipment, as discussed in Chapter 7.1, were initially non-specialised household items. These were not specifically designed for wine production but could be repurposed for such tasks. Wine could, in principle, be made in any vessel or item that was sufficiently wide and deep to allow for the pressing of fruit. However, the scale of wine production indicated by archaeological evidence far exceeds what could feasibly be achieved using simple household implements. For instance, the quantities of wine stored in large storage vessels, such as the *karases* found in the Aratsani Valley (where approximately 220,000 liters of wine were stored) and Teishebaini (which housed an estimated 400,000 liters) point to a highly organised and large-scale production system (Khalpakhcyan 1961; Bedigian and Harlan, 1986; Arutyunyan, 1964). These figures highlight the need for specialised equipment to efficiently process such vast quantities of wine. Reliance on small, non-specialised household items would have been impractical for production of this magnitude (see the practical example discussed in Section 8.6). Furthermore, household items, by their very nature, are typically multifunctional and not designed for the repetitive, high-capacity tasks required in industrial-scale wine production. Their limited capacity would necessitate a large number of tools and a significant amount of labour, making them inefficient for large-scale operations. Additionally, the wear and

tear resulting from processing the substantial quantities of grapes needed to produce hundreds of thousands of liters of wine would also render these tools impractical due to their lack of durability. This collectively supports the argument that it is unrealistic to imagine that the Urartians established a large-scale wine industry using solely household items. Therefore, such items were not cataloged here.

8.2.2: Type 2: Simple Installation



Map 8.1: Distribution of Type 2 wine installations in Armenia and peripheries from the Chalcolithic through to the Middle Bronze Age.

There is evidence of simple installations (see Chapter 7.2 for details) of wine equipment dating back as early as the beginning of the 5th millennium - first half of the 4th millennium BCE found at Areni-1 cave (Areshian et al., 2012; Tumanyan, 2008; Barnard et al., 2011; Hovhannisyan et al., 2015, pp. 414-415). Simple installations are present in 10 out of the 49 site-phases (see Map 8.1).

The confirmed example from Areni-1 cave is the oldest value-added tree fruit production facility in the world, found to date. The cave structure features a basin-like clay platform that funnels into a large, semi-subterranean jar, which is surrounded by an assortment of storage vessels (Areshian et al., 2012, pp.123-124; Hovhannisyan et al., 2015, pp.387-388) (Photo 8.X). In the same context, desiccated grape seeds, skins, rachises and pedicels were discovered dating back to the Late Chalcolithic period (ca. 4050–3800 BC), with additional *Vitis* remains traced to the Bronze and Middle Ages (Smith et al., 2014, pp.247-248; Gasberyan, 2014). Moreover, chemical analyses have bolstered the idea of a grape pressing and winemaking facility by detecting malvidin, a compound relatively specific to red wine and pomegranate juice, on ceramic fragments (Cheynier et al., 2006; Alighourchi et al., 2007; Barnard et al., 2011, p.983).



Photo 8.X: Areni-1 cave simple installation (photo by V.Newson).

Similar processing equipment comes from the Chalcolithic (3900-3000 BCE) site of Adablur, in which a stone platform channels into a collection receptacle, near storage vessels with traces of malvidin close to a water source (Tumanyan, 2008). In addition, there are the Early and Middle

Bronze Age sites of Ketī, Talin, Tsaghkalanj, Shengavit, Agarak, Malyan and Meri (see [Appendix 12](#)) where a treading area and a collection receptacle were found. The installation at Shengavit also has evidence of grape seeds, skins and pedicels within the collection receptacle. The installation was found close to wine vat clay moulds (Rothmann, 2024).

A slightly different construction of the simple installation comes from the Middle Bronze Age (2500–2100 BCE) site of Haftavan Tepe, where structures made of thin stone slabs radiated outward from a small base, also constructed from a slab of stone and featuring small holes near the top or bottom. The presence of these holes most likely served to facilitate drainage or the insertion of tools or rods used for manipulating materials during pressing, such as a pole from a torsion press. The lime found on some of the slabs suggests that some form of liquid was likely being processed on top of them and the lime may have been used to prevent contamination during processing or to stop the liquid from seeping into the stone and affecting the equipment or the quality of the product during and after processing (reference). Lime on an *aragast* is also common at other Middle Bronze Age processing sites. Additional fragments of slabs with similar small round holes were uncovered in a contemporary context in Area C4, suggesting the presence of other installations in this part of the town. These findings point to a relatively large-scale industry during the Middle Bronze Age (Burney, 1973; Hovhannisyan et al., 2015, p. 88).

Materials

The *aragasts* found within settlements were made of stone, while the ones in the cave were made of clay. Stone, as a more permanent material, was likely chosen for processing equipment in settlements because it was durable and practical for regular more frequent use. Its sturdiness and ability to withstand repeated use in a high-activity context made it ideal for the daily demands of production. In contrast, the use of clay in the cave could imply a different function. Clay may have been selected for its mobility in and around the cave or for burial purposes. This mobility would have made clay vessels or tools more adaptable for use in the cave environment, where space might have been limited or where the need for easily movable equipment was greater. For example, clay *aragasts* could have been transported in and out of different cave chambers depending on the specific needs of the task or ritual at hand. Furthermore, the shift to more

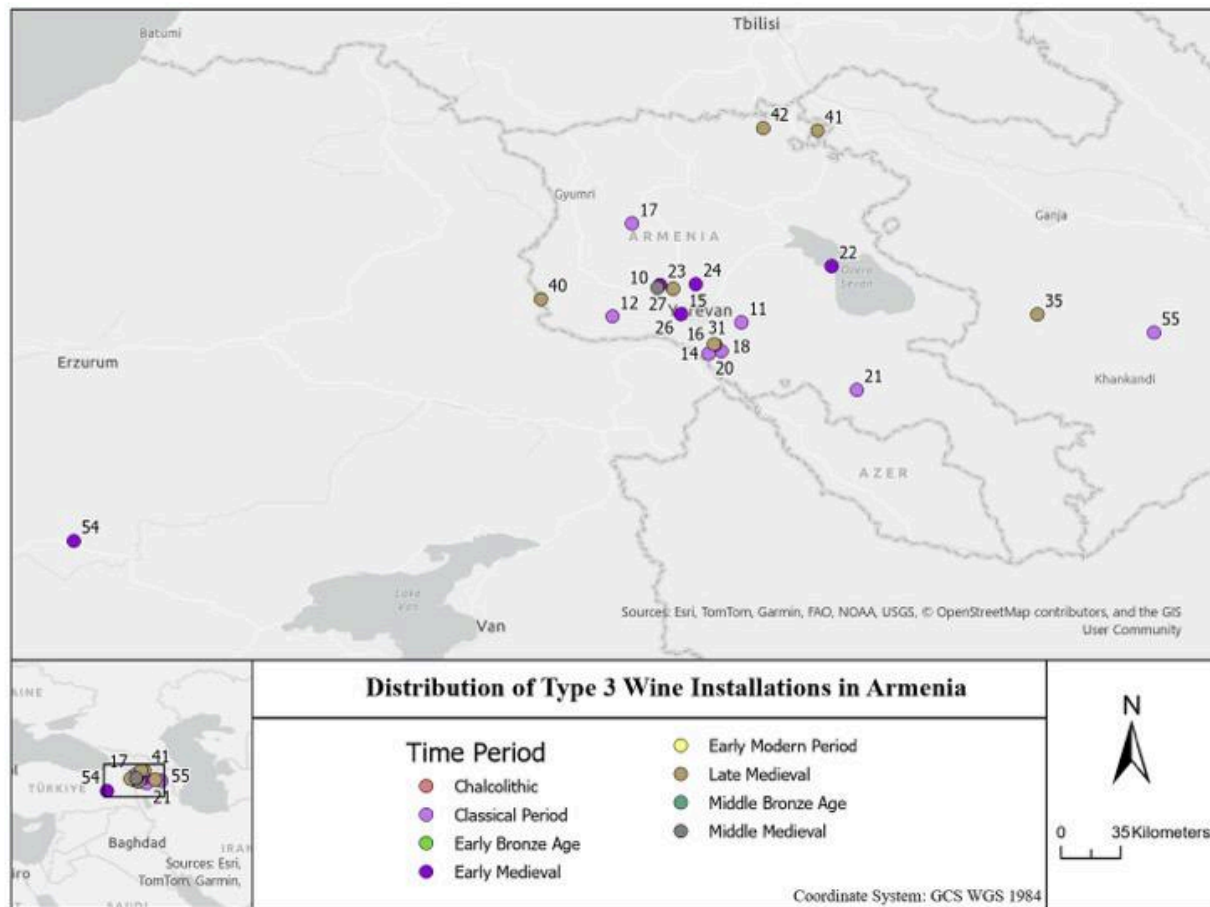
permanent material could indicate a more established and sustained production system, reflecting the integration of winemaking into the routine economic and social activities of the settlement.

Locations

In earlier periods, such as the Chalcolithic and Bronze Ages, processing equipment and installations were typically located within settlements or, on rare occasions, in caves. This suggests that wine production was a localised activity, likely centered on community-driven purposes such as local consumption and possibly ritualistic or communal practices. The placement of processing equipment within settlements indicates that production was an integral part of daily life, conducted within or near domestic or community spaces for ease of access and use. In contrast, the use of caves for processing may point to a ritual or symbolic function. Caves could also provide a controlled environment with stable temperatures and humidity, ideal for preserving or processing products like wine.

Over time, as economies grew more complex and trade networks expanded, wine production sites appear to have shifted from central locations within settlements to specialised areas outside them (see Types 3, 4 and 5). This transition could have been driven by several factors, including the need to manage the mess and noise of production away from populated areas, the desire to maintain an air of mystery or exclusivity around the process or the increased scale of production as wine became a tradable commodity. Such spatial separation would have facilitated more efficient production and distribution, aligning with the evolving role of wine in both economic and cultural contexts.

8.2.3: Type 3: Improved Installation with a Tarapan



Map 8.2: Distribution of Type 3 wine installations in Armenia and peripheries from the Classical Period through to the Late Medieval.

Type 3 installations first appeared as early as the 4th century BCE. During the same period, the earliest known use of an intermediate vat (IV) in Armenia was recorded, marking a significant innovation in winemaking. This vat was placed between the *aragast* and the collection receptacle (Hovhannisyan et al., 2015, p. 94). Similar intermediate vats are known from surrounding regions as early as the Iron Age (10th century BCE), such as at Tel Michal in Palestine (Herzog, Rapp and Negbi, 1988, pp. 73-75). By the 3rd century BCE, the use of intermediate vats had become widespread in wineries, either integrated into or positioned adjacent to the treading floor (Frankel, 1999). Improved installations featuring a *tarapan* (a traditional separate stone structure used to extract the must from pressed grapes that is placed either to the side or on top of the *aragast*) are the most prevalent type, found in 22 out of the 49 site-phases (Map 8.2).

The introduction of the intermediate vat significantly enhanced both the efficiency and quality of the winemaking process. Primarily, the intermediate vat facilitates the initial collection of free-run juice, the highest quality juice derived from the gentle pressing of grapes before any significant pressure is applied. This practice ensures that the finest juice, typically more aromatic and less tannic, remains separate from the juice obtained during subsequent, more forceful pressing. Furthermore, the intermediate vat provides a controlled environment in which the juice can begin fermentation before being transferred to storage vessels, particularly for red wines. This controlled fermentation is crucial for ensuring optimal conditions, which directly influence the wine's flavour profile and stability. Additionally, the intermediate vat allows for the settling of solids such as grape skins, seeds and other particulate matter, which can be separated before the juice advances to the next stage. The use of an intermediate vat could also streamline the overall workflow of the pressing operation if white wine was being made or if the juice was being directly placed into fermentation vessels. In this case, the intermediate vat would enable a continuous process in which juice from the press is rapidly transferred, allowing the press to be immediately used for the next batch. This advancement significantly increases the throughput and overall efficiency of winemaking.

Another notable improvement to the efficacy of winemaking installations was the integration of a *tarapan*/Տարաբան in the 4th century BCE. The absence of *tarapans* in Armenian contexts prior to the 4th century BCE establishes a *terminus post quem* for the presses, indicating a 4th century BCE or later origin. The *tarapan*, characterised by its pear-shaped design featuring grooves encircling its perimeter, a spout and a directly positioned collection vessel, was strategically installed either upon or adjacent to the plastered floors of the aragast, accompanied by weights (Phalanjyan, 2015; Tumanyan, 2008; Harutyunyan et al., 2005). The grapes were initially either treated within the *tarapan* or the must was further crushed by being placed in the centre of the *tarapan*. Through the grooves, the juice would pass into either a *takar* or a stone basin which was either attached or on the other side of a wall attached through a pipe. This allowed for different qualities of wine to be more easily produced, along with different additives (i.e. juice from the second crushing had a higher sugar and resin content compared to the third crushing)(Participant 14, personal communication, 2022). The earliest examples come from Agarak (4th century BCE-4th century CE), Armavir (3rd century BCE), Garni (3rd century BCE), Dvin (3rd century BCE), Hnaberd (2nd century BCE), Kaghstrashen (2nd century BCE)

Verin Artashat (2nd century BCE), Yeghanatzor (1st century BCE-1st century CE) and Khojabagher (3rd century CE)(Phalanjyan, 2015; Hovhannisyan et al., 2015; Vayots Dzor Museum of Yeghegnadzor) but they continued to be used throughout the medieval and pre-industrial periods. Notably, wine presses from the ethnographic project (Chapter 5) exhibited evidence of continued use, primarily for heritage purposes and to maintain a connection to ancestral production techniques. This ongoing use suggests a possible continuity of winemaking methods, potentially dating back to at least the 3rd century BCE, though it is important to consider that these methods may have been reintroduced or adapted over time and older examples might have been used differently in earlier periods.

Another significant advantage of the *trarapan* lies in its function as a multipurpose piece of transportable, sophisticated equipment. On the one hand, it could be employed as a simple installation, comprising areas for grape crushing and a collection basin underneath, that could be moved to various parts of the vineyard or even indoors, depending on weather conditions such as rain or wind. Many *trarapans* were constructed from red tuff stone, a material that weighs 20-30% less than other types of stone, making these devices more transportable while still strong enough to perform crushing and pressing operations (Participant 41, personal communication, 2023).

Alternatively, the *tarapan* could have served as a press bed for a simple lever and weight press (SLWP). The pear-shaped design, peripheral grooves and methods of usage for producing value-added products are remarkably similar to the freestanding pear-shaped press beds with peripheral grooves found in SLWPs from the Late Bronze Age on Crete. Examples have been found at Kommos (c. 1700-1620 BCE), Vathypetro (c. 16th century BCE) and Phaistos (c. 1700-1470 BCE), as well as from the Iron Age in Greece (7th century BCE Athens), while a lever and screw presses are known from the Iron Age in Greece (Olympus) and Cyprus (Kouris Valley-Dameftis; Frankel, 1999, pp. 61-67). This raises the possibility that SLWPs may have existed in Armenia as early as the 3rd century BCE and potentially even in the earlier Urartian period. However, no such equipment, including niches or specialised weights that are not associated with other specific industries such as sesame oil production, has been identified to date.

The only rock-cut wine-pressing installations with secure dates in Armenia are located in the northern part of Agarak/Ագարակ/and date to the 4th century BCE to 4th century CE, as inferred from associated pottery evidence (Harutyunyan and Malfeito Ferreira, 2022, p. 9).

The presence of small *tarapans* beside the *aragasts* further helps to refine these dates. This is further corroborated by Agarak's heightened prosperity as an important trade centre between the 3rd century BCE and the 3rd century CE. An earlier date remains a slight possibility due to the potential for the prolonged use of rock-cut equipment and the presence of Urartian *pithoi* burials at the edge of the northern rock outcrop of the installations (Yengibaryan, 2011, pp. 152-154).

Usually, wine-pressing buildings were located either outside a settlement or adjacent to a cathedral or church, as seen at Zvarnots, Etchmiadzin and Yeghvard (Khalpakhchyan, 1961; Karakhanyan and Melkonyan, 1985; Tiratsyan, 2003; Ghafadaryan, 1959). Notably, no evidence of wine storage has been associated with these installations, suggesting that their primary function was likely focused on production rather than storage (Hovhannisyan et al., 2015, pp. 105-110). This pattern of placement is further supported by iconographic evidence, such as the depiction at the Surb Kach Church on Aghtamar Island. A 10th-century CE frieze on the side of the church shows a large stone building with a two-arched cover, resting on the main walls and supporting pillars, likely representing a wine press. The frieze also situates the wine press in the vineyard, with the building being surrounded by grape vines, aligning with the common practice of situating wine presses near vineyards or religious structures (Mnatsakanyan, 1983; Tumanyan, 2008). Furthermore, Medieval paintings and manuscripts suggest the continuous use of *aragast* with foot treading instead of mechanical presses (Hovhannisyan et al., 2015, pp. 97-98, 135-136; Arutyunyan, 2005).

Three wine presses, which differ from the traditional medieval type, were excavated outside the settlements of Bagheri Chala/Բաղերի Չալա and Loruti Hogher/Լորուտի Հոգեր in Lori Province and date to the 12th or 13th centuries CE (Hobosyan, 2010). These presses feature a basin made from a stone nav Chapter 5, section 5.1), similar to those found in Khandzan, instead of the typical stone *aragast* (Hobosyan, 2010, 2014). In one press, the must flowed out from the basin through a clay pipe installed under the floor. A small stone *takar* was built against the eastern wall of the basin. A one-square-metre lime-plastered platform on the thin northern wall likely served for pouring in grapes. With only a 500-litre *takar* in the basin, holding just a tenth of the must, it is

presumed that the remaining wine was stored in a cellar or transported to the settlement, mirroring practices that were possibly observed in Urartu, where fruit juice was transported elsewhere after processing (Hovhannisyan et al., 2015, pp.101-104).

Locations

A dominant pattern is the consistent placement of wine presses near old vineyards or settlements. This suggests that winemaking was closely tied to agricultural practices, with wine presses strategically located near the source of raw materials (grapes). This setup would have facilitated the efficient processing of grapes, as proximity to the vineyard made it easier to transport the harvested fruit to the presses.

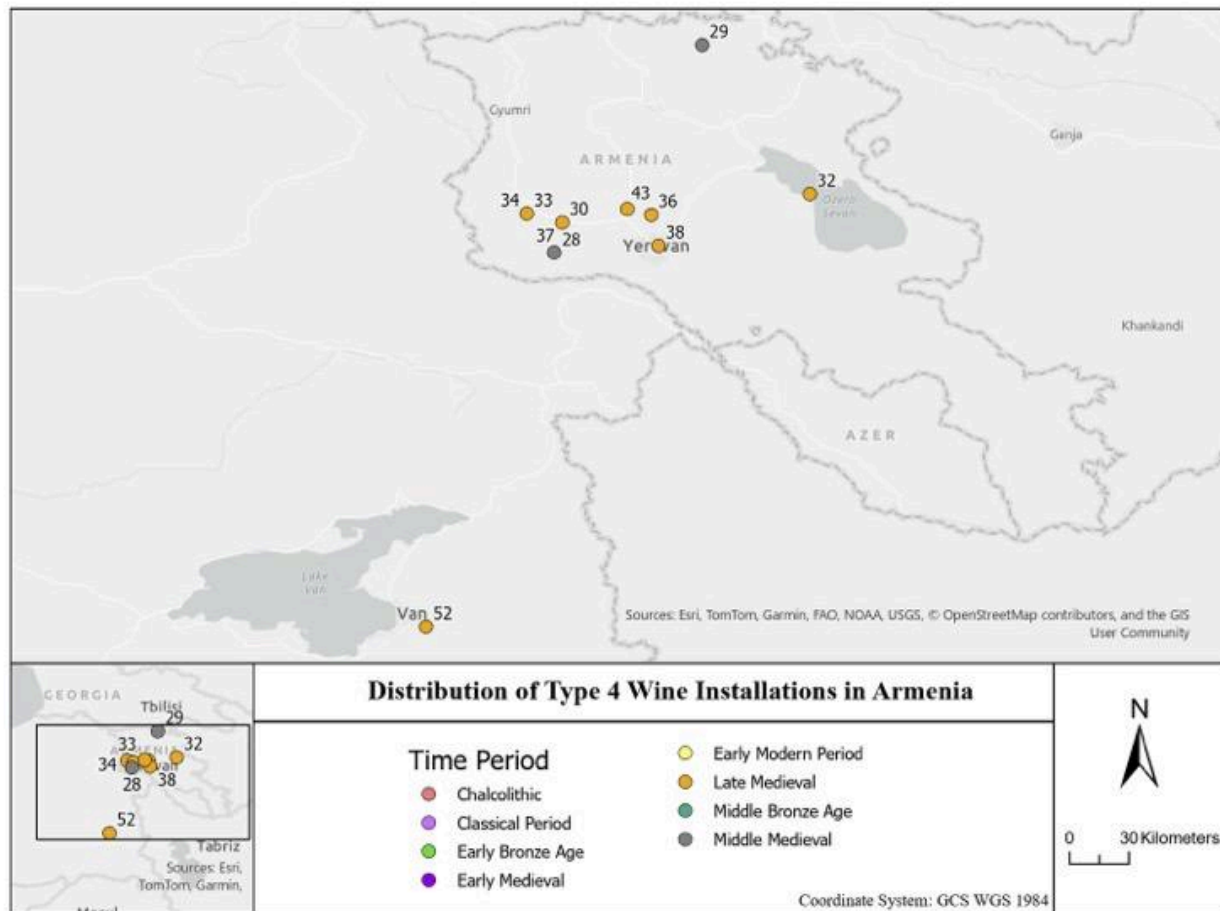
Another recurring pattern is the presence of wine presses near religious sites, such as cathedrals and monasteries. It is also likely tied to the rise of Christianity and the establishment of state-sponsored religious practices after Christianity became the state religion in 301 CE (Tiratsyan, 2003). Cathedrals and monasteries played an increasingly important role in daily life, not only in spiritual matters but also in the production of goods, including wine, which was used in religious rites such as the Eucharist. The proximity of wine presses to these institutions might have served to highlight their sacred or symbolic role in winemaking.

Moreover, the archaeological focus in Armenia during the Medieval period tends to emphasise religious sites, likely due to their prominence and long-standing significance. Excavations and surveys are often concentrated around cathedrals, monasteries and other religious structures because these sites are more frequently preserved, attract greater attention and are more easily identifiable. As a result, there may be a bias in the archaeological record that emphasises purposefully built religious architecture over more secular wine presses or smaller rural installations. This focus can create a skewed understanding of the broader wine industry of the time, potentially overlooking the widespread, more decentralised winemaking activities that may have occurred in less prominent locations. The increased excavation and survey efforts around these religious sites could unintentionally highlight the Church's dominant role in the production and consumption of wine, reinforcing the idea that religious institutions played a central role in controlling the wine trade and its consumption across the Medieval period in Armenia.

This concentration of wine production within religious institutions signifies a shift in economic power, with the church becoming a key player in resource management and distribution. The religious significance of these production sites is further underscored by biblical references, such as Matthew 21:33, which suggests that winepresses should be located in vineyards on less fertile land (Ahlström, 1978, pp. 19-21). Additionally, the presence of wine presses near elite buildings, such as palaces and gardens, suggests that winemaking was both a domestic and elite activity. Wine presses located near palaces or elite gardens could indicate a more controlled, high-quality production process tailored for the consumption of the elite. This setup may have facilitated the production of finer wines, which were likely reserved for the ruling class or used in state-sponsored events, feasts and diplomatic functions.

The variability in the locations of wine presses, ranging from domestic settlements to religious and elite sites, points to a market that was complex and varied. The differing proximity to agricultural, religious, and elite centers likely created diverse markets for wine, with some production focused on local consumption, others on ritual use and still others on trade.

8.2.4: Type 4: Complex Installations



Map 8.3: Distribution of Type 4 wine installations in Armenia and peripheries from the Middle Medieval through to the Late Medieval.

Complex installations began to emerge during the Middle Medieval period and were characterised by the presence of multiple improved equipment components (Type 3), including more than one CV (collection vat), IV (intermediate vat) and *tarapan* made from red tuff stone. These complex installations are documented in 11 out of the 49 site-phases (see Map 8.3). The majority of these complex installations come from the province of Aragatsotn.

The appearance of complex installations in the Middle Medieval period signifies a notable advancement in the scale and sophistication of wine production. Such installations suggest a move towards more organised and probably larger-scale wine production processes. The use of red tuff for these installations indicates a level of technological and material investment, as red tuff is a durable and workable stone that could withstand the rigours of wine production over

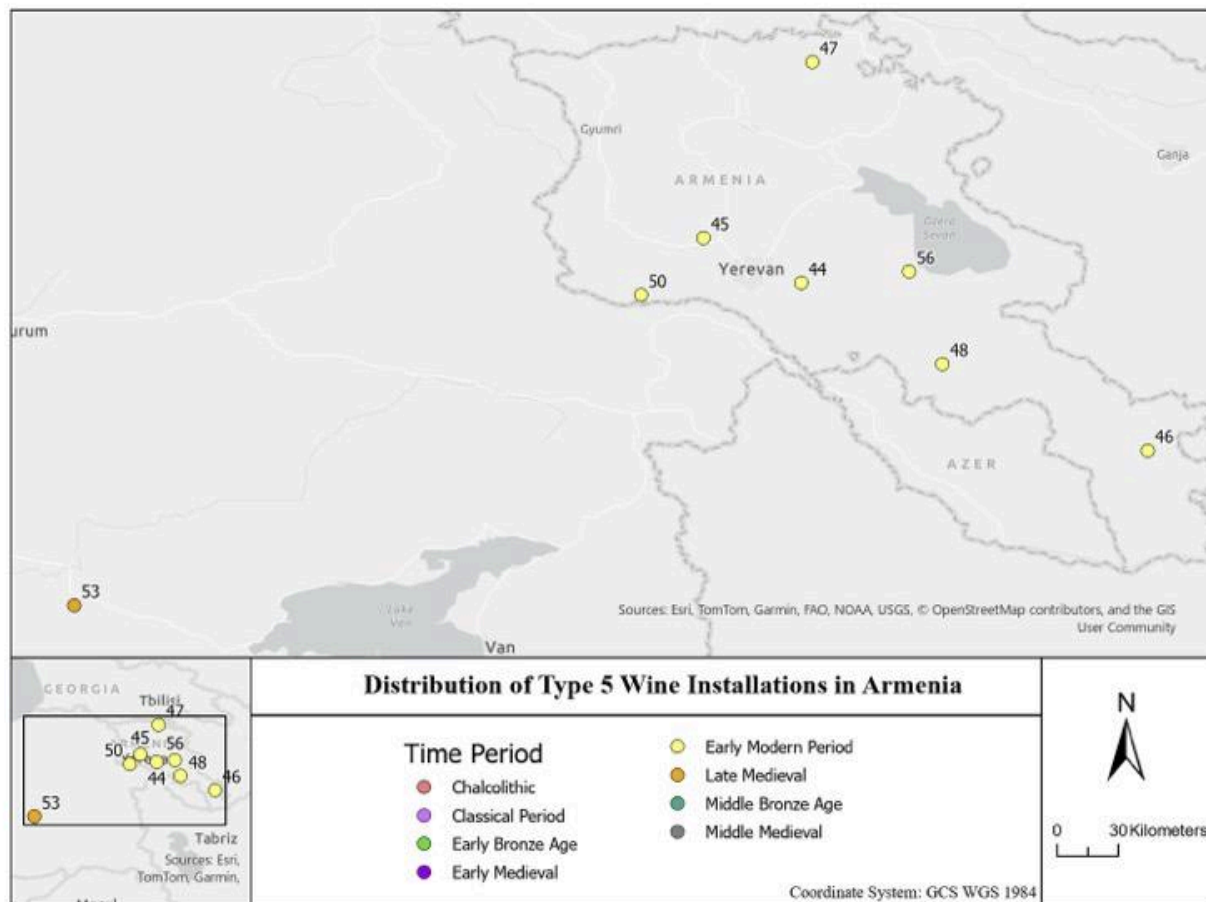
time.

The presence of multiple vats and *tarapans* within these installations likely improved the efficiency of the wine production process. While collection vats would facilitate the gathering of freshly crushed grapes, intermediate vats could allow for fermentation and settling and *tarapans* would aid in the pressing of grapes. This arrangement would streamline the workflow, possibly reducing labour requirements and thus increasing overall productivity. The ability to handle greater quantities of grapes and wine implies that production was aimed at meeting higher demand, potentially for both local consumption and broader distribution.

Locations

The majority of the site-phases have an unspecified location, with only two having a clearly defined placement. Based on the available context, the only discernible pattern that emerges is the placement of wine presses in association with religious or sacred sites, specifically a cathedral or a monastery. The proximity of wine presses to cathedrals and monasteries may suggest that, during the Medieval period, the wine industry was increasingly taken over by religious institutions for large-scale consumption, possibly for liturgical or communal purposes. As the Church became a central institution in medieval Armenian society, it may have assumed control over significant aspects of the economy, including winemaking. In addition, monasteries and cathedrals often functioned as self-sustaining centers, where agricultural production, including viticulture, supported the clergy and surrounding communities.

8.2.5: Type 5: Complete Installations



Map 8.4: Distribution of Type 5 wine installations in Armenia and peripheries from the Late Medieval through to Early Modern Period.

The industrial buildings of the Early Modern period (15th century CE -18th century CE) typically contained wine press installations, either improved or composite and wine cellars together, typically divided into two or more sections. These are considered complete installations. Complete installations are present in 6 out of the 49 site-phases (Map 8.4). Different types of presses could have been used or found on the *aragast*, like basket and horizontal screw presses (see Chapter 4 for more details on pre-industrial presses). During the 19th to 20th centuries, residential and industrial sections were typically housed within the same building (Arakelyan and Karakhanyan, 1962, Khachatryan and Kanetsyan, 2002; Tumanyan, 2008). The residential part was usually situated above the wine press and wine cellars. One of the best-preserved complete wine installations was uncovered on the poor-quality land of a vineyard at Dalma/Դալմա (Hovhannisyan et al., 2015, pp.105-106).

The industrial section housed the *aragast*, the *gub* and the movable or immovable containers for the juice and must. *Takars* were shaped like truncated cones, narrowing at the top. While these buildings had structural differences due to the landscape and construction period, they all featured low, narrow entrances and few windows to maintain stable indoor temperatures. The buildings had arched covers made of tuff stones. Red tuff stones have been used in the construction of wine installations since at least the 3rd century BCE and continued to be used long thereafter (Pötzl, 2021). During the Early Modern period, complete wine installations often consisted of multiple storeys, with the cellar typically located below the installations (see Chapter 5; Hovhannisyan et al., 2015, pp. 105; Harutyunyan et al., 2005). For example, at the site of Vagharshapat, the lime plastered *aragast*, *gub* and both movable containers for juice and must were situated in the industrial section of the building, with the winepress positioned above the wine cellar. This arrangement is further corroborated by the writings of Agatangeghos (Khalpakhchyan, 1961).

The wine installation, wine press and cellar rooms were connected by a large channel running horizontally from the Shoghagavank Monastery (Gegharkunik), potentially indicating an earlier dating for these complete winery features. Although the monastery was originally built in the 9th century CE (Gasparian and Petrosyan, 2020), the type and size of the stones, along with the double-vaulted architecture, suggest a later date for the wine installation. It is likely from the 15th century CE, as it resembles other stonework from monasteries in the region (Harutyunyan et al., 2005).

Locations

The patterns suggest a dual system of wine production in which religious institutions dominated large-scale or communal production, often linked to rituals and societal influence, while smaller-scale production occurred in residential settings, likely for private or localised use. This duality reflects the versatile and integral role of wine in both sacred and everyday life. The presence of wine presses in residential buildings (basements) suggests that wine production was not exclusively a large-scale, institutional activity but was also practiced on a smaller scale for household consumption or local trade. These residential contexts indicate a diversification of

production settings, with certain households or private spaces playing a role in meeting local demand.

8.3 Contemporary Evidence

As wine installations evolved into purpose-built and sophisticated structures, their design differences began to reflect regional climatic conditions. In areas with dry harvesting months, such as the Levant, Turkey and North Africa, wine presses typically featured large treading floors with open collecting vats and were generally fixed in place (Avshalom-Gorni et al., 2008). In areas like Greece and Cyprus, where substantial rainfall might occur during the harvesting season, it was common practice to channel the juice into ceramic vessels and the vessels tended to be mobile, although if fixed, they were usually covered (Frankel, 2016; Frankel, 1999).

Due to Urartu's varied topography and rugged terrain, the kingdom experienced diverse climates and precipitation patterns. In general, the region's precipitation pattern was characterised by dry summers and autumns, coinciding with the grape harvesting season and wet winters (Izdebski and Preiser-Kapeller, 2024, pp. 309–311). This seasonal pattern likely positioned Urartu alongside regions such as the Levant and Turkey, where dry harvesting months enabled the use of large, fixed treading floors for winemaking. Moreover, the reliance on irrigation systems, such as aqueducts, during the growing season highlights the broader agricultural strategies that ensured water availability for vines and other crops when it was most needed, further emphasising the adaptation of winemaking practices to regional climatic conditions (Hardie and Considine, 1976; Çifçi and Greaves, 2013).

Regarding contemporarily available evidence about the mid-9th century BCE to the early 6th century BCE around the eastern Mediterranean, there is limited data. Such evidence has been categorised into two sections: simple installations (Type 2) and simple lever and weight presses (see Chapter 7, section 4). The examples found to date from these areas are all fixed, suggesting the Urartian ones were probably also fixed (not mobile). All of the surviving installations were either made of stone or rock-cut.

8.3.1 Simple Installations

Areas with limited rainfall include modern day Lebanon, Palestine, Syria and parts of Turkey (Frankel, 1999, p. 60). Syria and Turkey lack direct evidence of wine production equipment during the periods under investigation but there is evidence of wine consumption and storage in these regions. The only confirmed evidence of a simple installation from Lebanon comes from the Phoenician site of Tell el-Burak, dating to the 8th–7th centuries BCE (Orsingher et al., 2020, pp. 1227–1229). There are several examples of simple installations found in Palestine with confirmed dates (see Table 8.2). At Tell Qasile (c. 10th–9th centuries BCE), wine production took place in Room J8 and the courtyard, where a plastered wine-vat with an adjoining plastered treading floor was built in the southeast corner (Mazar, 1950–1951, pp. 137, 139). Similarly, at Rishon (c. 1000–586 BCE), an oval, rock-cut installation with thick walls, layered with multiple coats of plaster, was used for winemaking (Segal, 2000, p. 66). Tel Lod (c. 9th century BCE) featured large floor depressions coated with multiple layers of dense plaster, serving as a rock-cut wine press (Yannai and Marder, 2000, p. 65).

At Beth Shemesh (c. 1000–586 BCE), Room 315 contained simple installations consisting of a large flat stone plastered with a collection basin hollowed out of stone, alongside two plastered vats connected by channels of varying sizes (Grant and Wright, 1938, pp. 2–4; Alström, 1978, p. 25). Ashkelon (c. 9th–7th centuries BCE) had wine presses in Building 776, Press 777 in Room 780 and Press 420, featuring treading floor platforms and collection basins lined with high-quality plaster. These presses were modest in size (approx. 3 × 3 m) and included a settling basin and plastered collecting vat, similar in design to Tel el-Burak but smaller (Stager, 2011, p. 5). During the 8th–7th centuries BCE, several settlements outside urban centers exhibited a standard press design. Rogem Gannim had eight presses, Giv'at Massuah five, Beit Safafa four, Mana'at sixteen and Khirbet er-Ras two. All shared the same basic structure: a modest treading floor, a settling basin and a plastered collecting vat, typically located outside the main settlement areas near tumuli or open land (Greenberg and Cinamon, 2006, pp. 229, 236).

Here it is worth noting that in regions of Palestine where precipitation was more frequent in both the growing and harvesting seasons, such as around Beth Shemesh and Ashkelon (Frankel, 1999; Stager, 1996; Fantalkin, 2004), wine presses were typically located within settlements and

settlement buildings. In contrast, in areas with less precipitation, wine presses tended to be found outside settlements. The concentration of wine presses at sites like Beit Safafa (4), Mana'at (16) and Rogem Gannim (8) (Table 8.2), particularly in the absence of associated nucleated villages, suggests that these installations were likely part of a centrally managed system overseen by the state or royal authorities. This implies that wine production in these areas was not primarily a small-scale, community-driven activity (such as a village or family cooperative) but rather an organised, large-scale effort integrated into the state economy. Such centralisation highlights wine as a significant commodity within the broader economic framework, potentially intended for trade, taxation or distribution as part of state-controlled resources. Alternatively, the arrangement may have facilitated oversight by collectors of tithes, rents and similar obligations on behalf of elite individuals, rather than indicating direct state control. Lastly, it is important to note that during earlier periods wine production relied predominantly on simple installations rather than SLWPs. These basic setups were far more common.

Site	Chronology (BCE)	Location	Press	Source
Tell Qasile	c.10th-9th centuries	Room J8 and courtyard	Plastered wine-vat with treading floor in SE corner	Mazar, 1950-1951, pp. 137,139
Rishon	c.1000-586	Rock-cut	Oval rock-cut press with thick plaster walls	Segal, 2000, p. 66
Tel Lod	c. 9th century	Rock-cut	Large floor depressions coated with multiple plaster layers	Yannai and Marder, 2000, p. 65
Beth Shemesh	c.1000-586	Room 315	Plastered stone basins and two vats with connecting channels	Grant and Wright, 1938, pp. 2-4; Alström, 1978, p. 25
Ashkelon	c. 9th-7th centuries	Building 776, press 777 in room 780, press 420	Treading floors, collection basins, plastered vats.	Stager, 2011, p. 5
Rogem Gannim	c.8-7th centuries	Near tumulus	8 presses: modest treading floors, settling	Greenberg and Cinamon 2006, p.229

		burials	basins, plastered collecting vats	
Giv'at Massuah	c.8-7th centuries	Outside settlement	5 presses of standard type: treading floor, settling basin, plastered vat	Greenberg and Cinamon 2006, p. 236
Beit Safafa	c.8-7th centuries	Outside settlement	4 presses, standard type	Greenberg and Cinamon 2006, p. 236
Manaúat	c.8-7th centuries	Outside settlement	16 presses, standard type	Greenberg and Cinamon 2006, p. 236
Khirbet er-Ras	c.8-7th centuries	Outside settlement	2 presses, standard type	Greenberg and Cinamon 2006, p. 236

Table 8.2: Some simple installation examples from Palestine – where most of the evidence in this study is concentrated –along with their dates, locations, descriptions and relevant references.

8.3.2 Simple Lever and Weight Presses

Evidence of simple lever and weight presses (SLWP) (for more information, consult Chapter 7, Section 7.4) in Palestine dates back to the Iron Age, at the site of Kh. Hudash dating to c. 8th century BCE or later (Eitam, 1980, pg. 7,40, pl 11). In contrast, evidence of SLWPs in use for wine production extends further back in the broader Mediterranean region. Notably, at Alassa Paliotaverna in Cyprus, SLWPs are documented as early as the Late Bronze Age (LBA). The presence of SLWPs at this site, which dates to approximately the 14th-12th centuries BCE, highlights that such technology was in use in the Eastern Mediterranean well before the Iron Age in Palestine (Hadjisavvas, 2020, pp. 38-41). The earlier adoption of SLWPs in Cyprus and potentially other Mediterranean regions suggests the technology spread through trade or cultural exchanges, influencing areas at different times (see section 7.4). While evidence of SLWPs in regions like Crete and Syria exists from the LBA, no definitive examples of wine processing have been found. This absence does not rule out their use, as the technology may have left few traces, especially in temporary or dispersed settings or if later modifications obscured earlier uses. Smaller, localised wine production could also account for fewer remains. Moreover, the development of similar technological systems in different regions may suggest a broader,

interconnected network of wine production and trade, even if specific instances of use remain undocumented.

The rarity of SLWPs for wine processing implies that traditional methods, such as treading, were likely sufficient to meet the wine production needs of the Urartian period. These methods may have been favored for their reliability and alignment with established practices. This could also reflect a lack of perceived value in adopting new technologies for tasks that were already well-served by existing techniques. The high initial investment and potential risks associated with SLWPs (e.g., overpressing grapes and compromising quality) might have deterred their use, particularly if simpler installations provided a simple, cost-effective solution. The limited evidence might also result from preservation biases or gaps in the archaeological record, specifically in terms of SLWPs linked to archaeobotanical data (i.e., grapes).

8.4 Possible Urartian Wine Press

In an interview, an elderly Armenian (Participant 42) from the Ararat marzer (Արարատ մարզ) showed the team a rock-cut simple installation press (Type 2 see below) on the periphery of their property that they claimed was a Urartian wine press. The installation included a square treading floor (2.7m²) and a square stone collection vat (0.3m³). Notably, the dimension and shape resemble rock-cut processing installations from Agarak (TF: 1.5m² to 3m² and CV: 0.4m³ to 1.92 m³)(measured by this author). These installations are significantly smaller - about one third of the size of rock-cut processing installations dating from the Iron Age in the Levant, like those discovered at Tel el-Nasba (McCown 1947, p. 257, pl 99) and Kh. Hudash (Eitam, 1979, p. 146).

The claim that this installation is a Urartian wine press was based on three factors. Firstly, there is a generational ‘oral history’ linking the rock-cut simple installation to the Urartian period, a tradition that extends over a known three hundred years. Secondly, it is in close physical proximity to possible Urartian architecture. Situated approximately 400m away from this supposed Urartian wine press is a Urartian cave burial, excavated by Soviet archaeologists during the 1970s (Participant 42, personal communication, 2020). However, this author was

unable to find at this time any Russian or Armenian literature mentioning either the burial or the press. Most rock-cut structures in the Ararat region, including tombs, mausoleums, terraces, channels and cisterns, have been attributed to Urartian workmanship (Dan et al., 2022, p. 316), suggesting that similarly built installations could also be Urartian. Thirdly, the Participant claimed that three pieces of red-polished ceramics were found inside the collection receptacle and looked to be Urartian Red Burnished Ware (URBW) based on the photos. However, the photo was not coloured and he did not know where they were moved to. If authentic, these ceramics tentatively date the installation to the 8th-7th century BCE, due to their red gloss and lack of any visible inclusions (Iskra et al., 2024; French and Summers, 1994).

The validity of this claim remains uncertain and unsubstantiated, as there is no record of the current storage location of these ceramic artefacts, relying solely on visual documentation from the individual (photo taken in the 1970s) and the reliability of historical and generational recollections. Nevertheless, if the installation did indeed function as a Urartian wine press, its proximity to the cave burial could suggest a potential ritual or ceremonial association, such as the production of wine or vinegar for burial or ceremonial purposes. Additionally, the absence of *tarapans* in the wine press might indicate that it dates to before the 2nd century BCE, when *tarapans* became common in nearby areas, as at Artashat, Dvin, Kaghtsrashen and Verin Artashat (Hovhannisyan et al., 2015). While further investigation is needed to confirm its validity, it is included here for the sake of completeness.

8.5 Discussion: Theoretical Framework and Conceptual Analysis

Hovhannisyan et al. (2015, p. 91) claim that rock-cut simple installation wine presses were widespread during the rise and history of Urartu, though they provide no specific locations or references. Similarly, Khalpakhcyan (1961) reports the discovery of wine presses and wine cellars at the palace of Teishebaini but offers evidence only for the wine cellar (the *karases*) and its walls. This lack of detailed references and ambiguity underscores the need for further investigation into the nature and location of wine production facilities.

In this context, the absence of evidence for any processing equipment further raises the possibility that wine production took place off-site, away from fortresses and settlements since

they have been so heavily excavated and surveyed. This could imply a range of setups, from highly advanced to extremely simple. The hypothesis proposed in this section progresses from the less likely scenario of mobile installations, encompassing both simple setups and small, locally widespread presses, to the more likely scenario of fixed installations, such as SLWPs. Ultimately, it suggests the most probable scenario: large, fixed and simple installations specifically designed for treading grapes into wine. These installations were likely situated on poor-quality land within vineyards or near settlements, where they could facilitate large-scale production.

8.5.1 Mobile Installations: General Considerations, Simple Installations and SLWP

Urtian wine processing installations were probably not mobile installations. It is easier to transport grapes to the processing equipment rather than to bring the processing equipment to the grapes, as the latter involves moving significantly more weight (the weight would vary depending on which installation). Transporting grapes to a centralised location is also more economical. This maximises the usage of the capital investment, the pressing equipment. Building multiple presses would not be cost-effective and possibly require more labour. This approach is practical for small-scale operations, for personal consumption or possible community trade but not the large-scale Urtian wine industry.

An even less likely possibility is that the processing installations were mobile structures made from stone, clay or wood. Grapes would be collected in *pithoi* and the installations could be moved into shelters as needed, similar to practices documented in mainland Greece, the Cyclades and Crete (Frankel, 1999, pp. 59–60; Sarpaki, 2019; Sarpaki, 2012, pp. 215–217; Platon and Kopaka, 1993). Such mobile installations have been found within settlements during the Bronze Age, including at Akrotiri, Knossos, Palaikastro and Phourni (Platon and Kopaka, 1993). At Akrotiri, an urban site where approximately 2.5 acres have been excavated, only one wine-pressing installation and based on its size would have one person treading in it has been uncovered (Sarpaki, 2012, p. 215). This suggests that wine pressing likely did not take place within the settlement itself but, as in other regions, in outlying areas such as vineyards. These mobile installations may have been moved into shelters during poor weather or at the end of the harvest season.

For this scenario to work, the treading floors would need to be small (0.8–1 m², accommodating a single person) and constructed from lightweight materials like clay and wood to enable transportation. However, these materials are less durable than stone, requiring more frequent replacement. In contrast, fixed stone installations offer greater durability, reducing long-term costs associated with maintenance and replacement. The limited size of mobile installations would constrain the volume of grapes processed at any given time, creating a bottleneck for large-scale production. Additionally, managing and maintaining multiple small mobile units would be far less efficient than using permanent facilities optimised for higher processing capacities. From a labour perspective, a single larger unit that accommodates multiple individuals treading grapes would allow for worker rotation, enabling continuous operation without interruptions. This efficiency is not achievable with smaller, single-person units. Overall, the small size and logistical challenges of mobile installations align better with a smaller-scale wine industry than what is often envisioned for Urartu.

The use of mobile SLWPs would have been impractical due to the considerable time and physical effort required to transport their various components across vineyards and into storage areas. The stone niches and/or press beds, given their substantial weight, were likely fixed installations, while the wooden beam, baskets and weights would have needed to be moved, assuming they were indeed mobile. Transporting grapes to a stationary press would have been far more efficient than relocating the press to the grapes, as the latter involves significantly more logistical challenges, especially for larger scales of production. Although clay press beds could be moved more easily, they would have likely fractured under the weight and pressure exerted by the SLWP, with wooden press beds potentially suffering similar damage. However, neither clay nor wooden press beds would have been likely to survive in the archaeological record.

8.5.2 Fixed Installations: Karase, Two-Storey Processing Installations and SLWP

Karases

There is a slim possibility that *karases* functioned not only as storage vessels for fermenting grape juice but also as *aragasts*, treading floors used for pressing grapes. This proposed dual function finds some support in modern, historical and archaeological evidence. Mago, the 5th-century BCE Carthaginian writer, provides detailed instructions on grape processing,

describing how grapes were spread out to dry slightly before being placed in a large jar. The stalks were removed and the grapes were crushed by foot directly inside the jar, rather than on a separate treading floor (Limbergen and Komar, 2024). The morphological characteristics of *karases* align with this practice. Their wide mouths could plausibly accommodate one or even two individuals, making it feasible to tread and macerate grapes directly within the vessel. This interpretation is further supported by visual evidence from Photos 8.1 and 8.2, which show individuals either inside or adjacent to *karases*, clearly demonstrating the vessels' capacity to contain a person or potentially two. The substantial thickness and robust ceramic fabric of these jars would have allowed them to withstand the mechanical stresses of treading without structural failure. While this interpretation cannot be confirmed conclusively, it presents a compelling alternative to the conventional understanding of *karases* solely as fermentation or storage containers.



Photo 8.1: Alik Avetisyan crouching inside a 260-gallon karas, filling it with newly harvested grapes. (photo courtesy of Zorah Wines, 2017).

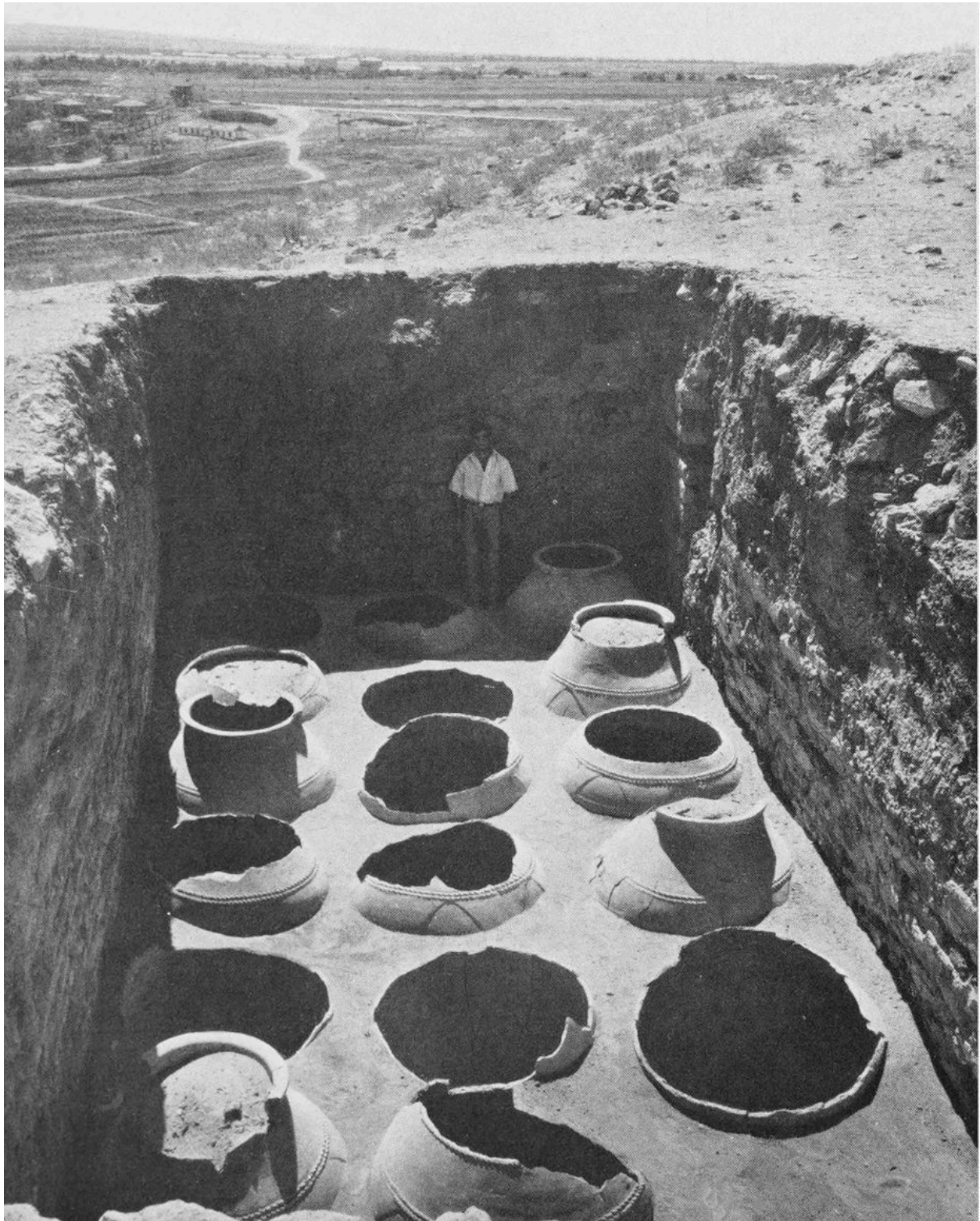


Photo 8.2: Excavator included for scale near karases uncovered during the 1960 excavations at Karmir Blur (photo courtesy of Edward Bacon, 1963).

This technique has parallels in the production of other fermented products. For example, dates and figs were often macerated in storage vessels and later transformed into wine by adding water, as detailed in Chapter 7. Such practices illustrate the multifunctionality of these jars in ancient winemaking processes. However, this was not by treading. Further evidence of grape treading inside fermentation jars comes from iconographic depictions from antiquity. As noted by Kourakou Dragona (2015, pp. 111–118), illustrations and reliefs often show individuals crushing grapes directly within the vessels where fermentation took place. This method economised space by eliminating the need for separate containers and reduced the labour involved, particularly in transferring juice between collection receptacles and fermentation jars. By consolidating these steps, winemakers streamlined production while minimising the risk of contamination or flavour loss, which could otherwise occur during transfers.

While the wide mouths of some *karases* might accommodate a person, this alone does not demonstrate their suitability for grape treading. Performing such activity inside a deep, narrow ceramic jar would be ergonomically challenging and inefficient. The depth and restricted space would impede movement, reducing the effectiveness of grape crushing compared to open treading floors or shallow vats specifically designed for this purpose. The risk of injury or slippage is high in these confined, curved-bottom vessels, especially when surfaces become slick with juice. Ventilation and visibility are also limited within deep jars, posing further risks during prolonged manual labour and potentially affecting fermentation, as oxygen plays a crucial role in the initial stages of grape processing. Thus, even if *karases* could physically contain a person, this does not imply they were functionally optimised for grape treading. Furthermore, there is a lack of wear patterns indicative of treading in other *karases* that have been excavated. If these vessels had been used for such purposes, one would expect clear morphological adaptations or reinforcements (such as larger rims, foot supports or integrated handles) to accommodate the mechanical stress and human movement involved.

However, the main issue with this method is that using *karases* for both primary production and storage would have been inefficient for the scale of winemaking the Urartians required. This is because the process of moving juice and grape skins between different production stages, such as

from a treading floor to a collection receptacle and then to a fermentation vessel, was far more practical for handling the large quantities of grapes involved and would ensure no bottlenecking. Thus, the Urartians likely relied on other methods better suited to processing such high volumes, like a larger treading installation.

Two-Storey Processing Installations

Both Çilingiroğlu (2001, pp. 69-71) and Tumanyan (2008) claim that the limestone water pipe discovered in Room 6 of Ayanis Fortress could have been used to transport wine from an upper-floor or adjacent workshops, which featured processing equipment, to storage vessels within the room or to the *karases* further below. However, there is no evidence of wine processing equipment at Ayanis, excluding fermentation aids like strainers and sulphur, let alone indications of a two-storey installation with an *aragast*, *gub* and *takar* (Işıklı, 2014; Çilingiroğlu, 2012). It is more likely that the pipe at the fortress functioned to transfer liquids from *pithoi* brought from the presses found outside the fortress to the *karases* for fermentation. The grape juice then could be transported from outside the fortress, probably produced on poor quality land inside the vineyards, to the fortress for this longer fermentation stage, where brief air exposure might have been beneficial in fermenting and creating stronger flavours (see argument below).

No evidence of wine production within state-run buildings has been found across Armenia and neighbouring regions; only storage and production equipment for dry foodstuffs like sesame seeds and grains has been documented (Iskra, 2021; Fuller, 2003, pp. 132-133). For grapes, a wet foodstuff, there is evidence of storage (e.g., *karases* and wine cellars) but not of processing within these fortresses. At the site of Teishebaini, for example, three large rooms in the northeast corner were dedicated to sesame oil production. One of these rooms contained a large vat used for soaking grain prior to pressing. In the second room, a significant quantity of sesame oil cake (the residue left after oil production) was found on the floor, along with weights and crushing stones. The wooden press that likely stood in this room was destroyed in the fire that consumed the rest of the site. In addition to the oil production area, there was also a brewhouse for beer production, which contained a stone vat with traces of malted barley and other ceramics, such as

funnels and a fermentation vessel (Bedigian and Harlan, 1986, pp. 146-147). All this clearly demonstrates that the processing areas featured rooms arranged side by side for different stages of production, rather than multi-story production sites. However, this arrangement did not seem to apply to wine cellars and wine presses. It further indicates a centralised, controlled approach to oil production in which it was produced within state-run-buildings and therefore state controlled. This was likely due to the importance of sesame oil in Urartian society for culinary, medicinal or possibly ritualistic purposes.

The earliest evidence for such a two-storey wine processing installation, dates to the Medieval period and no contemporary Iron Age sites from surrounding areas have yielded examples of such facilities. The use of two-story wine processing facilities in Armenia does not appear until the late Medieval period, around the 15th century CE (over 2000 year old difference), at the Shoghagavank Monastery (Gegharkunik) (Gasparyan et al., 2020; Gasparyan, 2014).

Fixed Simple Lever and Weight Press

The Urartians utilised SLWPs within their fortresses, such as at Teishebaini and Yoncatepe, to process sesame seeds into oil (Dönmez and Belli, 2007). This demonstrates that they possessed advanced technology capable of producing value-added products, offering advantages in scalability, processing quantities and operational control. The SLWPs were essential for handling certain dry crops like sesame, flax and gold-of-pleasure, which were unsuitable for traditional treading methods. These processes required tremendous force, up to 6000 kPa, far greater than what was needed for treating grapes (Thanaphon Charoensri et al., 2017).

While SLWPs were efficient, their application to winemaking posed significant challenges. Unlike sesame, grapes could be processed using simpler installations, a method supported by both archaeological evidence and historical practices. One major drawback of using SLWPs for winemaking was the risk of over-pressing grapes, which could crush the seeds, releasing excessive tannins and resulting in poor-quality, bitter-tasting wine. Several factors influenced this risk, including the weight applied during pressing, the design of the press (e.g., the distance between the press bed and niches) and the distribution of weight relative to the niches. To mitigate these risks, small and lightweight weights would have been required, further

complicating the practicality of SLWPs for winemaking. Consequently, SLWPs were a riskier option compared to traditional treading, which effectively produced the required quantity and potential quality of wine.

Another logistical challenge was the overlapping harvest seasons of grapes and sesame seeds, both typically gathered from late summer to early autumn (Bedigian, 2010; Bedigian and Harlan, 1986, pp. 138-139; Asatryan et al., 2024, pp. 150-151). This overlap likely necessitated specialisation in the use of SLWPs, prioritising sesame oil production over multipurpose applications. Within Urtian fortresses, sesame oil production appears to have taken precedence, while wine processing was conducted elsewhere. This distinction was likely due to the greater force required to extract oil from sesame, a dry foodstuff, compared to the relatively lower pressure needed for grape processing. SLWP technology was particularly suited for producing the high pressure (kPa) necessary for sesame oil extraction. In contrast, other, more practical methods were already in use for grape processing, making the adoption of SLWPs for winemaking unnecessary.

Although SLWPs required a greater initial investment in equipment, they were less labour-intensive compared to treading, both in terms of physical effort and workforce size. However, evidence suggests that treading was sufficient for the production levels needed in Urtian fortresses, meeting storage demands with relatively minimal labour. The case study from Section 8.6 highlights this efficiency, indicating that SLWPs were not essential for winemaking. Furthermore, there is very limited evidence of SLWPs being used for wine processing in contemporary Urtian contexts. Instead, large, simple installations, where treading would have taken place, were more common. Only a few examples of SLWP wine processing facilities have been identified, primarily in Cyprus and Palestine (see Section 8.3.2), dating to earlier and contemporary periods.

At Ayanis, in the northwest corner of the ceremonial aisle (room 10), a rectangular chalkstone feature resembling an altar was found *in situ*, with a grooved interior and a central hole (Batmaz, 2013, pp. 68-70). This feature measured 40 cm by 20 cm, with the central hole, which may have served as either a drain or a socket, measuring 5 cm in diameter. Although this structure was not a functional press, it could have served as a miniature representation of a wine press that the

Uartians might have used for wine production, adapted for use in a ritualistic context. Similar examples have been observed in Egyptian tombs (see Royal Ontario Museum collection). The design of this feature closely resembles Iron Age freestanding rectangular SLWP press beds with a central vat and no bore, which were excavated at Tel Mique (Dothan and Gitin, 1984, 1986; Eitam, 1986; Heltzer and Eitam, 1987, pp. 81-97), Tel Batash (Kelm and Mazar, 1983, Heltzer and Eitam, 1987, pp. 121-125) and Tel Gezer (Macalister, 1912, pp. 61-65). In room 11, which is considered an extension of the ceremonial aisle, a weight stone was discovered that may have been part of the ceremonial SLWP found in the ceremonial aisle. Additionally, drop-shaped stones, which strongly resemble grape seeds, were found in the corner of the aisle. Although their function remains unknown, their limited number suggests they were neither part of a wall mosaic nor used as the eyes of statues. Instead, their proximity to the chalkstone feature indicates a possible connection to a SLWP or their use as stoppers (Batmaz, 2013, pp. 69–71). However, this interpretation is circumstantial at best and could alternatively relate to the significance of sesame oil production, which used similar equipment or even another industry entirely.

The Uartians demonstrated advanced technological capabilities with their use of SLWPs for sesame oil production. However, the limitations and logistical challenges of applying this technology to wine processing, coupled with the overlap of harvest seasons and economic considerations, suggest a specialisation of equipment for non wine industries.

8.5.3 Most Likely Scenario: Fixed Large Simple Installations

Based on archaeological and historical evidence from Armenian wine processing equipment, as well as similar presses from geographically comparable regions during the Uartian period, it can be inferred that Uartian wine presses were likely large, fixed installations designed to produce wine on a significant scale. These presses would have featured large treading floors designed for the initial pressing of grapes, facilitating the extraction of the grape must. A bore or connecting channel would have been integral to directing the must from the treading area to a collection vat. *Pithoi* would have been employed to transport the grape must to the *karases*, typically stored in fortresses or other settlements.

The example of the wine press at Tell el-Burak offers an illustrative model for understanding what Uartian wine presses may have been like, although it represents a possible rather than

probable interpretation. However, given its geographical proximity to Urartian territory, similar climatic conditions and scale of wine production, the Tell el-Burak installation from the late 8th–6th centuries BCE provides a relevant comparative case. The dating of this press is supported by ceramics, stratigraphic evidence and radiocarbon analysis of organic materials (Orendi and Deckers, 2018, pp. 717–718). The press was situated near the settlement’s terrace wall (Orsingher et al., 2020, pp. 1226–1227) and included a stone treading floor measuring 11.2 m² and a collection basin measuring 4.9 m² (Orsingher et al., 2020, pp. 1227–1229). Significantly, there is no evidence of a lever-and-weight mechanism or other complex equipment, suggesting that juice extraction relied on manual grape treading. This feature provides a plausible analogy for how Urartians may have processed wine. By examining the materials, dimensions and manual functionality of the Tell el-Burak press, researchers can propose foundational models for interpreting and reconstructing Urartian wine presses. However, these reconstructions remain hypothetical, grounded in comparative analysis rather than direct archaeological evidence from Urartu itself.

The dimensions and layout of the Tell el-Burak press establish a benchmark for the scale of wine production that can be anticipated in Urartian installations. Based on this comparison, it can be inferred that Urartian wine presses would have had a treading floor measuring approximately 10–12 m², while the collection vat would have had a capacity of around 4.5–5.5 m². These dimensions reflect the scale of production that was feasible given the environmental and technological constraints of the time and the wine storage available in the wine cellars.

Both contemporary and historical evidence from the region indicates that wine processing equipment was fixed rather than mobile. This suggests that Urartian presses were likely constructed as permanent installations. The wine presses would have been used frequently, necessitating materials that could withstand repeated, consecutive use and heavy loads without degrading or wearing out (i.e., not clay). Stone and rock provide the robustness required for daily operations and the physical stresses associated with crushing and pressing grapes. It also ensured longevity, reducing the need for repairs or replacements which would also be economically beneficial. Stone and rock are resistant to environmental factors such as moisture, heat and cold. Given the climatic conditions of the region, which could include significant temperature fluctuations and potential exposure to the elements, durable materials would ensure that the wine

presses remained functional and stable. Stone and rock provide the necessary strength to support the weight of the treading labourers..

8.5.4 Urartian Centralised Wine Economy and Possible Locations

The kings of Urartu established a highly centralised and unified economic system, utilising local administrators, satellite sites and fortresses to support agricultural production (Çifçi, 2014). Built upon the region's natural resources such as mines, water and labour, this system was driven by purposeful economic activity (Arutyunyan, 1964, p. 2005). Inscriptions highlight the critical role of the monarchy in wine production, with royal control over numerous vineyards, palaces and fortresses, emphasising the king's involvement in viticulture and his authority over land and property dedicated to wine production (Çifçi, 2014, pp. 59–60, 67–68; Electronic Corpus of Urartian Texts). The crown managed wine storage and distribution, which were integral to the redistributive system connecting settlements and regions (Turker, 2015, pp. 10–12). Additionally, wine served as a key diplomatic and ceremonial asset, exchanged with neighbouring kingdoms or used in religious rituals and royal feasts, often hosted in palaces that acted as political and ceremonial centres (Hovhannisyan et al., 2015, pp. 328–329; Gökce, 2016; Çifçi, 2014, pp. 183–188; Batmaz, 2013). These events required substantial quantities of wine, highlighting the crown's need for control over its production.

Archaeological evidence of large-scale wine storage facilities at sites like Ayanis, Teishebaini and Bastam further reflects the centralised nature of the Urartian wine economy (Çifçi, 2017, pp. 80–84). These facilities, often containing large *karases*, further support the idea that the state was directly involved in managing wine production and distribution. While small-scale or personal production may have occurred, the majority of wine production likely fell under state oversight. The state could also ensure quality and uniformity through a comprehensive resource control system. This centralised approach extended beyond wine to encompass broader agricultural production. Inscriptions and archaeological evidence suggest that residents of outer towns were tied to the administrative, religious or military structures of nearby fortresses, with their needs met through a redistributive system overseen by the state (Çifçi, 2014, pp. 59–60; Grekian, 2017, p. 121). The absence of public squares, markets or communal spaces in urban centres, excluding temples supported by the crown, further suggests the dominance of the state

and the general lack of private property or independent economic activities (Grekyan, 2017, p. 122). Goods like wine, sesame oil and beer were produced in both central or peripheral areas and channelled through redistributive networks (Bonfanti and Dan, 2024, pp. 67–68; Fuller, 2003, pp. 132–133). The sparsely populated cores of Urartian cities reflect their administrative and military focus, not independent economic or communal activity. There may still have been smaller forms of local trade or private enterprise but the state was dominant..

Fortresses such as Kamir Blur, which housed specialised areas for beer and oil production and wine storage, exemplify the sophistication of Urartian resource management (Bonfanti and Dan, 2024, pp. 67–68; Seidl, 2004, fig. 2). These installations suggest that value-added commodities like wine were tightly regulated by the state, with local administrators overseeing vineyard cultivation, pressing and storage. By centralising these operations within fortified complexes, the Urartian state ensured direct administrative control, strategically using wine in religious, political and economic contexts. In Urartu, wine was a significant commodity in the royal/state economy. Inscriptions suggest that viticulture and viniculture were integral to the economy, with kings constructing aqueducts and dedicating vineyards to themselves, their families or deities (Tsatskheladze, 2021). Wine storage facilities, such as those found at Ayanis, Kef Kalesi, Teishebaini, Bastam, Toprakkale, Armavir, Altintepe and Yoncatep, demonstrate the centralised authority over the wine industry, underscoring wine's role in the royal and state economy (Çifçi, 2017, pp. 80–84; Gökce, 2016). A similar practice is observed at Yervandashat in the 3rd century BCE, where a "hall of pithoi" containing 36 large pithoi was discovered although no processing equipment was found on-site. This mirrors Urartian patterns, where storage facilities were likely managed by the state, with processing equipment located elsewhere, also under royal control (Çifçi, 2017; Earley-Spadon, 2023; Seidl, 2006). Notably, wine presses were generally situated within or near vineyards, separate from settlements, as seen in later periods (see [Appendix 12](#)).

Recent studies suggest that grape processing in Urartu occurred near vineyards, rather than within settlements, despite the centralised nature of the economy. Excavations of palaces and fortresses have shown a notable absence of wine-processing equipment, indicating that presses were located outside urban centres. Distribution patterns of historic Armenian and modern wine presses, along with logistical and socio-economic considerations, support the conclusion that Urartian wine presses operated as part of a state-run system, likely positioned on the outskirts of

settlements to optimise production efficiency. Archaeological evidence from Tushpa and Teishebaini reveals terraced vineyards, based on grape pollen, anthrosols, flat surfaces on slopes and alignment with natural features, just outside settlement walls, alongside grape seeds and pollen in residential areas (Dönmez and Belli, 2007, pp. 296–297). This suggests that vineyards were closely integrated with settlements for easier access and transportation, while the wine production process itself was centralised at presses near the vineyards. This arrangement avoided dispersion across multiple locations or smaller independent units, enhancing efficiency (Dallakyan et al., 2020, p. 1005; Smith, 2000).

The centralised system of wine production reflects both practical and strategic considerations. Proximity to vineyards allowed for the immediate processing of grapes after harvest, reducing spoilage, minimising transportation costs and facilitating efficient juice extraction. The wine could then be transported to larger storage vessels (*karases*) within settlements, likely in palatial or fortress areas, for fermentation and storage. This centralisation not only enhanced operational efficiency but provided the Urartian state with greater control over wine quality and production processes. Similar practices are evident at Tell el-Burak, where a wine press was found near the settlement's terrace wall (Orsingher et al., 2020, pp. 1226–1227; Orsingher et al., 2018). Further evidence for the centralised production system of the Urartian state is found in fortresses like Kamir Blur, which housed specialised production areas for beer and oil alongside large-scale wine storage facilities (Bonfanti and Dan, 2024, pp. 67–68; Seidl, 2004, fig. 2). Again, these installations demonstrate the state's organised production process, managed from fortified centres with local administrators overseeing vineyard cultivation, pressing and storage. The scale and sophistication of these facilities suggest that wine, as a value-added product, was tightly controlled by the state, rather than produced by smaller, independent units.

8.5.5 *Pithoi Collection and Transportation*

This type of equipment suggests a two-stage process: pressing the grapes into smaller storage vessels, like pithoi or even large animal skins (written evidence supports this as an option for trading) then transferring the must to the *karases* within the fortress for further fermenting. The Urartians likely used smaller *pithoi* rather than large *karases* to transfer wine from the vineyards to the fortress for several practical and logistical reasons.



Photo 8.2: Man transporting an empty karas using a donkey (Photo by V. Newson, 2020).

Pithoi, being smaller and lighter than large *karases*, were much easier to handle and transport over potentially rough terrain. Their reduced size and weight allowed for easier lifting and carrying by labourers or animals, such as donkeys or oxen. Smaller *pithoi* could also be transported using various means, such as carts, pack-animals or even by hand, depending on the distance and terrain. This versatility would not be feasible with the much larger and heavier *karases*. Photo 8.2 depicts a donkey struggling to transport an empty *karas*, which has an approximate weight of 200–400 kg (Serioj Asatryan, personal communication, 2020; Avetisian, 1999, pp. 294–296). Ethnographic evidence highlights the difficulty of manoeuvring such large vessels, even with the aid of a donkey. Transporting them often requires a considerable amount of time and multiple animals (Participant 46, personal communication, 2020). When filled with wine, up to 900 litres at maximum capacity, with the wine itself weighing 1 kg/L, the total weight reaches approximately 900 kg (Participant 2, personal communication, 2021). This far exceeds the load a typical donkey can carry, as donkeys are generally capable of transporting no more than 75 kg before their speed declines significantly and the risk of harm increases

(Goulder, 2015; Goulder, 2019). In Photo 8.2, the donkey was attempting to move a weight well beyond its capacity. However, the use of a small wooden flatbed with wheels helped distribute some of the load and facilitated movement. Moreover, when transporting loads uphill, the burden becomes even more onerous. It is generally recommended that a donkey or other beast of burden should only pull loads up to 2.7 times its own body weight (Gebresenbet et al., 2016, p. 113), making smaller *pithoi* or animal skins more appropriate for transportation. Furthermore, smaller *pithoi* are less likely to break or crack during transport compared to larger, more unwieldy *karases*. In the event of an accident, losing a single *pithos* would result in less wine being lost than if a large *karas* were damaged. Additionally, smaller vessels are more stable and less prone to tipping over during transport.

Upon arrival at the fortress, *pithoi* were easier to handle and manoeuvre within storage areas. This was particularly important when the wine needed to be moved to different rooms or levels within the fortress for further fermentation inside *karases*. Unlike *pithoi*, *karases* were half-buried into the ground to ensure temperature control during fermentation and were not easily movable. Some modern-day winery owners in Armenia have reported needing to demolish walls and doors to bring *karases* into their wineries for fermentation, motivated by the unique fermentation qualities of *karases* and their traditional significance. Others have chosen to build their wineries around already existing or pre-installed *karases*, since that approach is relatively easier than moving them (Participant 23, personal communications, 2020) (Photo 8.3).



Photo 8.3: Wine being stirred during the fermentation stage in a karase. The storage area was built around the karases that were already there.

Smaller vessels can be sealed more effectively, reducing the wine's exposure to air and potential oxidation during transport and storage, helping to maintain the wine's quality and flavour. Once transferred to the *karases*, the brief exposure to oxygen could aid the fermentation process, suggesting that using smaller pithoi for initial transport had practical benefits for wine quality. Producing large *karases* also requires more raw materials and labour, making them more expensive and resource-intensive to produce and replace. This is why they often remained in the ground. In contrast, smaller *pithoi* require less material and are easier to produce in large quantities, making them a more economical choice for transporting wine to the fortress.

8.6 Survey: Argishtikhinili

In conjunction with the ethnographic project discussed in Chapter 5, both surface (pedestrian) and subsurface (geophysical) surveys were conducted at Argishtikhinili. The geophysical work was carried out by two geophysical technicians. Surveying the Urartian site of Argishtikhinili was particularly important given its significant role in the administrative and economic control

of the Ararat plain, especially regarding the cultivation and production of wine. The presence of wine storage facilities, capable of holding up to 160,000 liters during the harvest season, highlights the site's importance in managing large-scale wine production and storage. During this period, wine was typically not stored for more than six or seven months to prevent spoilage (Piotrovsky, 1959, 1969; Martirosyan, 1974). There is also evidence of domesticated grape pips found at the site, with no context given (Hovhannisyan et al., 2015). The site's strategic location on the left bank of the Aras River provided abundant access to water and irrigation, making it ideal for grape cultivation and, consequently, wine processing (Khatchadourian, 2007, p. 58). The construction of irrigation canals by Argishtikhinili's administrators ensured that grapes had access to water during dry growing seasons. Additionally, their regulation of economic goods, including wine, suggests that the site was central to ancient viticulture and winemaking in the region. Argishtikhinili's long-standing infrastructure of palaces, temples and dwellings (used well into the post-Urartian period) indicates that many of its original facilities, including wine storage equipment and possibly winemaking equipment, were likely preserved, reused or adapted with more sophisticated technologies over time (Khatchadourian, 2007, pp.59-60). This possible continuity in usage increases the likelihood that remnants of ancient winemaking infrastructure remain intact.

The methodological approach employed in other regions (Limbergen, 2015, p. 171) cannot be applied to Urartu due to the absence of evidence for specialised wine-processing equipment. Traditionally, this approach relies on reviewing archaeological evidence of pressing equipment to estimate their numbers and wine production ratios. These figures are then used to evaluate processing capacity for annual yield estimates, compare them with potential agricultural yields and subtract local consumption to determine the exportable surplus. Given the lack of direct evidence in Urartu, an indirect methodological approach was adopted. By analysing the number of *karases* discovered, the minimum quantity of wine produced by the end of the harvest season can be inferred. To further quantify the wine production process, it is necessary to reverse-engineer the required infrastructure. Specifically, calculating the required treading floor area, likely a large-scale, simple treading installation, as discussed in Section 8.5, involves estimating grape yields per square meter and the corresponding juice yield. By working backwards from the volume of wine implied by the *karases*, it is possible to estimate the scale of grape cultivation and the extent of treading floor area required for processing the harvested

grapes. This reverse calculation provides insights into the agricultural and processing practices of the Ararat Plain, despite the absence of direct archaeological evidence.

Assumptions:

1. *Grape Crushing Yield per Square Metre*: As established in Chapter 4, each person typically required 0.8 to 1 square metre of space to tread productively. The amount of grape juice extracted during treading varies depending on grape variety, grape quality and pressing efficiency. Ethnographic data from section 5.4, suggests that the average grape crushing output per person on a traditional stone treading floor is 103 kg of grapes per hour (based on an average of $87+94+97+117+120 / 5 = 103$) (Participants 3,39,42,52 and 72, personal communications, 2020, 2021). This estimate assumes that the Urartian pressing equipment would also consist of large-scale, solid stone treading floors.
2. *Working Hours*: Workers can tread grapes for approximately 4 to 6 hours per day, including breaks. Treading is physically demanding, so it cannot be done continuously like mechanised processes (Participants 12, 30 and 33, personal communication, 2021). They could have had multiple shifts per day
3. *Harvesting Times*: The grape harvest in Armenia typically takes place from August to November. In the Vayots Dzor region, the harvest lasts between 8 and 10 weeks or approximately 56 to 70 days (Participants 16 and 33, personal communication, 2020). There was urgency in processing grapes into liquid and initiating the fermentation process as the quality of the grapes quickly deteriorated after harvest. Written documents indicate that the Urartian wine traded and used as tribute was not sweet wine (produced from dried grapes) (Batmaz, 2013), emphasising the need to process the grapes while fresh.
4. *Juice Yield*: The yield of juice from crushed grapes generally ranges from 60% to 70%, depending on the grape variety (Haight and Grump, 1994, pp. 113-116). For the Sev Areni, Arevik and Banants varieties, the yield is approximately 65% (Participants 4, 30 and 52, personal communication, 2020).
5. *Wine Production*: The volume of wine produced is assumed to be equal to the volume of grape juice extracted. Therefore, to produce 160,000 L of wine, 160,000 L of grape juice must be extracted.

Calculations:

Step 1: Calculate the amount of grapes required using the juice yield

Since the volume of wine is equal to the volume of grape juice, 160,000 L of juice is needed to produce the 160,000L of wine for which there is storage provision at Argishtikhinili in the Urartian period. Approximately 65% of the grape weight turns into juice for the Sev Areni, Arevik and Banants grape varieties.

- Grapes needed = 160,000L / 65% = 246,150 kg of grapes (approximately)

Step 2: Estimate the number of people needed to tread the grapes

According to the data, each person can tread 103 kg of grapes per hour. The workers can tread for 4-6 hours per day. Thus, the amount of grapes tread per person per day is:

- Min: 4hrs * 103kg/hr/person = **412** kg/per person/ per day
- Average: 5hrs * 103kg/hr/person = **515** kg/per person/ per day
- Max: 6hrs * 103kg/hr/person = **618** kg/per person/ per day

To find out how many people are needed, we divide the total grape weight by the amount one person can tread in a day and divide it by the number of available days. The number of days available range typically from 56 to 70 days (average 63 days). The equation is:

$$\text{People Needed} = \frac{\text{amount of grapes (kg)}}{\text{kg/person/day} * \text{harvest days}} = x$$

Lowest	Average	Highest
618*56 days = 34,608 246,150 / 34,608 = 7.1 or 7 people	515*56 days = 28,840 246,150 / 28,840 = 8.5 or 9 people	412*56 days = 23,072 246,150 / 23,072 = 10.7 or 11 people
618*63 days = 38,934 246,150 / 38,934 = 6.3 or 6 people	515*63 days = 32,445 246,150 / 32,445 = 7.6 or 8 people	412*63 days= 25,956 246,150 / 25,956= 9.5 or 10 people

618*70 days = 43,260 246,150 / 43,260 = 5.7 or 6 people	515*70 days = 36,050 246,150 / 36,050 = 6.8 or 7 people	412*70 days= 28,840 246,150 / 28,840 = 8.5 or 9 people
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∴ Approximately six to eleven people are needed to tread the grapes to produce 160,000 L of wine within the 56 to 70-day harvest season.

Step 3: Estimate the amount of treading space required

Each person requires 0.8 to 1 square metre of treading space (see Chapter 4). Assuming each of the six to eleven people treads at the same time and using the higher estimate of 1 square metre per person for simplicity:

$$\text{Treading Space Required} = \text{\#of people treading} * \text{treading space (m}^2\text{)}$$

Six People

- Treading space required = 6 people x 0.8m² = **4.8 m²**
- Treading space required = 6 people x 0.9m² = **5.4 m²**
- Treading space required = 6 people x 1.0m² = **6 m²**

- Treading space required = 8 people x 0.8m² = **6.4 m²**
- Treading space required = 8 people x 0.9m² = **7.2 m²**
- Treading space required = 8 people x 1.0m² = **8 m²**

Seven People

- Treading space required = 7 people x 0.8m² = **5.6 m²**
- Treading space required = 7 people x 0.9m² = **6.3 m²**
- Treading space required = 7 people x 1.0m² = **7 m²**

Nine People

- Treading space required = 9 people x 0.8m² = **7.2 m²**
- Treading space required = 9 people x 0.9m² = **8.1 m²**
- Treading space required = 9 people x 1.0m² = **9 m²**

Eight People

Ten People

- Treading space required = 10 people
x 0.8m² = **8 m²**

- Treading space required = 10 people
x 0.9m² = **9 m²**

- Treading space required = 10 people
x 1.0m² = **10 m²**

- Treading space required = 11 people
x 0.8m² = **8.8 m²**

- Treading space required = 11 people
x 0.9m² = **9.9 m²**

- Treading space required = 11 people
x 1.0m² = **11 m²**

Eleven People

∴ To produce 160,000 L of wine, you would need between six to eleven people treading at one time and between about five to eleven square metres of space over the harvest period.

Based on the dimensions of the only confirmed wine press at the site of Tell el-Burak, which dates to the same period and lies within the same climatic and precipitation zone, the treading floor measures approximately 10-12 m². It is likely that a similarly sized treading floor was used at Argishtikhinili, where a large-scale press, operated by ten or more people, could have produced 160,000 liters or more, using a treading floor of up to 11 m². Alternatively, multiple medium-scale presses could have been used to achieve the same output. For example, press one might have had a treading floor of up to 4 m² with 4 people, press two could have had a treading floor of up to 4 m² with 4 people and press three could have had a treading floor of up to 3 m² with 3 people. Either way, given the population estimates of Argishtikhinili (3,000-4,000 people) (Grekyan, 2017), employing around eleven individuals for grape processing represents a small fraction of the population. This figure remains modest even when considering the likelihood of additional labourers needed for other winemaking roles, such as grape collection, pressing, fermentation management and storage. Moreover, maintaining the required pace to meet such production levels throughout the harvest season would likely necessitate rotating shifts of workers, further emphasising the manageable scale of labour involved. The wine industry at Argishtikhinili thus emerged as an operation that, while significant in output, did not demand extensive human resources.

This analysis highlights that, while the scale of wine production at sites like Argishtikhinili may be impressive, it did not necessarily require vast human resources or involve a significant portion

of the population's labour (i.e., labour intensive) as one might initially assume. Instead, it suggests that wine production was well-integrated into the broader economic framework, operating efficiently without placing undue strain on the workforce. This aligns with a model of a specialised yet manageable industry, reflective of the settlement's broader social and economic priorities.

To produce 160,000 liters of wine, approximately 246,150 kilograms (271.4 tons) of grapes are required. According to Participants 13, 35, 67 and 70, an average yield of around 12 tons per hectare can be achieved from the indigenous grape varieties of the Ararat plain, such as Sev Areni (Սև Արեւիկ), Arevik (Արեւիկ) and/or Banants (Բանանց). This means that approximately 22.6 hectares of vineyards would be needed, representing 2% of the total economic zone. These figures indicate that such an operation would exceed the capacity of a few households and require a much larger enterprise.

To locate such potential installations, a pedestrian and geophysical survey was conducted in the area between the outer town fortification walls made of stone and the Urartian irrigation canals, a network constructed by King Argishti I between the Aras River and its tributary, the Kasakh River. This area was the presumed boundary of the Argishtikhinili economic zone, which includes various town buildings and agricultural horticultural land (Martirosyan, 1974). The total area is approximately 2,500 acres or 1,100 hectares. The 2,5000 acres were divided into manageable sub-areas and stratified random sampling was used to ensure coverage of diverse terrain types and areas. The survey involved walking of 10 x 10 metre transects.

Ground-penetrating radar (GPR) surveys were conducted along pre-defined transects within each sub-area. To identify potential locations for a wine processing installation, the following areas were the focus of the ground penetrating radar (GPR) survey: near ancient storage facilities, sloping terrain, industrial zones, water sources and agricultural/horticultural zones (Table 8.3). Wine presses were strategically located in areas that facilitated both production and storage. They were often situated near ancient storage facilities such as granaries or cellars, allowing easy access to containers and efficient transfer of processed wine. Gentle slopes or terraced land were also favored, enabling the gravity flow of grape juice from the treading basin to the collection basin. Additionally, wine presses could be found within residential or industrial zones, reflecting

both domestic and larger-scale production. Sites with existing foundations, scattered across hills or near settlement outskirts, were likely chosen to house basins or channels integral to wine processing. Proximity to water sources, such as wells, canals or aqueducts, was crucial for cleaning and processing and sites near these features were examined for channels or depressions aligned with water flow or drainage systems. Finally, presses were logically positioned near vineyards to minimise grape transport, with flat areas near historic or modern vineyards surveyed for subsurface anomalies like rectangular depressions or channels that could indicate the remains of wine press components. Across all these locations, ground-penetrating radar (GPR) was employed to detect linear or rectangular anomalies, carved rock features and depressions, helping to identify the likely sites and structures associated with ancient wine production. These locations were further based on the location of contemporary presses around settlements, the location of Armenian presses throughout history and ethnographic data from Chapter 5.

Location	Reasoning	GPR Focus
Near Ancient Storage Facilities	Close to granaries or cellars for easy access to storage containers.	Linear or rectangular anomalies suggesting man-made structures.
Sloping Areas or Terraced Land	Gravity-assisted juice flows from treading to collection basins.	Anomalies indicating carved basins or depressions.
Industrial Zones	Domestic and large-scale wine production.	Foundations or building remains; hidden basins or channels.
Near Water Sources or Drainage Systems	Water needed for cleaning and processing.	Channels or depressions aligned with water flow or drainage systems.
Near Historic and Modern Vineyards	Minimise transport distance from grape-growing areas.	Rectangular depressions or channels near historic or modern vineyard sites.

Table 8.3: A list of GPR survey locations, along with the reasoning for selecting these locations and the specific focus of the GPR investigations.

Some anomalies were found using GPR but, unfortunately, the information cannot be published or shared right now. The data are intended to be made available to the public in the summer of 2026, when the government releases them, including maps and aerial plans/photography.

8.7 Survey: Aghavnadzor, Vayots Dzor

These factors, ritualistic wine use in Urartian burial practices, proximity to a significant winemaking site, nearby Urartian fortress and evidence of ancient horticultural landscapes, provide a basis for investigating the potential existence of a winepress in Aghavnadzor. Firstly, Aghavnadzor contains Urartian tombs dating to the 8th-7th centuries BCE, which exhibit ritualistic placements of a pitcher at the head of the deceased and a cup beneath the head (Hovhannisyan et al., 2015, pp. 328-329). This burial practice suggests that wine played a significant role in funerary rituals and cultural tradition of the period and enjoyed a cultural significance that warrants further exploration of the area. Secondly, Aghavnadzor is located approximately 10.5 kilometres from the Areni-1 cave, where an ancient winepress was discovered in proximity to clay structures containing skulls (Gasparyan, 2014; Gasparyan et al., 2021, pp. 1-2). This find connects wine and possibly vinegar production, along with related tools, to afterlife and funerary rituals. The close geographical location implies that similar practices could be present in Aghavnadzor, potentially indicating the existence of a winepress in or near the village or even close to the Urartian burials. Additionally, the proximity of Aghavnadzor to the Urartian fortress of Getap (less than 15 km away) indicates that the area may have been an important part of the administrative landscape or their economic zone of the fortress, specifically for agriculture and horticulture (Gasparyan et al., 2021, pp. 1-2). Additionally, considerable evidence of ancient horticultural landscapes around the tombs and their periphery further supports the likelihood of viticultural activities in the area (Gasparyan et al., 2020). It was also in close proximity to some of the participants of the ethnographic study (see Chapter 5)

Based on Google Earth (Photos 8.4 and 8.5), satellite images and drone footage of the ancient horticultural landscapes, particularly areas near Urartian burials, potential survey areas were identified. A surface survey was conducted to detect surface artefacts, such as pottery fragments or architectural remains, that might indicate the presence of a winepress. The survey involved walking 10 x 10 metre transects. Ground-penetrating radar (GPR) was also used to identify anomalies or structures that could suggest the presence of a winepress or related infrastructure.



Photos 8.4 and 8.5: Google Earth images of old vineyards surrounding Aghavnadzor, Vayots Dzor. Note: the square foundation of permanent stone building on poor quality of land close to a few vineyards (inside the red box).

GPR was strategically deployed over targeted areas, including known tombs and burial sites, ancient horticultural landscapes (poor-quality land), irrigation channels and agricultural

infrastructure, potential building foundations and areas adjacent to historical paths or roads (Table 8.5). Survey locations were selected based on their potential connection to ancient winemaking activities. Areas around known tombs and burial sites were prioritised due to the presence of wine-related artefacts. GPR was used to detect linear or rectangular subsurface anomalies indicative of storage or production facilities. Ancient horticultural landscapes, particularly on poor-quality land, were also targeted, as these areas may contain vineyard-related infrastructure such as storage pits or fermentation zones. Surveys focused on visible vineyard layouts and adjacent cultivation zones. Historical irrigation channels and agricultural terraces were surveyed, as vineyards likely relied on irrigation and associated winemaking facilities may have been integrated with this infrastructure. GPR was also applied to detect potential building foundations, given that wine presses were often housed in small enclosed structures. Finally, sites near historical paths or roads were examined to identify infrastructure facilitating the transport of wine products from vineyards to fortresses or markets. Unfortunately, no evidence of wine processing equipment was found during the survey.

Location	Reasoning	GPR Focus
Around Known Tombs and Burial Sites	Wine-related artefacts in tombs suggest nearby storage or production areas.	Detect linear or rectangular anomalies indicating man-made structures.
Near Ancient Horticultural Landscapes (Poor Quality Land)	Past agricultural activity may include vineyards; poor-quality land might hide winemaking features.	Scan vineyard layouts or adjacent cultivation zones for storage pits or winepress infrastructure.
Along Irrigation Channels and Agricultural Infrastructure	Vineyards require irrigation; wine presses may be nearby.	Survey along ancient channels or terraces for subsurface structures, especially on poor-quality land.
Potential Building Foundations	Wine presses were likely housed in small buildings.	Detect subsurface foundations or walls indicating winemaking facilities.
Adjacent to Historical Paths or Roads	Vineyards were likely near transport routes for trade or delivery.	Survey along historical paths or roads for related infrastructure.

Table 8.5: A list of GPR survey locations, along with the reasoning for selecting these locations and the specific focus of the GPR investigations.

8.8 Where to Look Next?

Future research should investigate potential Urartian wine press locations, especially in peripheral and hinterland areas near major fortresses, palaces or sites with clear evidence of large-scale storage and economic significance. Focusing on areas with little to no history of excavation or survey work can be highly beneficial for several reasons. Undisturbed sites offer the potential for significant new discoveries while preserving their original stratigraphy and context, minimising the risk of compromised data. Advances in technology, such as remote sensing, LiDAR and ground-penetrating radar, further enhance the ability to uncover hidden structures or artefacts without invasive methods, making it easier than ever to explore and document previously overlooked areas. Below are a list of sites that have been identified as potential areas of interest for further study based on previous lack or limited archaeological activity (excavations and surveys), historical significance and their relationship to viticulture, trade and settlement patterns in the region (Table 8.6) (Zimanskly, 1998, 2011, 2021; Mapping Ancient Urartu, 2023).

Agrap Tepe remains largely under-studied despite its proximity to Lake Urmia, an area historically known for grape cultivation. Agrap Tepe is part of a cluster of three mounds situated close to one another. It is highly probable that at least one of these mounds played a central role in controlling viticulture and wine production in the surrounding area. Further study could clarify its role in the ancient wine trade and local economy. Anzaf comprises two fortresses located approximately 500 meters apart. The site was part of a land reclamation project during the Urartian expansion into its northern territories. Historical records indicate that Urartian kings, upon conquering new lands, often established vineyards both as religious offerings and as symbols of status and power. Anzaf is strategically positioned between two major water sources, Lake Van and Etcek and lies around 4–6 km from both Toprakkale and Van. Its location made it an important administrative and military base, acting as a key link between the Van Lake Basin and northwestern Iranian regions. Further excavation could provide valuable insights into its role in regional trade and viticulture. Aragac is located near a modern-day region known for its significant wine industry. Its elevation is particularly suitable for grape cultivation, making it a

candidate for past viticultural activity. Further exploration could help determine its historical importance, particularly in relation to regional trade and viticulture.

Despite being mentioned in past archaeological records, Iğdır remains under-studied. Further exploration could help determine its historical importance, particularly in relation to regional trade and viticulture. Although a relatively small site, Kayalıdere has yielded exceptionally well-preserved artefacts during brief excavations. The site is located close to the Murat River, an area historically documented as being significant for viticulture. Kayalıdere is best known for the Urartian Kayalıdere Castle and the Urartian rock tomb located west of the site. Given its strategic position along the Murat River trade route, crucial for westward trade under the Van-based Urartian Kingdom, it is highly plausible that wine production was conducted nearby to facilitate easy transportation along the trade routes. Norşuntepe has a long history of occupation, with architecture spanning from the Chalcolithic period through the Iron Age. It is located near a water source, a critical factor for settlement sustainability and viticulture activities. Excavations have mainly focused within the site itself, revealing structures that suggest trade and storage functions. A possible caravanserai, discovered on the southern terrace, indicates that Norşuntepe may have played a role in regional trade networks. The presence of storage areas supports the hypothesis that wine production, fermentation and trade might have taken place in and around this location.

Qalatgah was discovered accidentally during excavations at Hasanlu and only a single site report has been published on its findings. The site's proximity to Lake Urmia suggests it may have been part of a broader network of horticultural and trade centers in the region. Further research is needed to clarify its historical function and significance, with a focus on viticulture and viniculture. To date, no formal excavations have been conducted at Sequindel. The only available information comes from brief surveys focused on the site's structural remains, including its walls, tombs. The site was rich in epigraphy. Future archaeological work could help determine its broader historical role, with a focus on viticulture and viniculture. Although only a preliminary survey was conducted, Şirinkle has yielded valuable inscriptions, tombs and tunnels. These findings suggest that the site may have been a significant cultural or administrative center. More extensive research could reveal further insights into its historical importance, with a focus on viticulture and viniculture. A survey was conducted at Umdem Tepe, which lies at the

northernmost border of the region. Given its frontier location, the site may have played a role in regional defense, trade or viticulture expansion. Investigations at Zernaki Tepe have primarily focused on the site itself rather than its surrounding hinterlands. Further exploration of the broader landscape could provide a more comprehensive understanding of its historical role and connections to viticulture and viticulture.

Possible Sites	Previous Work	Other Reasonings
Agrap Tepe	1964	Under-studied; near Lake Urmia; part of mound cluster; likely linked to viticulture and wine trade.
Anzaf	1956, 1991-1996	Two fortresses; strategic location between water sources; Urartian vineyards likely; trade and administrative center.
Aragac	1954-1955	Elevated area suitable for grape cultivation; potential role in regional trade and viticulture.
Iğdir	1913, 1966	Under-studied; further research may clarify roles in viticulture and trade.
Kayalidere	1964-1965	Small but artefact-rich site; near Murat River; strategic trade route; likely wine production nearby.
Norşuntepe	1968-1974	Long occupation; near water; storage and trade structures suggest possible wine production and trade.
Qalatgah	1968	Accidental discovery near Lake Urmia; potential viticulture/trade center; limited research.
Sequindel	1967, 1977-1978	No formal excavation; structural remains and epigraphy; potential role in viticulture.
Şirinkle	1987	Preliminary survey; inscriptions, tombs, tunnels; possible cultural/admin center; viticulture potential.
Umdem Tepe	1978	Northern frontier site; possible role in defense, trade or viticulture expansion.
Zernaki Tepe	1957, 1996	Focused on site itself; surrounding landscape under-studied; potential viticulture links.

Table 8.6: Suggested Urartian areas in which survey work focusing on viniculture and viticulture should take place (Zimansky, 1998, 2011, 2021; Mapping Ancient Urartu, 2023).

8.9 Conclusion

This chapter has addressed the paradox of an extensive wine industry existing without clear material evidence of wine processing installations. Through interdisciplinary methods, combining comparative archaeology, ethnographic analogy and environmental constraints, a plausible model for Urartian wine processing equipment has been reconstructed and provided new insights into potential press locations and production methods. To this author's knowledge, this work is the first to compile a listing of specialised Armenian grape wine processing equipment and to focus on how the winemaking process evolved over time, along with the significance of these changes. It is also the first to concentrate solely and in detail on Urartian grape wine processing equipment, using as detailed evidence as possible.

By comparing Urartian winemaking with contemporaneous practices in the eastern Mediterranean and Near East, this chapter demonstrates that Urartian wine production likely shared similarities with other ancient cultures. The prevailing theory suggests that Urartian wine presses were typically located outside settlements, on marginal lands within or near vineyards, to facilitate efficient grape processing by minimising transportation. These presses were likely large, fixed installations with extensive treading floors, designed to maximise juice extraction during Urartu's dry harvest seasons.

Comparative evidence from similar climates, such as Tell el-Burak in modern Lebanon, suggests that Urartian wine presses resembled other large-scale, simple installations. Despite the availability of more advanced pressing technology, such as SLWPs for sesame oil, Urartian winemaking likely relied on manual grape treading, a labour-intensive but effective method suited to the scale of production observed in case studies. This preference indicates that Urartian winemakers prioritised practicality and tradition over technological innovation, despite their sophisticated understanding of fermentation.

Urartian wine presses were likely constructed from durable materials like stone or rock to ensure stability, longevity and resistance to environmental degradation. The centralisation of wine production under state control likely enabled Urartu to meet both domestic and external market demands. Large storage capacities at sites such as Teishebaini suggest production exceeded local consumption and supported exports to regions like Assyria and Babylonia. This surplus aligns

with Urartu's broader economic strategy, where centralised oversight likely allowed rulers to regulate production in response to market fluctuations, scaling output efficiently during periods of high demand.

The findings suggest that wine pressing installations were likely located outside fortified settlements, possibly near vineyards, rather than within palatial or fortress settings. This aligns with broader regional patterns where wine production often occurred in rural areas, closer to agricultural resources. Future research should investigate potential Urartian wine press locations, especially in peripheral and hinterland areas near major fortresses, palaces or sites with clear evidence of large-scale storage and economic significance and areas with little to no history of excavation or survey work. Exploring these areas will also help fill knowledge gaps and counter biases that arise from focusing on well-known sites, leading to a more balanced understanding of Urartu. Additionally, further investigation into the socio-political and economic contexts in which these technologies developed and were used will enhance our understanding of Urartian material culture and the kingdom's broader economic strategies.

While this chapter has made strides in reconstructing Urartian wine presses and understanding their place within the broader economic and physical landscape, it also serves a broader methodological framework and highlights the need of multidisciplinary approaches in archaeology for investigating lost or missing material culture, particularly processing equipment.

Chapter 9 - The Fruits of My Labour: Juicy Conclusions

9.1 Research Question 1[RQ1]

There is a discernible, though complex, transformation in how tree fruits were exploited between the Pre-Pottery Neolithic (c. 10,000 BCE) and the Iron Age (c. 700 BCE). Early on, fruits were primarily gathered and consumed in their raw form, as evidenced by archaeobotanical remains of wild grapes, olives, figs, pomegranates and dates. Over time, societies increasingly engaged in deliberate and systematic processing, producing value-added products such as dried fruit, wine and olive oil. While these trends are broadly true, the evidence, especially from the Neolithic, is mediated by preservation biases, with burned structures and submerged contexts disproportionately preserving early processing traces. Consequently, the apparent scarcity of Neolithic value-added products may reflect both genuine scale limitations and differential preservation.

9.1.1 Pre-Pottery Neolithic and Neolithic: Gathering and Early Processing

During the Pre-Pottery Neolithic and Neolithic periods, archaeobotanical evidence indicates that wild fruits and on rare occasions, early domesticated varieties, were generally present but in limited quantities. These remains are typically found in domestic contexts, suggesting that fruit collection was primarily for immediate consumption. Simple, non-specialised household tools, such as pestles, mortars and weights on boards, appear in the archaeological record and likely facilitated small-scale extraction.

Even in this early period, there is evidence of processing experiments, fermentation, olive crushing and rudimentary drying, indicating attempts to transform perishable fruits. However, these experiments were sporadic and likely aimed at immediate household use rather than surplus production. Preservation conditions, such as burned structures or submerged sites, have enhanced the detection of these early practices. Therefore, while the Neolithic record demonstrates that early processing occurred, the scale and economic significance were limited and must be interpreted cautiously.

9.1.2 Chalcolithic and Bronze Ages: Expansion and Intensification

From the Chalcolithic into the Early Bronze Age, the archaeobotanical record becomes richer and more geographically widespread. Fruit remains expand beyond their natural habitats and both the number and density of remains increase. This quantitative growth corresponds with more systematic processing: drying of fruit for raisins, production of wine and olive oil. These developments represent early efforts to transform perishable produce into storable commodities, laying the foundation for surplus-oriented systems.

Key trends during this period include:

- Spread and accumulation of remains: Fruits transported beyond natural distributions, often in large caches, indicate deliberate accumulation for processing.
- Emergence of specialised installations: Treading floors, collection vats and simple lever and weight presses demonstrate more intentional processing.
- Differentiated fruit pathways: While grapes and olives became widespread, pomegranates and dates appear primarily in elite, ritual or trade contexts.

These changes illustrate that the transformation was partly driven by expanding scale: larger, denser assemblages and more structured processing installations allowed higher throughput and eventual surplus, enabling participation in regional networks. At the same time, small-scale household processing persisted, showing that scale expansion was both a driver and outcome of economic intensification.

9.1.3 Technological Developments Across Periods

Technological innovation mirrors these scalar shifts. Simple household tools sufficed in the earliest phases for immediate consumption, while small- to medium-scale installations from the Chalcolithic onward supported systematic processing. By the Late Bronze Age and Iron Age, larger installations, expansive treading floors, vats, SLWPs and large stone rollers, enabled greater control, standardisation and production volume. These larger-scale systems coexisted with smaller household operations, highlighting that scale expansion did not entirely replace local, immediate-use practices.

9.1.4 Scaling and Economic Implications

The evolution of fruit exploitation closely aligns with broader economic transformations. Early Neolithic processing reflects small-scale, local subsistence, whereas later installations indicate ambitious, surplus-oriented production. This trajectory parallels Andy Bevan's (2020) concept of the stored products revolution: just as cereal storage facilitated larger economic networks, systematic processing, storage and standardisation of fruit products enabled reliable local consumption and integration into trade systems.

Indicators of scale expansion include:

- Quantity and distribution of remains: deliberate accumulation and transport beyond natural habitats.
- Processing intensity: evolution from sporadic household experiments to systematic production (drying, fermentation, oil production).
- Technological sophistication: larger, standardised installations capable of higher volume.
- Economic integration: surplus production for storage and trade.

While early Neolithic experiments existed, major transformations, from raw consumption to value-added, surplus-oriented production, were strongly driven by increasing scale, which in turn reinforced participation in wider economic networks. Notably, while the trajectory is gradual and regionally variable, scale expansion emerges as a key factor linking technological and economic change.

9.1.5 Regional Considerations and Caveats

Evidence remains uneven across the eastern Mediterranean. Research focuses on Palestine and Cyprus, whereas regions like Lebanon, Turkey and Armenia are less well studied, particularly regarding processing installations. Consequently, both the timing and intensity of scale expansion may vary regionally. Nevertheless, the general pattern is clear: fruit exploitation evolves from raw, immediate-use consumption in the Pre-Pottery Neolithic to deliberate, large-scale processing integrated into regional exchange by the Late Bronze Age and Iron Age.

9.1.6 Conclusion

The long-term transformation in tree fruit exploitation reflects an interplay of technology, scale and economic strategy. Preservation biases must be considered when interpreting early evidence but the overall trend illustrates a shift from small-scale household consumption to surplus-oriented, value-added production embedded within broader networks. Scalar expansion was both a cause and consequence of this process and the parallels with Bevan's stored products revolution highlight how innovations in storage and processing facilitated wider economic change (Bevan, 2020). Early experimental processing laid the groundwork but only with larger-scale, systematic installations did fruit production become a meaningful component of regional economic systems.

9.2. Research Question 2 [RQ2]

The shift from consuming fresh tree fruits to systematically processing them into value-added products, such as dried fruits, wine, vinegar and oil, was neither uniform nor linear across the eastern Mediterranean and Armenia. The timing, scale and technological complexity of this transition varied across regions, reflecting differences in local ecological conditions, trade networks and socio-economic priorities. Early fruit processing coexisted with direct consumption, indicating that technological innovations were responses to changing demands and opportunities rather than simple linear progressions.

Initially, fruits were consumed directly with minimal processing, typically in domestic contexts. Early Neolithic activities reveal simple processing techniques, such as grape treading and primitive oil extraction, demonstrating that value-added production began alongside fresh consumption. Over time, the appearance of processing residues and dedicated equipment signals a gradual shift toward surplus production for storage or trade.

9.2.1 Southern Levant (Palestine and Jordan)

In the Southern Levant, fresh fruits, including grapes, olives, figs and dates, are attested from the Pre-Pottery Neolithic period, often sourced from wild plants. Evidence of early fruit processing appears during the Neolithic, with practices such as grape treading and olive oil extraction. By the Early Bronze Age, specialised installations and caches of seeds and residues indicate the emergence of surplus production. Both non-specialised and specialised processing equipment

were in use, alongside the first recorded appearance of pomegranates. By the end of the Iron Age, standardised simple lever and weight presses (SLWPs) were widely employed, as seen at Ekron. This rapid adoption of advanced processing technology suggests that changes were driven not only by innovation but also by expanding trade and population growth.

9.2.2 Northern Levant (Lebanon and Syria)

The Northern Levant also shows early consumption of grapes, olives and figs, yet large-scale, value-added processing emerged later than in Palestine. By the Middle and Late Bronze Ages, small, dedicated presses and extensive processing residues reflect a growing economic shift. Pomegranates appear in the Early to Middle Bronze Age, often associated with elite or ritual contexts, highlighting the gradual integration of fruits into trade and social hierarchies. Early SLWP use in the Late Bronze Age indicates that the scale of production and distribution was a primary factor driving technological adoption.

9.2.3 The Aegean (Greece and Turkey)

In the Aegean, early fruit consumption is attested during the Pre-Pottery Neolithic and Neolithic periods, including evidence for raisins in Turkey and wine in Greece. Specialised processing equipment did not appear until the Early and Middle Bronze Ages, coinciding with the rise of complex societies and maritime trade networks. Here, technological sophistication and scale increased together: simple household tools evolved into specialised systems to meet rising demand, demonstrating the role of population growth and market pressures in advancing value-added production.

9.2.4 Cyprus

Cyprus shows early evidence of grapes, olives and figs from the Pre-Pottery Neolithic and Neolithic periods, with pomegranates appearing in the Early Bronze Age. Oil production was established early and by the Late Bronze Age, Cyprus had adopted advanced pressing technologies, including SLWPs. The rapid uptake of specialised equipment underscores the influence of interregional trade and integrated economic networks, where scale and market connections accelerated technological innovation.

9.2.5 Armenia

In Armenia, early grape domestication is documented at Areni-1, alongside sparse evidence for other fruits such as pomegranates. Specialised processing equipment appeared relatively late and early systems focused on sesame oil rather than olive oil, reflecting local ecological constraints and market priorities.

9.2.6 Egypt

In Egypt, although fruits were consumed and valued by elites, evidence for large-scale processing is limited. This reinforces the conclusion that the shift from raw consumption to value-added production was contingent upon local economic and social structures.

9.2.7 Scale as a Driver of Technological Adoption

The scale of production and distribution strongly influenced technological development. In regions such as Palestine, Cyprus and Crete, the adoption of larger, specialised installations, like SLWPs, coincided with population growth, expanding trade networks and rising market demand. Here, technological innovation is closely aligned with the need to produce larger quantities and standardised quality for storage or trade. In Lebanon, Syria, Armenia and Egypt, smaller-scale or delayed adoption of specialised equipment meant that fresh consumption remained dominant for longer periods. In these contexts, limited production scale reduced the incentive to invest in complex processing technologies.

9.2.8 Synthesis and Broader Implications

Overall, temporal changes in fruit processing were not purely technological or linear. Instead, they were closely tied to the expansion of production scale, ecological constraints, social organisation and market integration. Larger-scale economies adopted advanced technologies more rapidly, while smaller-scale or subsistence-oriented contexts maintained simpler practices. These incremental, regionally variable shifts align with broader models of economic change, such as Andy Bevan's stored products revolution in the first millennium BCE, in which surplus and storage capacity reshaped production, distribution and social structures. The archaeological evidence demonstrates that technological innovations in fruit processing were adaptive responses

to changing scales of production, trade pressures and consumption patterns, rather than inevitable or uniform progressions.

9.3 Research Question 3 [RQ3]

The diachronic analysis of tree fruit processing in the Eastern Mediterranean and Armenia appears to suggest a transformation from localised consumption to a more market-oriented, large-scale production of what may be considered high-value commodities. Initially, communities gathered wild tree fruits primarily for immediate consumption. Around the same time (or somewhat later), they began using non-specialised household tools at both household and village levels to produce more durable goods, such as dried fruits, wine, vinegar and olive oil. Over time, evidence suggests that advances in domestication, enabling higher yields per tree and a greater number of trees than could be harvested in the wild, combined with the development of more specialised processing equipment and techniques increased the production volumes, simplified processes and enhanced reproducibility. These value-added commodities, with their longer shelf lives and easier transport, appear to have played a crucial role in expanding trade networks and potentially spurring economic growth. Moreover, the high economic value of these processed products seemingly justified significant investments in specialised production techniques and infrastructure. Regions that appear to have mastered efficient processing methods might have been able to produce standardised, high-quality goods that could have fetched premium prices in various markets. This, in turn, may have spurred local economic growth by creating specialised industries and supporting increased labour organisation, while also potentially encouraging innovation and technological advancements. Ultimately, these developments could have led to an accumulation of wealth, further reinforcing trade networks and perhaps contributing to broader economic expansion in ancient societies.

9.3.1 Technological Innovations and Regional Adaptations

Technological innovations, particularly the advent of advanced processing equipment and storage infrastructure, seem to have been key to this transformation. They not only appear to have increased production efficiency, ease and product consistency but also may have mitigated some of the inherent risks of cultivating perennial crops with long maturation periods and vulnerability to environmental challenges. Moreover, regional variations in processing methods

and infrastructure seem to underscore the adaptability of ancient societies to their local environmental conditions and resource availability. Some regions may have developed highly efficient, standardised systems that integrated seamlessly into extensive trade networks, while others appear to have maintained small- to medium-scale operations that balanced local consumption with some surplus production for trade. Ultimately, these developments seem to illustrate how shifts in agricultural practices and technological investments were likely linked to market variability, potentially driving regional economic differentiation and contributing, at least to some extent, to the broader evolution of ancient economies.

9.3.2 Scale, Equipment and Economic Implications

The progression from fresh fruit consumption to systematic processing illustrates a nuanced economic evolution rather than a linear technological advancement. The evidence indicates that while the same basic tools could be used to produce a wide range of outcomes, regions differed in both the scale and sophistication of their processing installations, which in turn influenced the quantity and potential quality of wine, vinegar and oil produced. Advanced equipment such as simple lever and weight presses (SLWPs) allowed for precise pressure control, critical for determining the style and consistency of the final product. For example, modern analogies show that small differences in applied pressure can lead to noticeable differences in the production of red versus white wines or in the extraction efficiency and flavor profile of olive oil.

Regions like Cyprus, Crete and parts of Syria, which adopted these advanced technologies during the Late Bronze Age, likely benefited from enhanced production efficiency and consistency. This would have enabled them to generate higher outputs for a given labour input and an easier way of producing diverse products. In contrast, for areas like Palestine, widespread adoption of such equipment is only observed around the 8th–7th century BCE. This suggests that either earlier production was more localised and less standardised, reflecting different market demands or economic constraints, or, as ceramics from Egypt dating to the Early Bronze Age indicate, simple installations were effectively meeting regional demand.

Moreover, the type of tree fruit processed, whether grapes, olives or other fruits, also shaped production outcomes. While the processing equipment itself does not alter the intrinsic qualities of the fruits, it facilitates extraction in ways that can accentuate or diminish certain

characteristics. The variations in equipment, from simple, household-scale tools to larger, specialised installations, reflect adaptations to local agricultural practices and market needs.

9.3.3 Installation Dimensions and Production Scale

Additionally, the dimensions of the processing installations, such as the size of the treading crushing areas, press beds and storage or fermentation vessels, offer indirect evidence of production scale. A larger setup could indicate an operation geared toward producing larger quantities for trade, while smaller installations might have focused on artisanal methods where labour intensity and time invested led to a superior or specialised product. However, the archaeological remains primarily capture the material side of production. They do not record the direct labour inputs or the subtle processing decisions (like fine-tuning pressure or adjusting fermentation times) that modern winemaking demonstrates can drastically influence the final product's flavor, acidity or consistency.

Most processing equipment could handle various tree fruits, suggesting that simple installations and SLWPs were likely multi-use. Evidence from LBA Cyprus shows SLWPs were used for both wine and oil production. Storable fruits like dates, dried figs and pomegranates offer extended processing windows (4–6 months) compared to highly perishable crops like grapes and olives, which require immediate processing. Multipurpose equipment was economically beneficial, ensuring close to year-round use rather than seasonal idleness. For instance, dates and olives, with minimal harvest overlap, could be processed using the same stone rollers or SLWPs. Archaeological remains reflect the final use of presses rather than their full range of adaptations. Sites like Tel Ekron and Zayit show that collection vats and TCAs had varied functions, challenging the notion of single-use equipment. The design of TCAs allowed flexibility in extraction techniques, while SLWPs could accommodate different fruits by swapping storage bags, provided thorough cleaning was performed. Concerns about cross-contamination between wine and oil were likely mitigated by technological solutions, including plaster or lime coatings on treading floors and collection vats, as seen at sites like Jenin-Megiddo and Kouklia-Styllarka. Stone-slab treading floors enabled deep cleaning, maintaining equipment versatility. Historical evidence also suggests oil may have been intentionally used in wine storage to prevent oxidation, implying a functional overlap in ancient processing techniques.

9.3.4 Production Strategies

These technological innovations allowed for the large-scale production of value-added products, potentially catering to broader markets with mass-produced, standardised outputs. In contrast, smaller-scale operations, which likely used simpler methods like manual treading or torsion presses, may have produced higher-quality but lower-quantity goods intended for niche or elite consumption. This duality further supports the idea that even with similar basic equipment, the scale and organisation of production could yield a wide range of product qualities and quantities serving a variety of markets. Ultimately, the coexistence of both basic and sophisticated processing systems throughout these regions illustrates that ancient economies were not uniform. Rather, they were characterised by a diverse array of production methods that responded to varying demands for quantity, quality and product type. The ability to efficiently produce a range of value-added products played a crucial role in shaping local consumption patterns and facilitating trade networks.

9.3.5 Regional Variation and Market Dynamics

These differences, driven by both technological innovation and regional economic needs, underscore the complex market variability in ancient tree fruit use and the production of wine, vinegar and oil. Regional differences in the timing, scale and complexity of processing equipment reflect diverse market demands. Some regions rapidly developed surplus production systems aimed at trade, while others maintained simpler, household-based production. Variability in quality, from everyday consumption to elite or ritual products, highlights the multifaceted nature of ancient markets. The choice between investing in sophisticated installations versus using multipurpose non specialised tools underscores the interplay between local ecological potential, cultural practices and economic or societal needs. These regional differences are best understood as responses to local ecological conditions, cultural preferences and the evolving demands of both domestic consumption and interregional trade. In summary, the trend represents market variability: while all regions eventually transitioned to value-added production, the extent, nature and sophistication of that processing varied widely, reflecting different regional market/societal dynamics and priorities.

9.4 Research Question 4 [RQ4]

9.4.1 Challenges in the Archaeological Record

The persistent mismatch between abundant textual, iconographic and large-scale storage ceramics indicators of Urartian winemaking on one hand and the near-total absence of direct archaeological evidence for presses on the other, highlights the value of comparative, multidisciplinary methods. It also highlights the influence of taphonomic filters and the uneven preservation of early installations. This underscores a broader point: gaps in the archaeological record, whether in Urartu or Neolithic sites, should not be interpreted as evidence of non-use. Rather, they emphasise the need to integrate preservation biases into interpretations of technological and economic change. Across all case studies, consideration of scale, ephemeral installations and post-depositional loss is essential to accurately reconstruct the evolution of fruit processing and its economic implications.

9.4.2 Comparative and Multidisciplinary Approaches

By integrating ethnographic analogies, chronology of wine presses in the Urartian area from prehistory to the modern period and comparisons with well-documented wine presses in neighbouring regions, this study shows how it is possible to potentially reconstruct, albeit inferentially, the likely location, construction and function of Urartian wine-processing installations. Urartian wine presses were likely fixed, large and simple installations with a treading floor and a collection *pithoi* in which the liquid would be transported to fortresses and palaces to be fermented in *karases*.

Because ethnographic evidence shows that small, mobile presses were seldom practical for large-scale production, it is reasonable to infer that Urartian installations likely consisted of fixed, stone-cut treading floors on a large-scale, located near vineyards or beyond fortress walls. This aligns with the longstanding practice, both historically and in the modern era, of placing pressing sites in outlying areas to simplify harvest logistics. Modern and historical Armenian wine-pressing traditions, moreover, offer insight into what Urartian presses might have looked like, where they were built and how they operated.

9.4.3 *Typology and Chronology of Presses*

Chronological comparisons with known press types reveal an evolutionary path from small-scale, household items to more complex, permanent installations. Pinpointing early phases in former Urartian territories becomes more manageable once researchers understand which press layouts predominated at particular times. Contemporary analyses referencing sites such as Tell el-Burak (Lebanon), the Phoenician coast and parts of Palestine further indicate that large rock-cut or stone-built treading floors, rather than lever-and-weight presses, were customary in the 1st millennium BCE for wine production. Observing how lever-and-weight presses for grapes are scarce in neighbouring regions and how simpler installations are more common, supports the hypothesis that Urartu likewise depended on simple or improved treading floors (larger in scale in terms of treading floor and collection vat and added sections for grape drying and additives).

This wider, regional perspective also clarifies which press types are improbable, like fully mobile or multi-storey configurations and which are more likely, such as large, open-air treading basins placed near vineyards. Additionally, the use of large *karases* for storage implies a high grape output, which can be reconciled with known treading capacities gleaned from ethnographic sources. Each of these lines of evidence separately suggests that Urartian wine presses were fixed, large-scale sites located away from fortress interiors. Their true strength, however, emerges when these lines of evidence converge and reinforce one another.

9.4.4 *Indirect Reconstruction Methodology*

Given the lack of direct evidence in Urartu, an indirect methodological approach was adopted which involved reverse-engineering the likely necessary infrastructure. By analysing the number of *karases* discovered, researchers can infer the minimum quantity of wine produced by the end of the harvest season since wine would likely be stored up until six or seven months. From those storage capacities, it becomes possible to reverse-engineer the pressing infrastructure, estimating grape yields per square metre and calculating the necessary treading area. These production estimates can then be cross-checked with ethnographic data (as a heuristic) on treading floors, as well as prehistoric and historic processing equipment from Urartian contexts and analogous, geographically contemporary systems. This would provide estimates of how much space, labour and daily throughput would have been required.

Surveying prospective facilities, such as sloping or terraced land, industrial zones outside settlements, areas near water sources and both historic and modern vineyard locations, beyond already well-studied Urartian sites, guided by geophysical and pedestrian reconnaissance, further refines the search for off-site locations that might have featured large, simple treading floors. At Argishtikhinili, for example, geophysical and pedestrian surveys, combined with ethnographic insights into traditional Armenian wine presses, underscore how relatively modest treading areas, just 10–12 m², can yield large volumes of wine when operated efficiently. The logistical and economic logic similarly points to off-site, permanent installations in vineyard landscapes rather than more complex or mobile alternatives.

9.4.5 Implications and Conclusions

This approach is broadly applicable whenever direct remains of specialised equipment have vanished. In summary, this framework demonstrates that even in the absence of direct physical remains, a comprehensive, interdisciplinary strategy can yield plausible reconstructions of wine presses and other processing equipment.

9.5 Future Research

These suggestions for future research are ordered based on the chapters of this work.

9.5.1 Expanding and Cross-Cultural Studies

Expanding ethnographic studies into other historically significant but less-explored areas could reveal how traditional methods of fruit cultivation and processing have persisted or evolved over time. By incorporating modern analogues into archaeological interpretations, scholars can enhance their understanding of production methods, labour arrangements and the socioeconomic dynamics of ancient agricultural communities. Additionally, cross-cultural comparisons will facilitate the identification of universal and region-specific trends in tree fruit production.

9.5.2 Building on the Archaeobotanical Database

The comprehensive database of archaeobotanical data compiled in this study serves as a key resource for future research, representing the most extensive dataset currently available on tree

fruits, grapes, olives, figs, pomegranates and dates for the time periods in question (Pre Pottery Neolithic to the Iron Age). Future scholars can build on this foundation by expanding the dataset to include additional regions, extending the chronological scope and/or continuously incorporating newly discovered data. By integrating more diverse environmental, cultural and technological contexts, researchers can refine interpretations of past horticultural and agricultural and economic systems and gain a deeper understanding of diachronic shifts in fruit cultivation, consumption and processing.

The rise in the number of site-phases yielding fruit remains does not automatically indicate an increased reliance on or consumption of specific fruits. As noted in the introduction to Chapter 6, this trend is more plausibly linked to the expanding number of archaeological sites that have been excavated and recorded across particular regions. Recognising this distinction is essential to prevent misinterpretation of the evidence as direct proof of shifts in dietary habits or cultural practices. For future research and to both refine and expand upon the dataset presented here, it would be beneficial to move beyond simple counts of occurrences. Specifically, the use of relative rather than absolute frequencies would provide a more robust and comparable measure. For example, calculating the percentage of archaeobotanical reports that document the presence of a given fruit within assemblages from each geographic region would offer a clearer picture of distributional patterns. Such an approach would help to control for differences in site density, excavation intensity and publication bias, thereby allowing for stronger and more meaningful interpretations of the archaeobotanical record.

9.5.3 Investigating Processing Equipment

A future study on processing equipment should focus on rock-cut and free-standing simple installations, which were essential for early tree fruit processing but remain largely overlooked due to their vast numbers, potentially tens of thousands across the studied regions and challenges in dating. These factors made a detailed analysis beyond the scope of this study. However, compiling and analysing these features could significantly enhance our understanding of past production methods, technological choices and regional variations. Specifically, such a study could improve our understanding of production scale and organisation (determine whether processing was primarily a domestic, communal or industrial activity, its likely use for

small-scale or large-scale processing and whether it was seasonal, temporary or part of long-term economic strategies). It could identify regional and chronological patterns (examining the shape, size and material composition across different regions can help identify technological traditions and regional adaptations, cross-referencing these installations with dated sites can provide insight into changes in agricultural processing technologies over time and GIS mapping of these features may reveal clustering patterns that indicate economic hubs, trade routes or production zones). A structured, multi-method approach should include data compilation and surveys, GIS and spatial analysis, morphological and material studies, chronological and functional interpretation and comparative analysis with other processing equipment to fully integrate these installations into discussions of ancient economies and technological evolution.

9.5.4 Spatial Analysis of Equipment

Spatial analysis of processing equipment presents another crucial avenue for future research, particularly as more equipment is identified in regions beyond Palestine. This aspect was not explored in this study due to the focus on the southern Levant, which would have introduced significant bias in assessing the distribution of processing installations. Mapping the distribution of tools and installations across different archaeological sites can help determine whether processing was centralised or dispersed, shedding light on broader socio-economic and labour structures. This approach also facilitates comparisons between urban and rural production strategies, potentially revealing trade dynamics and distinctions between household and commercial-scale activities.

9.5.5 Experimental Archaeology

An experimental archaeology study on tree fruit processing could offer valuable insights into past production techniques, technological choices and resource use. By physically testing the pressures required to process different tree fruits into value-added products, researchers could move beyond the theoretical calculations in this study to empirical data, providing a more nuanced understanding of processing methods. A key avenue of exploration would be replicating traditional and prehistoric techniques using both non-specialised and specialised equipment. Experimenting with different pressures on these tools could clarify their effectiveness and whether they were optimised for specific fruits, further expanding on the calculations and

explanations in this work. Comparing traditional methods with Roman and Byzantine or even later equipment could also reveal how technological advancements improved efficiency, yield and quality. Beyond the technical aspects, such an experiment could contribute to discussions on labour investment and the broader implications of fruit processing in historical contexts.

9.5.6 Methodological Approaches for Fieldwork

The methodological approach developed in this dissertation should be used by other researchers who are investigating areas where there should be processing equipment but are not present or limited. This methodology should be used in conjunction with geophysical and pedestrian surveys in key farming areas like vineyards and terraced lands. These surveys can help detect hidden archaeological features, such as ancient treading floors and processing sites, that regular excavations, typically focused on areas with visible or known architecture, might miss. Once potential sites are identified, targeted excavations can confirm and refine these findings. This approach can also be applied to other regions and agricultural industries where evidence of specialised processing equipment is scarce. It allows for cross-cultural comparisons of ancient technology and economies. Studying these processing sites in relation to trade, labour and production scales can also give us a better understanding of historical production, technological advancements and economic systems.

9.5.7 Integrating Multiple Evidence Types

To enhance the study of tree fruit consumption and value-added processing, future research should integrate various evidence types, including ancient texts, chemical residue analysis and ceramic studies, encompassing both storage and typological analyses, within a long-term framework. This comprehensive approach can elucidate technological, economic and social aspects of fruit production and processing, revealing storage patterns, production scales and the economic significance of fruit-processing industries. Moreover, residue analysis can directly identify the biochemical composition of processed fruit products, confirming their use and trade. However, this study did not incorporate these methods due to several constraints. Access to well-preserved organic residues and suitable ceramic samples was limited by site conditions and available excavation materials. Chemical residue analysis requires specialised laboratory facilities, funding and collaboration with biochemistry experts, which were beyond the logistical

and resource scope of this research. While ancient texts could provide valuable contextual information, their availability and relevance to the specific sites studied were limited, as surviving records often focus on broader economic or administrative aspects rather than technical details of fruit processing. Conducting a comprehensive ceramic analysis of storage cellars, specific vessels and typologies would constitute a substantial research endeavor, comparable to an entire dissertation. Given these constraints, this study prioritised processing equipment and archaeobotanical data, which were more directly applicable to the research questions and feasible within the available funding, resources and timeframe. Future research can build upon these findings by incorporating these additional methods to provide a more comprehensive understanding of tree fruit production and processing.

9.5.8 Using AI to Identify Hidden Evidence

It may also be possible to search for historic and ancient processing equipment in the Armenian landscape using artificial intelligence (AI), building on precedents in which similar approaches have been proven successful in other fields (Gattiglia, 2025). For instance, Sakai et al. (2024) employed AI systems to identify 303 new figurative geoglyphs in six months by training algorithms on a dataset of known examples and then subsequently comparing these learned patterns against high-resolution images of the plateau. Comparable methods have been applied to detect submerged shipwrecks in the Mediterranean (Karamitrou et al., 2023), to locate hidden temple complexes in the dense jungles of Cambodia (Landauer et al., 2025) and for detecting archaeological sites within the Mesopotamian floodplain environment (Casini et al., 2023).

Following this model, the proposed approach would begin with the compilation of datasets consisting of confirmed wine press structures and their associated architectural and landscape features from similar areas around the Caucasus and the Eastern Mediterranean. An AI algorithm could then be trained to recognise similar markers within aerial and satellite imagery of the Armenian terrain. Once trained, the system would systematically scan the landscape to highlight locations that exhibit the defining characteristics of these processing installations. By prioritising areas for targeted archaeological survey, this methodology would not only increase the efficiency of fieldwork (walking surveys and possibly excavation) but also expand the geographic and

thematic scope of research, offering the potential to uncover previously unrecorded sites and gain new insights into historical production practices in the region.

9.5.9 Multidisciplinary Collaboration and Future Directions

Ultimately, this thesis contributes both by synthesising existing research and introducing new empirical data and methodology. While it integrates diverse studies, it also provides a foundation for future multidisciplinary research, encouraging collaboration among archaeobotanists, archaeologists, historians, economists, mechanical engineers and biochemists. These collaborations can help refine our understanding of ancient economies, particularly in relation to tree fruit processing, market variability and socio-economic change.

Reference List

- Abbo, S., Gopher, A. and Lev–Yadun, S. (2015) ‘Fruit Domestication in the Near East’, in *Plant Breeding Reviews: Volume 39*. John Wiley & Sons, Ltd, pp. 325–378.
- Achaya, K. T. (1993) *Ghani: The Traditional Oil Mill of India*. Kemblesville: Olearius.
- Adam–Blondon, A.–F., Martinez–Zapater, J.–M. and Kole, C. (eds) (2016) *Genetics, Genomics and Breeding of Grapes*. London: CRC Press.
- Adams, R. and Simmons, D. (1996) ‘Archaeobotanical remains’, D. Frankel, D. and Webb, J. M (eds.) *Marki Alonia. An early and middle Bronze Age town in Cyprus. Excavations 1990 – 1994* 123 (1), pp. 221–252.
- Adhikari, P. B., Xu, Q. and Notaguchi, M. (2022) ‘Compatible Graft Establishment in Fruit Trees and Its Potential Markers’, *Agronomy*, 12(8), p. 19–81.
- Adiba, A. *et al.* (2024) ‘Growth and physiological responses of various pomegranate (*Punica granatum* L.) cultivars to induce drought stress’, *Vegetos*, 37(3), pp. 887–899.
- Adrianov, B. V. (2016) *Ancient Irrigation Systems of the Aral Sea Area*. Oxford: Oxbow Books.
- Aguilar Criado, E. *et al.* (1981) ‘El cultivo de la viña. La fabricación de aguardiente y la colonia agrícola de Galeón: Estudio etnológico de la evolución y crisis de las actividades económicas tradicionales de Cazalla de la Sierra (Sevilla)’, *Etnografía española*, (2), pp. 187–288.
- Aharoni, Y. (1953) ‘Bet Sittah’, *Israel Exploration Journal*, 3, p. 266.
- Ahlström, G. W. (1978) ‘Wine Presses and Cup–Marks of the Jenin–Megiddo Survey’, *Bulletin of the American Schools of Oriental Research*, 231, pp. 19–49.
- Ak, B., Hatipoğlu, İ. and Dikmetaş, B. (2021) ‘Propagation of Fruit Trees’, in Pakyurek, M. (ed). *Recent Headways in Pomology*. Ankara: Iksad Publishing house, p. 398.
- Akagić, A. *et al.* (2020) ‘Geographic Variability of Sugars and Organic Acids in Selected Wild Fruit Species’, *Foods*, 9(4), p. 462.
- Albright, W. F. (1938) ‘The Excavation of Tell Beit Mirsim: II’, *The Annual of the American Schools of Oriental Research*, 17, pp. 1936–137.
- Aleid, S. M., Al–Khayri, J. M. and Al–Bahrany, A. M. (2015) ‘Date Palm Status and Perspective in Saudi Arabia’, in Al–Khayri, J. M., Jain, S. M. and Johnson, D. V. (eds) *Date Palm Genetic Resources and Utilization*. Dordrecht: Springer Netherlands, pp. 49–95.
- Alenazy, M. (2020) Video calls and email correspondences, 16 July 2020.
- Alemayehu, M. (2023) ‘Growth Requirements and Propagation of Date Palm’, in Al–Khayri, J., Mohan Jain, S., Johnson, D. and Krueger, R. (eds.) *Date Palm*. Crop Production Science in Horticulture, pp. 141–178.

- Ali, M. Z. and Dirar, H. A. (1984) 'A Microbiological Study of Sudanese Date Wines', *Journal of Food Science*, 49(2), pp. 459–460.
- Alighourchi, H., Barzegar, M. and Abbasi, S. (2008) 'Anthocyanins characterization of 15 Iranian pomegranate (*Punica granatum* L.) varieties and their variation after cold storage and pasteurization', *European Food Research and Technology*, 227(3), pp. 881–887.
- Alkhamaly, M. (2020–2021) Skype conversations, 5 December 2020, 17 February 2021.
- Al-Khayri, J.M, Mohan Jain, S. and Johnson, D. (2018) *Advances in Plant Breeding Strategies: Fruits*. Cham: Springer.
- Allaby, R.G. *et al.* (2022) 'A novel cost framework reveals evidence for competitive selection in the evolution of complex traits during plant domestication', *Journal of Theoretical Biology*, 537, 111004.
- Almanza–Merchán, P. J., Fischer, G. and Cely R., G. E. (2014) 'The importance of pruning to the quality of wine grape fruits (*Vitis vinifera* L.) cultivated under high–altitude tropical conditions', *Agronomía Colombiana*, 32(3), pp. 341–348.
- Alotaibi, K. D. *et al.* (2023) 'Date palm cultivation: A review of soil and environmental conditions and future challenges', *Land Degradation & Development*, 34(9), pp. 2431–2444.
- Al-shahib, W. and Marshall, R. J. (2003) 'The fruit of the date palm: its possible use as the best food for the future?', *International Journal of Food Sciences and Nutrition*, 54(4), pp. 247–259.
- Ammar, A. *et al.* (2024) 'Fig (*Ficus carica* L.) vulnerability to climate change: Combined effects of water stress and high temperature on ecophysiological behaviour of different cultivars', *South African Journal of Botany*, 147(2), pp. 482–492.
- Amouretti, M. C. (1981) 'Des agronomes latins aux agronomes provençaux, moulins à huile[From Latin agronomists to Provençal agronomists, oil mills]', *Provence historique*, 31, pp. 84–100.
- Amouretti, M. C. (1986) *Le pain et l'huile dans la Grèce antique [bread and oil in ancient Greek]*. Paris: Centre de recherche d'histoire ancienne (Annales littéraires de l'Université de Besançon, 67).
- Amouretti, M.–C. and Brun, J.–P. (1993) *La Production du vin et de l'huile en Méditerranée [Oil and Wine Production in the Mediterranean Area]*. Athenes: Ecole française d'Athènes (Bulletin de correspondance hellénique. Supplement, 26).
- Amouretti, M. C. and Comet, G. (1991) *L'évolution des techniques est-elle autonome? [Is the evolution of techniques autonomous?]*. Aix-en-Provence: Université de Provence.
- Amponsah, P., Jangra, M. and Goyal, P. (2019) 'Medical Enhancement and sensory analysis of dates fruit wine', *International Journal of Biological Research*, 9(2), pp. 149–156.
- Ana, D. (2022) *Wine Is Our Bread: Labour and Value in Moldovan Winemaking*. New York: Berghahn Books.

- Andersen, G. L. *et al.* (2014) ‘Traditional nomadic tending of trees in the Red Sea Hills’, *Journal of Arid Environments*, 106, pp. 36–44.
- Andrade, I. P. de S. *et al.* (2014) ‘Water requirement and yield of fig trees under different drip irrigation management’, *Engenharia Agrícola*, 34, pp. 17–27.
- Andriani, G. F. and Walsh, N. (2002) ‘Physical properties and textural parameters of calcarenitic rocks: qualitative and quantitative evaluations’, *Engineering Geology*, 67(1–2), pp. 5–15.
- Angelakis, A. N. *et al.* (2020) ‘Irrigation of World Agricultural Lands: Evolution through the Millennia’, *Water*, 12(1285).
- Angelini, L. (1967) *Bergamo e la Bergamasca [Bergamo and the Bergamo area]*. Poligrafische Bols Bergamo.
- Areshian, G. E. *et al.* (2012) ‘The chalcolithic of the Near East and south–eastern Europe: discoveries and new perspectives from the cave complex Areni–1, Armenia’, *Antiquity*, 86(331), pp. 115–130.
- Arie, E. (2008) ‘Reconsidering the Iron Age II Strata at Tel Dan: Archaeological and Historical Implications’, *Tel Aviv*, 35(1), pp. 6–64.
- Armani, V. (1962) ‘Le pressoir à huile “U Frangu” [The “U Fragnu” oil press]’, *Corse historique*, 5(6), pp. 71–74.
- Arnoni, Y. and Berry, E. M. (2015) ‘On the Origins and Evolution of the Mediterranean Diet’, in Preedy, V. R. and Watson, R. R. (eds) *The Mediterranean Diet*. San Diego: Academic Press, pp. 3–11.
- Arranz–Otaegui, A. *et al.* (2016) ‘Regional diversity on the timing for the initial appearance of cereal cultivation and domestication in southwest Asia’, *Proceedings of the National Academy of Sciences*, 113(49), pp. 14001–14006.
- Artzy, M. and Gitin, S. (1995) ‘Nami: a second millennium international maritime trading center in the Mediterranean’, *Recent Excavations in Israel*, pp. 17–40.
- Asatryan, H. *et al.* (2022) ‘Dynamics of the development of viticulture in RA: The econometric case study’, *Statistical Journal of the IAOS*, 38(4), pp. 1461–1471.
- Asatryan, H. *et al.* (2024) ‘Analyzing commercial grape farm efficiency in Armavir region (Armenia) by using a two–stage empirical approach’, *Statistical Journal of the IAOS*, 40(1), pp. 149–160.
- Asatryan, S. (2020) Face-to-face conversations, 27 June 2020.
- Asgary, S., Javanmard, S. and Zarfeshany, A. (2014) ‘Potent health effects of pomegranate’, *Advanced Biomedical Research*, 3(1), pp. 100–110.
- Ashraf, Z. and Hamidi–Esfahani, Z. (2011) ‘Date and Date Processing: A Review’, *Food Reviews International*, 27(2), pp. 101–133.

- Ashrafi, S. H., Bodaghi, H. and Rezaei, M. (2023) 'Morphological diversity of indigenous wild pomegranate (*Punica granatum* L. var. *spinosa*) accessions from northeast of Iran', *Food Science and Nutrition*, 11(2), pp. 1001–1012.
- Assirey, E. A. R. (2015) 'Nutritional composition of fruit of 10 date palm (*Phoenix dactylifera* L.) cultivars grown in Saudi Arabia', *Journal of Taibah University for Science*, 9(1), pp. 75–79.
- Atrash, W., Overman, A. and Gendelman, P. (eds) (2022) *Cities, Monuments and Objects in the Roman and Byzantine Levant Studies in Honour of Gabi Mazor*. Oxford: Archaeopress.
- Aumeeruddy–Thomas, Y. and Hossaert–McKey, M. (2024) *Fig Trees and Humans: Ficus Ecology and Mutualisms across Cultures*. New York: Berghahn Books.
- Avetisian, H. (1999) 'Urartian Ceramics from the Ararat Valley as a Cultural Phenomenon (A Tentative Representation)', *Iran and the Caucasus*, 3/4, pp. 293–314.
- Avetisyan, P. (2008) 'Recently Found Archaeological Sites of Armenia (Agarak)', *Aramazd. Armenian Journal of Near Eastern studies*, 3, pp. 39–50.
- Avitsur, S. (1976) *Man and His Work: Historical Atlas of Tools and Workshops in the Holy Land*. Carta.
- Avitsur, S. (1986) בית הבד המסורתי [The Traditional Oil Press]. Tel Aviv: Ha–Aretz Museum.
- Avshalom–Gorni, D., Frankel, R. and Getzov, N. (2008) 'A Complex Winepress from Mishmar Ha–'Emeq: Evidence for the Peak in the Development of the Wine Industry in Eretz Israel in Antiquity', *'Atiqot*, 5, pp. 65–67.
- Ayalon, E., Frankel, R. and Kloner, A. (2009) *Oil and Wine Presses in Israel from the Hellenistic, Roman and Byzantine Periods*. Oxford: BAR Publishing.
- Aydinoğlu, U. and Alkac, E. (2008) 'Rock–cut Wine Presses in Rough', *Olba*, 16, pp. 277–290.
- Baas, J. (1980) 'Ein bedeutsamer botanischer Fund der Gattung *Echium* Linne aus Kamid el–Loz [A significant botanical find of the genus *Echium* Linne from Kamid el–Loz]' in Hachmann R (ed.) *Bericht über die Ergebnisse der Ausgrabungen in Kamid el–Loz in den Jahren 1968 bis 1970*, Saarbrücker Beiträge zur Altertumskunde 22. Habelt: Bonn, pp 111–115.
- Bacilieri, R. *et al.* (2013) 'Genetic structure in cultivated grapevines is linked to geography and human selection', *BMC Plant Biology*, 13(1), pp. 13–25.
- Badalyan, R. S. *et al.* (2007) 'Village, Fortress and Town in Bronze and Iron Age Southern Caucasia: A Preliminary Report on the 2003–2006 Investigations of Project ArAGATS on the Tsaghkahovit Plain, Republic of Armenia', *AMIT*, 40, pp. 45–105.
- Badizadegan, M. (1975) 'Growth of pomegranate (*Punica granatum* L.) as affected by soil moisture tension', *Journal of Horticultural Science*, 50(3), pp. 227–232.
- Bahrami, S. (2023) *Date Palms as Living Infrastructure: An Ethnography of Human–Plant Relationship in Bam City, Iran*. masters. Concordia University.

- Bakker, J. D. *et al.* (2021) 'Of Mice and Merchants: Connectedness and the Location of Economic Activity in the Iron Age', *The Review of Economics and Statistics*, 103(4), pp. 652–665.
- Balakian, P. (2013) 'Raphael Lemkin, Cultural Destruction and the Armenian Genocide', *Holocaust and Genocide Studies*, 27(1), pp. 57–89.
- Baldoni, L. *et al.* (2006) 'Genetic Structure of Wild and Cultivated Olives in the Central Mediterranean Basin', *Annals of Botany*, 98(5), pp. 935–942.
- Bandaru, H. and Bakshi, M. (2020) 'Fruit Leather: Preparation, packaging and its effect on sensorial and physico–chemical properties: A review', *Journal of Pharmacognosy and Phytochemistry*, 9(6), pp. 1699–1709.
- Baramki, D. C. (1933) 'A Byzantine Bath a Qalandia', *Quarterly of the Department of Antiquities in Palestine*, 3, pp. 105–109.
- Baramki, D. C. (1934) 'Recent Discoveries of Byzantine Remains in Palestine', *Quarterly of the Department of Antiquities in Palestine*, 4, pp. 118–121.
- Barisashviti, E. (2011) *Making wine in kvevri: a unique Georgian tradition*. Biological Farming Association 'Elkana'.
- Barja, F. and Bourgeois, J. (2009) 'The history of vinegar and acetification systems', *Archives des Sciences*, 62(2), pp. 147–160.
- Barnard, H. *et al.* (2011) 'Chemical evidence for wine production around 4000 BCE in the Late Chalcolithic Near Eastern highlands', *Journal of Archaeological Science*, 38(5), pp. 977–984.
- Barnett, R. D. (1959) 'Further Russian Excavations in Armenia (1949–1953)', *Iraq*, 21(1), pp. 1–19.
- Baroja, J. C. (1956) 'Sobre maquinarias de tradicion antiqua y mediaval [About machinery of ancient and medieval tradition]', *Revistas dialectologia tradiciones populares*, 12, pp. 114–175.
- Barreveld, W. H. (1993) *Date Palm Products: FAO Agricultural Services Bulletin*. Food And Agriculture Organization Of The United Nations, 101.
- Bárta, J. *et al.* (2020) 'Applications of Geophysical Surveys for Archaeological Studies in Urban and Rural Areas in Czech Republic and Armenia', *Geosciences*, 10(9), pp. 1–26.
- Baruch, Y. (2007) 'Wine Presses with Stone Rollers from the Southern Judean Hills (Heb. Version)', *Judea and Samaria Research studies*, 16, pp. 299–321.
- Bar–Yosef, O. (1986) 'The walls of Jericho: an alternative explanation', *Current Anthropology*, 27, pp. 157 – 162.
- Bar–Yosef Mayer, D. E. *et al.* (2015) 'Neolithic Voyages to Cyprus: Wind Patterns, Routes and Mechanisms', *The Journal of Island and Coastal Archaeology*, 10(3), pp. 412–435.
- Bates, J. and Jiménez–Arteaga, C. (2024) 'Comparable quantification methodologies in

archaeobotany – a work-in-progress and debate’, *Vegetation History and Archaeobotany*, 33(5), pp. 671–686.

Batiuk, S. (2021) ‘Caucasian Cocktails: The Early Use of Alcohol in The Cradle of Wine’, in Stein, D., Costello, S. and Polinger Foster, K. (eds.) *The Routledge Companion to Ecstatic Experience in the Ancient World*. London: Routledge, pp. 101–120.

Batiuk, S. D. (2013) ‘The fruits of migration: Understanding the “longue durée” and the socio-economic relations of the Early Transcaucasian Culture’, *Journal of Anthropological Archaeology*, 32(4), pp. 449–477.

Batmaz, A. (2013) ‘A New Ceremonial Practice at Ayanis Fortress: The Urartian Sacred Tree Ritual on the Eastern Shore of Lake Van’, *Journal of Near Eastern Studies*, 72(1), pp. 65–83.

Batmaz, Atila (2015) ‘Votive Objects and their Storage Areas in Urartian Fortresses’, *Ancient Near Eastern Studies*, (0), pp. 127–205.

Bauer, A. A. (1998) ‘Cities of the Sea: Maritime Trade and the Origin of Philistine Settlement in the Early Iron Age Southern Levant’, *Oxford Journal of Archaeology*, 17(2), pp. 149–168.

Baughner, E. (2023) Email correspondences, 07 October 2023.

Becker, C. (2008) ‘The faunal remains from Dur–Katlimmu – Insights into the diet of the Assyrians. Archaeozoology of the Near East VIII’, *Maison de l’Orient et de la Méditerranée*. 49, pp. 561–580.

Bedigian, D. (2010) *Sesame: The genus Sesamum*. London: CRC Press.

Bedigian, D. and Harlan, J. R. (1986) ‘Evidence for cultivation of sesame in the ancient world’, *Economic Botany*, 40(2), pp. 137–154.

Behre, K.–E. (1970) ‘Kulturpflanzenreste aus Kamid el–Loz [Cultivated plant remains from Kamid el–Loz]’, *Saarbrücker Beiträge zur Altertumskunde*, 4, pp. 59–69.

Bekatorou, A. (2019) *Advances in Vinegar Production*. CRC Press.

Bel, A. (2017) ‘La production d’huile d’olive à Fès et dans la région [The production of olive oil in Fez and the region]’, *Bulletin de la Société Géographique d’Alger et de l’Afrique du Nord*, pp. 121–137.

Berihuete–Azorin, M. *et al.* (2023) ‘Archaeobotany in an era of change and challenge: potential and fragility of macro– and micro–remains’, *World Archaeology*, 55(3), pp. 299–314.

Bernardi, B. *et al.* (2018) ‘Harvesting system sustainability in Mediterranean olive cultivation’, *Science of The Total Environment*, 625, pp. 1446–1458.

Bernbeck R. *et al.* (2003) ‘The biography of an early Halaf village: Fistikli Höyük 1999–2000’, *Istanbul Mitteilungen*, 53, pp. 9–77.

Berry, E. M., Armoni, Y. and Aviram, M. (2011) ‘The Middle Eastern and Biblical Origins of the Mediterranean Diet’, *Public Health Nutrition*, 14(12A), pp. 2288–2295.

- Besnard, G., Terral, J.-F. and Cornille, A. (2018) 'On the origins and domestication of the olive: a review and perspectives', *Annals of Botany*, 121(3), pp. 385–403.
- Betz, M. (2021) 'Pruning the Community Orchard: Methods for Navigating Human– Fruit Tree Relations', in *Geographical Fieldwork in the 21st Century*. Routledge, p. 224–237.
- Bevan, A. (2010) 'Making and Marking Relationships: Bronze Age Brandings and Mediterranean Commodities', in Bevan, A. and Wengrow, D. (eds) *Cultures of Commodity Branding*. 1st edn. New York: Routledge.
- Bevan, A. (2025) 'A Stored-Products Revolution in the 1st Millenium BCE', *Archaeology International*, 22 (1), pp. 127-144.
- Bhat, S. V., Akhtar, R. and Amin, T. (2014) 'An Overview on the Biological Production of Vinegar', *International Journal of Fermented Foods*, 3(2), p. 139–155
- Bintliff, J. (2013) 'The Hellenistic to Roman Mediterranean: A proto–capitalist revolution', in Kerig, T. and Zimmermann, A. (eds.) *Economic archaeology: from structure to performance in European archaeology*. Bonn: Dr. Rudolf Habelt GmbH Publisher, pp. 285–292.
- Birch, S. E. P. (2018) *Multispecies Archaeology*. London: Routledge.
- Bird, D. (2010) *Understanding Wine Technology : The Science of Wine Explained*. DBQA Publishing.
- Birkás, M. *et al.* (2017) 'Review of soil tillage history and new challenges in Hungary', *Hungarian Geographical Bulletin*, 66(1), pp. 55–64.
- Blázquez, J. M. (1992) 'The Latest Work on the Export of Baetican Olive Oil to Rome and the Army', *Greece & Rome*, 39(2), pp. 173–188.
- Bliss, F. J. and Macalister, R. A. S. (1902) *Excavations in Palestine during the years 1898–1900*. London: Palestinian Exploration Fund.
- Blitzer, H. (1991) 'Olive Cultivation and Oil Production in Minoan Crete', in Amouretti, M. C., Brun, J. P. and Eitam, D. (eds) *Oil and Wine Production in the Mediterranean Area*. Paris: Centre de Recherche d'Histoire Ancienne (67), pp. 91–100.
- Bloch–Smith, E. and Nakhai, B. A. (1999) 'A Landscape Comes to Life: The Iron Age I', *Near Eastern Archaeology*, 62(2), pp. 62–127.
- Boardman, J. *et al.* (1997) 'The olive in the Mediterranean: its culture and use', *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 275(936), pp. 187–196.
- Boaretto, E., Bar–Yosef, O., Gopher, A., Goring–Morris, A.N. and Kozłowski, S.K., (2010). 'Radiocarbon chronology.', in Bar–Yosef, O., Goring–Morris, A.N. and Gopher, A. (eds.) *Gilgal: early Neolithic occupations in the Lower Jordan Valley. The excavations of Tamar Noy*. Oxford: Oxbow Books, pp. 33–38.

- Bogaard, A. and Charles, M. (1999) 'Addendum: summary of archaeobotanical work at al-Mudaybi', Mattingly, G.E (ed.) *Al-Karak resources project 1997: excavations at Khirbat al-Mudaybi*, 43, pp. 140–143.
- Bogaard, A. *et al.* (2017) 'Agricultural innovation and resilience in a long-lived early farming community: the 1,500-year sequence at Neolithic to early Chalcolithic Çatalhöyük, central Anatolia', *Anatolian Studies*, 67, pp. 1–28.
- Bombarely, A. *et al.* (2021) 'Elucidation of the Origin of the Monumental Olive Tree of Vouves in Crete, Greece', *Plants*, 10(11), pp. 1–18.
- Bonfanti, A. and Dan, R. (2024) 'Looking for the Signs An Unfinished Royal Bowl from Karmir–Blur of Minua, King of Urartu: An Unfinished Royal Bowl from Karmir–Blur of Minua, King of Urartu', *Annali di Ca' Foscari. Serie orientale*, 60(1), pp. 65–74.
- Bonhomme, V. *et al.* (2020) 'Eco–evo–devo implications and archaeobiological perspectives of trait covariance in fruits of wild and domesticated grapevines', *PLOS ONE*, 15(11), pp. 1–22.
- Bonn, M. (2013) *Vegetation and Climate History of the Southern Levant during the last 30,000 Years Based on Palynological Investigation*. Bonn: Rheinischen Friedrich Wilhelms Universität.
- Bonnett, A. (2003) 'Geography as the world discipline: connecting popular and academic geographical imaginations', *Area*, 35(1), pp. 55–63.
- Bookidis, N. (1990). *Ritual dining in the sanctuary of Demeter and Kore at Corinth: some questions*', in Murray, O. (ed.) *Symptica: A Symposium on the Symposion*. Oxford: Oxford Academic Press, pp. 86 – 94.
- Bordaz, J. (1973) 'Current Research in the Neolithic of South Central Turkey: Suberde, Er Baba and Their Chronological Implications', *American Journal of Archaeology*, 77(3), pp. 282–288.
- Borojevic, K. (2006) 'The Archaeobotanical Finds', in Finkelstein, I., Ussishkin, D., Halpern, B. (eds.) *Megiddo IV. The 1998– 2002 Seasons*. Tel Aviv: Tel Aviv University, Sonia and Marco Nadler Institute of Archaeology. Monograph Series No. 24. Emery and Claire Yass Publications in Archaeology.
- Borojevic, K. (2011) 'Interpreting, Dating and Reevaluating the Botanical Assemblage from Tell Kedesh: A Case Study of Historical Contamination', *Journal of Archaeological Science*, 38, pp. 829–842.
- Bosanquet, R. C. (1902) 'Excavations at Praesos I', *Annual of the British School at Rome*, 8, pp. 231–281.
- Boskou, D. (2006) *Olive oil: chemistry and technology*. 2nd ed. Champaign, Ill: AOCS Press.
- Botta, C. and Coccolin, L. (2012) 'Microbial dynamics and biodiversity in table olive fermentation: culture-dependent and –independent approaches', *Frontiers in Microbiology*, 3., pp. 154–165.
- Bouby, L. *et al.* (2021) 'Tracking the history of grapevine cultivation in Georgia by combining

geometric morphometrics and ancient DNA', *Vegetation History and Archaeobotany*, 30(1), pp. 63–76.

Bouby, L. *et al.* (2022) 'Talkin' About a Revolution. Changes and Continuities in Fruit Use in Southern France From Neolithic to Roman Times Using Archaeobotanical Data (ca. 5,800 BCE – 500 CE)', *Frontiers in Plant Science*, 13, pp. 1–22.

Boulay, T. (2015) 'Wine Appreciation in Ancient Greece', in Wilkins, J. and Nadeau, R. (eds) *A Companion to Food in the Ancient World*. 1st edn. Oxford: Wiley, pp. 273–282.

Boulton, R. B. *et al.* (1999) 'Microbiological Spoilage of Wine and its Control', in Boulton, R. B. *et al.* (eds) *Principles and Practices of Winemaking*. Boston, MA: Springer US, pp. 352–381.

Braadbaart, F., Marinova, E. and Sarpaki, A. (2016) 'Charred olive stones: experimental and archaeological evidence for recognizing olive processing residues used as fuel', *Vegetation History and Archaeobotany*, 25(5), pp. 415–430.

Breton, C. *et al.* (2006) 'De l'olivier à l'oléastre : origine et domestication de l'*Olea europaea* L. dans le Bassin méditerranéen [From the olive tree to the oleaster: origin and domestication of *Olea europaea* L. in the Mediterranean Basin]', *Cahiers Agricultures*, 15(4), pp. 329–336.

Broshi, M. (2007) 'Date Beer and Date Wine in Antiquity', *Palestine Exploration Quarterly*, 139(1), pp. 55–59.

Broshi, M. and Finkelstein, I. (1992) 'The Population of Palestine in Iron Age II', *Bulletin of the American Schools of Oriental Research*, 287, pp. 47–60.

Broshi, M. and Gophna, R. (1986) 'Middle Bronze Age II Palestine: Its Settlements and Population', *Bulletin of the American Schools of Oriental Research*, 261, pp. 73–90.

Brouant, J. (1646) *Traité de l'eau de vie ou anatomie théorique et pratique du vin*. Paris: J. de Senlecque and J. Henault.

Brun, J.-P. (1993) 'La Discrimination entre les installations oleicoles et vinicoles: discussion presentee par Jean-Pierre Brun (The Differentiation between Olive Oil and Wine Production Installations: Discussion Presented by Jean-Pierre Brun)', in *La Production du vin et de l'huile en Méditerranée (The production of wine and oil in the Mediterranean)*. Paris: Université de Provence, pp. 511–537.

Brun, J.-P. (2004) *Archéologie du vin et de l'huile dans L'Empire Romain [Archaeology of wine and oil during the Roman Empire]*. Paris: Errance.

Brun, J.-P. (2017) *Le vin et l'huile dans la Méditerranée antique. Viticulture, oléiculture et procédés de fabrication [Wine and oil in the ancient Mediterranean. Viticulture, olive growing and manufacturing processes]* Paris: Errance.

Brunner, B. (2021) *Taming Fruit: How Orchards Have Transformed the Land, Offered Sanctuary and Inspired Creativity*. Greystone Books Ltd.

Bruyère, B. (1879–1971) (1937) *Rapport sur les Fouilles de Deir etl Medineh – La Nécropole de*

l'Est [Reports on the digs of Deir el Medina –Necropolis of the east]. Paris: Institut Français d'Archéologie Orientale.

Brønsted, J. (1928) 'La basilique des cinq martyrs de Kapljuc [The Basilica of the Five Martyrs in Kljuc]', in Dyggve, E. and Brønsted, J. (eds) *Recherches de Salone*. Copenhagen: J.H. Schultz Imprimerie de l'Université, pp. 33–176.

Bull, R. *et al.* (1965) 'The Fifth Campaign at Balatah (Schechem)', *Bulletin of the American Schools of Oriental Research*, 180, pp. 7–41.

Bunimovitz, S. and Lederman, Z. (2008) 'A Border Case: Beth–Shemesh and the Rise of Ancient Israel', in Grabbe, L. (ed.) *From Late Bronze Age II to Iron IIA (c.1250–850 BCE): The Archaeology*. London: Bloomsbury Publishing, pp. 21–31.

Bunimovitz, S. and Lederman, Z. (2011) 'Canaanite Resistance: The Philistines and Beth–Shemes: A Case Study from Iron Age I', *Bulletin of the American Schools of Oriental Research*, 334, pp. 37–51.

Burney, C. (1973) 'Excavations at Haftavān Tepe 1971: Third Preliminary Report', *Iran*, 11, p. 153.

Burney, C. A. (1957) 'Uartian Fortresses and Towns in the Van Region', *Anatolian Studies*, 7, pp. 37–53.

Burton, P. and Lewit, T. (2019) 'Pliny's Presses: the True Story of the First Century Wine Press', *Klio*, 101(2), pp. 543–598.

Butzke, C. E., Vogt, E. E. and Chacón–Rodríguez, L. (2012) 'Effects of heat exposure on wine quality during transport and storage', *Journal of Wine Research*, 23(1), pp. 15–25.

Byeon, S.–E. and Lee, J. (2020) 'Differential responses of fruit quality and major targeted metabolites in three different cultivars of cold–stored figs (*Ficus carica* L.)', *Scientia Horticulturae*, 260, p. 108877.

Cadogan, G. (1986) *Maroni II*. Government Report. Report of the Department of Antiquities Cyprus, pp. 40–44.

Cahill, N. (2001) *Household and City Organization at Olynthus*. New Haven: Yale University Press.

Callot, O. (1987) 'Les huileries du Bronze Récent à Ougarit premiers éléments pour une étude [The oileries of the Bronze Age at Ugarit: First study elements]', in *Le Centre de la Ville Ras Shamra Ougarit III, 33e 44e Campagnes (1978–1984)*. Paris: Editions Recherche sur les Civilisations, pp. 197–212.

Camposeo, S., Vivaldi, G. A. and Gattullo, C. E. (2013) 'Ripening indices and harvesting times of different olive cultivars for continuous harvest', *Scientia Horticulturae*, 151, pp. 1–10.

Camps–Fabrer, H. (1953) *L'olivier et l'huile dans l'Afrique Romaine [Olive and olive in Roman Africa]*. Alger: Imprimerie Officielle.

- Cappers, R., van Thuyne, T. and Sikking, L. (2004) 'Plant remains from Predynastic el Abadiya 2 (Naqada area, Upper Egypt)', in Hendrickx, S. (ed.) *Egypt at Its Origins: Studies in Memory of Barbara Adams : Proceedings of the International Conference 'Origin of the State, Predynastic and Early Dynastic Egypt,' Krakow, 28 August – 1st September 2002*. Leuven: Peeters Publishers.
- Cappers, R. T. J. (2007) *Fields of Change: Progress in African Archaeobotany*. Groningen: Barkhuis Publishing and Groningen University Library.
- Carpenter, J. (1981) 'Excavations at Phaneromeni, 1975–1978', in Biers J. C. and D. Soren (eds.) *Studies in Cypriote Archaeology*. Los Angeles: University of California, pp. 59–78.
- Carr, M. K. V. (2013a) 'The Water Relations and Irrigation Requirements of Olive (*Olea europaea* L.): A review', *Experimental Agriculture*, 49(4), pp. 597–639.
- Carr, M. K. V. (2013b) 'The Water Relations and Irrigation Requirements of the Date Palm (*Phoenix dactylifera*): A Review', *Experimental Agriculture*, 49(1), pp. 91–113.
- Carrington Smith, J. (1994) 'A late Hellenistic wine press at Knossos', *American and British Studies Annual*, 89, pp. 359–376.
- Cartwright, C. R. (1993) 'The archaeobotanical remains from Tell es-Sa'idiyeh, Jordan', *Palestine Exploration Quarterly*, 125, pp. 73–74.
- Cartwright, C. R. (1994) 'The archaeobotanical remains from the 1993 season', *Palestine Exploration Quarterly*, 126, pp. 66–67.
- Cartwright, C.R. (1996) 'Preliminary report on the archaeobotanical material from the 1995 season on excavations at Tel es-Sadiyeh, Jordan', *Palestine Exploration Quarterly*, 129, pp. 73–75.
- Cartwright, C. R. (2002) 'Grape and grain: Dietary evidence from an Early Bronze Age store at Tell es-Sa'idiyeh, Jordan', *Palestine Exploration Quarterly*, 134(2), pp. 98–117.
- Carver, M. (2009) *Archaeological Investigation*. 1st edn. London: Routledge.
- Casanova, A. (1966) 'Technologie et communautés rurales : Notes sur les presses préindustrielles de Corse [Technology and rural communities: Notes on the pre-industrial presses of Corsica]', *Corse historique*, 21–22, pp. 37–61.
- Casanova, A. (1968) 'Typologie et diffusion des pressoirs preindustriels dans les communautés rurales de Corse [Typology and diffusion of pre-industrial presses in rural communities of Corsica]', *Corse historique*, 31–32, pp. 39–56.
- Casanova, A. (1990) *Paysans et machines à la fin du XVIIIe siècle: essai d'ethnologie historique [Peasants and machines at the end of the 18th century: historical ethnology essay]*. Paris: Les Belles Lettres.
- Casini, L. et al (2023) 'A human–AI collaboration workflow for archaeological sites detection', *Scientific Reports*, 12, 8699.

Cato (1979) 'Marcus Porcius Cato: De Agri Cultura', in Hooper, W. D. (ed.) *Cato and Varro*. London: Loeb, pp. 2–157.

Cejudo–Bastante, M. J. *et al.* (2013) 'Study of the volatile composition and sensory characteristics of new Sherry vinegar–derived products by maceration with fruits', *LWT – Food Science and Technology*, 50(2), pp. 469–479.

Cerdà, A. *et al.* (2020) 'Tillage Versus No–Tillage. Soil Properties and Hydrology in an Organic Persimmon Farm in Eastern Iberian Peninsula', *Water*, 12(6), 1539.

Chambon, G. (2018) 'Archaeology of Oenology: Drinking Wine at the Royal Table in Mari', *Die Welt des Orients*, 48(2), pp. 238–248.

Chandra, R. *et al.* (2010) 'Origin, history and domestication of pomegranate', *Fruit, Vegetable and Cereal Science and Biotechnology*, 2, pp. 1–6.

Chaniotis, A. and Hadjisavvas, S. (2012) 'Wine and olive oil in Crete and Cyprus: socio–economic aspects', *British School at Athens Studies*, 20, pp. 157–173.

Chao, C. T. and Krueger, R. R. (2007) 'The date palm (*Phoenix dactylifera* L.): overview of biology, uses and cultivation', *HortScience*, 42(5), pp. 1077–1082.

Chapman, E. A. *et al.* (2022) 'Perennials as Future Grain Crops: Opportunities and Challenges', *Frontiers in Plant Science*, 13, pp. 1–18.

Charles, M. and Bogaard, A (2001) 'Third–millennium BC charred plant remains from Tell Brak', in Oates, A., Oates, J. and McDonald, H. (eds.) *Excavations at Tell Brak. Nagar in the third millennium BC*, British School of Archaeology in Iraq, 2, pp. 301 – 326.

Chaudhary, B. R., Erskine, W. and Acciaioli, G. (2022) 'Hybrid knowledge and climate–resilient agriculture practices of the Tharu in the western Tarai, Nepal', *Frontiers in Political Science*, 4, pp. 1–19.

Chen, W.–K. *et al.* (2018) 'Influences of Berry Size on Fruit Composition and Wine Quality of *Vitis vinifera* L. cv. "Cabernet Sauvignon" Grapes', *South African Journal of Enology and Viticulture*, 39(1), pp. 67–76.

Chernoff, M. C. (1988). *The archaeobotanical material from Tel el Ifshar, Israel: a diachronic study of agricultural strategies during the third and second millennia B.C.E.* Brandeis: Brandeis University Press.

Chernoff, M. C. and Paley, S. M. (1998) 'Dynamics of Cereal Production at Tell el Ifshar, Israel during the Middle Bronze Age', *Journal of Field Archaeology*, 25(4), pp. 397–416.

Cheung, C. (2021) 'Managing food storage in the Roman Empire', *Quaternary International*, 597, pp. 63–75.

Cheynier, V. *et al.* (2006) 'Structure and Properties of Wine Pigments and Tannins', *American Journal of Enology and Viticulture*, 57(3), pp. 298–305.

Chiraz, M.–C. (2013) 'Growth of Young Olive Trees: Water Requirements in Relation to Canopy

- and Root Development', *American Journal of Plant Sciences*, 04(07), pp. 1316–1344.
- Chithiraichelvan, R. *et al.* (2017) 'Performance of Fig (*Ficus carica* L.) Under Different Planting Densities', *International Journal of Current Microbiology and Applied Sciences*, 6(6), pp. 2603–2610.
- Chong, S. T. (1992) 'Vegetative Propagation of Mangostee (*Garcinia Mangostana* L.)', *Acta Horticulturae*, (292), pp. 73–80.
- Christensen, L. P. and Peacock, W. L. (2013) 'The Raisin Drying Process', in *Raisin Production Manual*. Davis: University of California Press, pp. 207–216.
- Çifçi, A. (2014) *Interpretations of the socio-economic structure of the Urartian Kingdom*. Doctoral Thesis, Liverpool: University of Liverpool Press.
- Çifçi, A. (2017) *The Socio-Economic Organisation of the Urartian Kingdom*. Leiden: BRILL.
- Çifçi, A. and Greaves, A. (2013) 'Urartian Irrigation Systems', *Ancient Near Eastern Studies*, (0), pp. 191–214.
- Çilingiroğlu, A. (2012) 'Ayanis: An Iron Age Site in the East', in McMahon, G. and Steadman, S. (eds.) *The Oxford Handbook of Ancient Anatolia*. Oxford: Oxford University Press.
- Cimadomo, P. (2019) *The Southern Levant during the first centuries of Roman rule (64 BCE–135 CE)*. Oxford: Oxbow Books.
- Clark, J. K. *et al.* (2021) 'A contemporary concept of the value(s)-added food and agriculture sector and rural development', *Community Development*, 52(2), pp. 186–204.
- Claus, H. and Mojsov, K. (2018) 'Enzymes for Wine Fermentation: Current and Prospective Applications', *Fermentation*, 4(3), pp. 1–19.
- Cline, E. H. (ed.) (2012) *The Oxford Handbook of the Bronze Age Aegean*. 1st edn. Oxford: Oxford University Press.
- Cls, J. Z. (2011) *Mechanical Engineering Formulas and Review Manual*.
- Colledge, S., (2003). 'The charred plant remains in three of the pits 'in Peltenburg, E.J.(ed.) *The Colonisation and Settlement of Cyprus: Investigations at Kissonerga Mylouthkia, 1976–1996*. Sävöden: Paul Åströms Förlag, 239–245.
- Colledge, S., Conolly, J. and Shennan, S. (2004) 'Archaeobotanical Evidence for the Spread of Farming in the Eastern Mediterranean', *Current Anthropology*, 45(S4), pp. S35–S58.
- Colledge, S. (1994) *Plant exploitation on Epipalaeolithic and early Neolithic sites in the Levant*. Sheffield: University of Sheffield.
- Colledge, S. (2001). *Plant exploitation on Epipalaeolithic and Early Neolithic sites in the Levant*. Oxford: BAR, International Series.
- Colledge, S. and Conolly, J. (2014) 'Wild plant use in European Neolithic subsistence

economies: a formal assessment of preservation bias in archaeobotanical assemblages and the implications for understanding changes in plant diet breadth', *Quaternary Science Reviews*, 101, pp. 193–206.

Columella (1969) *Columella, Lucius Junius Moderatus: De Re Rustica* (3 vol). Translated by Ash, H.B., Forster, E.S. and Heffner. London: Loeb.

Compton, S. G. *et al.* (2020) 'First confirmed records of fig wasps (Hymenoptera: Chalcidoidea) associated with the Sycamore Fig *Ficus sycomorus* on a Mediterranean Island', *Entomologist's Gazette*, 71(2), pp. 121–124.

Conyers, L. (ed.) (2023) *Ground–Penetrating Radar for Archaeology*. Fourth Edition. Lanham: Rowman and Littlefield.

Conyers, L. B. and Leckebusch, J. (2010) 'Geophysical Archaeology Research Agendas for the Future: Some Ground-penetrating Radar Examples', *Archaeological Prospection*, 17(2), pp. 117–123.

Cook, R. J. (2011) *Landscapes of Irrigation in the Ptolemaic and Roman Fayum: Interdisciplinary Archaeological Survey and Excavation Near Kom Aushim (Ancient Karanis), Egypt*. Doctors Thesis, Ann Arbor: University of Michigan Press.

Coombe, B. (1995) 'Growth Stages of the Grapevine: Adoption of a system for identifying grapevine growth stages', *Australian Journal of Grape and Wine Research*, 1(2), pp. 104–110.

Coombe, B. and McCarthy, M. g. (2000) 'Dynamics of grape berry growth and physiology of ripening', *Australian Journal of Grape and Wine Research*, 6(2), pp. 131–135.

Corsetti, A. *et al.* (2012) 'Application of starter cultures to table olive fermentation: an overview on the experimental studies', *Frontiers in Microbiology*, 3, pp. 248.

Corti, C. (2018) 'Viticulture and Wine in Hittite Anatolia and Its Ancient Near Eastern Context: A Brief Introduction', *Die Welt des Orients*, 48(2), pp. 202–208.

Costantini, L. and Costantini–Biasini, L. (1985) 'Agriculture in Baluchistan between the 7th and the 3rd millennium BC', *Newsletter of Baluchistan Studies*, 2, pp. 16 – 30.

Coupaye, L. (2022) 'Making “Technology” Visible: Technical Activities and the Chaîne Opératoire', in Bruun, M. H. *et al.* (eds) *The Palgrave Handbook of the Anthropology of Technology*. Singapore: Springer Nature, pp. 37–60.

Coupry, M. J. (1959) 'Circonscription de Bourdeaux [Constituency of Bourdeaux]', *Gallia*, 17, pp. 377–409.

Courtois, J. C. (1962) 'Contribution à l'étude des civilisations du Bronze ancien à Ras Shamra–Ugarit [Contributions to the study of Bronze Age civilizations Ras Shamra Ugarit]', in Schaeffer, C. F. A. (ed.) *Ugaritica*. Paris: P.Geuthner, pp. 415–75.

- Crawford, P. (1987) 'Food for a Roman legion: the plant remains from el-Lejjun', in Parker, S.T. (ed.) *The Roman frontier in Central Jordan: Interim report on the Limes Arabicus Project, 1980–1985*. Oxford: BAR International Series, 340, pp. 691–704.
- Crawford, P. (1999). 'Botanical remains' in Stone, C.E. and Zimansky, P.E. (eds.) *The Iron Age settlement at 'Ain Dara, Syria. Survey and soundings*. Oxford: BAR International Series, 786, pp. 113 – 121.
- Cresswell, R. (1965) 'Un pressoir à olives au Liban: Essai de technologie comparé [An olive press in Lebanon: Comparative technology test]', in *Revue Française d'Anthropologie*, 5, pp. 33–63.
- Crisosto, H. *et al.* (2011) 'Fig (*Ficus carica* L.)', in Yahia, E. (ed.) *Postharvest Biology and Technology of Tropical and Subtropical Fruits*. Amsterdam: Elsevier, pp. 134–160.
- Cullen, L. M. and Cullen, L. (2002) *The Brandy Trade Under the Ancien Régime: Regional Specialisation in the Charente*. Cambridge University Press.
- Dabbou, Samia *et al.* (2011) 'Comparison of the Chemical Composition and the Organoleptic Profile of Virgin Olive Oil from Two Wild and Two Cultivated Tunisian *Olea europaea*', *Chemistry and Biodiversity*, 8(1), pp. 189–202.
- Dadelinyan (2020). Face-to-face conversation, 11 February 2020.
- Dallakyan, M. *et al.* (2020) 'Genetic diversity and traditional uses of aboriginal grape (*Vitis vinifera* L.) varieties from the main viticultural regions of Armenia', *Genetic Resources and Crop Evolution*, 67(4), pp. 999–1024.
- Dalman, G. (1908) 'Die Schalensteine Palästinas in ihrer Beziehung zu alter Kultur und Religion [The shell stones of Palestine in their relationship to ancient culture and religion]', *Palästina Jahrbuch*, 4, pp. 25–53.
- Dalman, G. (1928) *Arbeit und Site in Palästina* (7 vol). Gutersloh Bertelman.
- Damick, A. (2019) 'The first identification of *Phoenix dactylifera* (date palm) from Early Bronze Age Lebanon', *Vegetation History and Archaeobotany*, 28(5), pp. 583–589.
- Damick, A. and Woodworth, M. (2015) 'Steatite beads from Tell Fadous–Kfarabida: A case study in early Bronze Age technology in Northern Coastal Lebanon', *Journal of Archaeological Science: Reports*, 3, pp. 603–614.
- Dan, R., Petrosyan, A. and Aghaian, S. (2022) 'Recent investigations of rock-cut structures in Armenia', in *Armenia Maritima: Archaeological Heritage of the Land Uduri–Etiuni*. Los Angeles: University of California Press, pp. 316–337.
- Danielyan, D. H., Manasyan, H. D. and Papovyan, H. M. (392AD) Գինեգործության հիմունքներ [*The Basics of Winemaking*]. Yerevan: Hayastan Publishing House.
- Daryae, T. (2018) 'The Fall of Urartu and the Rise of Armenia', *UCI Center for Persian Studies*, pp. 38–44.

- Das, B. and Sarin, L. (1936) 'Vinegar from Dates', *Industrial and Engineering Chemistry*, 28(7), pp. 815–816.
- da Silva Simão, R. *et al.* (2020) 'Recent Advances in the Production of Fruit Leathers', *Food Engineering Reviews*, 12(1), pp. 68–82.
- Datuna (2020) Email correspondences, 11 June 2020.
- David, B. (2011) *Understanding Wine Technology, 3rd Edition: The Science of Wine Explained*. Board and Bench Publishing.
- Dawkins, R. M. (1902) 'Notes from Karpathos', *Annual of the British School at Athens*, 9, pp. 176–210.
- DeBolt, S., Cook, D. R. and Ford, C. M. (2006) 'l-Tartaric acid synthesis from vitamin C in higher plants', *Proceedings of the National Academy of Sciences*, 103(14), pp. 5608–5613.
- Decker, M. (2001) 'Food for an Empire: Wine and Oil Production in North Syria', in Decker, M. and Kingsley, S. (eds) *Economy and Exchange in the East Mediterranean during Late Antiquity*. Oxford: Oxbow Books, pp. 69–86.
- Deckers, K. *et al.* (2021) 'Intensive olive production at Levantine sites. New data from Fadous–Kfarabida and Khirbet–ez Zeraqon', *Journal of Archaeological Science: Reports*, 36, p. 102841.
- Del Fresno, J. M. *et al.* (2022) 'White must extraction methods', in Morata, A. (ed.) *White Wine Technology*. Amsterdam: Elsevier, pp. 39–47.
- de Moulins, D. (1997) *Agricultural Changes at Euphrates and Steppe Sites in the Mid–8th to the 6th Millennium B.C.* Oxford: BAR Publishing.
- Denham, T. *et al.* (2020) 'The domestication syndrome in vegetatively propagated field crops', *Annals of Botany*, 125(4), pp. 581–597.
- de Roller, G. (1989) 'The botanical remains', *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, 45, pp. 102 – 108.
- de Serres, O. (1803) *Le Théâtre d'Agriculture et Mesnage des Champs [The Theater d'Agriculture and Mesnage des Champs]*. 5th edn. Paris: Ches Abr. Saugrain.
- Devadoss, S. and Luckstead, J. (2010) 'An analysis of apple supply response', *International Journal of Production Economics*, 124(1), pp. 265–271.
- Diamante, L. M., Bai, X. and Busch, J. (2014) 'Fruit Leathers: Method of Preparation and Effect of Different Conditions on Qualities', *International Journal of Food Science*, 2014(1), p. 139890.
- Díaz, C. *et al.* (2013) 'Characterization of Selected Organic and Mineral Components of Qvevri Wines', *American Journal of Enology and Viticulture*, 64(4), pp. 532–537.
- Diez, C. M. *et al.* (2014) 'Olive domestication and diversification in the Mediterranean Basin',

New Phytologist, 206(1), pp. 436–447.

Dighton, A. *et al.* (2016) ‘Bronze Age olive domestication in the north Jordan valley: new morphological evidence for regional complexity in early arboricultural practice from Pella in Jordan’, *Vegetation History and Archaeobotany*, 26(4), pp. 403–413.

Dodd, E. (2020) *Roman and Late Antique Wine Production in the Eastern Mediterranean: A Comparative Archaeological Study at Antiochia ad Cragum (Turkey) and Delos (Greece)*. Oxford: Archaeopress Publishing Ltd.

Dodd, E. (2022) ‘The Archaeology of Wine Production in Roman and Pre-Roman Italy’, *American Journal of Archaeology*, 126(3), pp. 443–480.

Doijode, S. d (2012) *Seed Storage of Horticultural Crops*. Boca Raton: CRC Press.

Domarchi, J. (1954) ‘The Decline of the Ancient World: The Economic Evolution of the Hellenistic States’, *Diogenes*, 2(8), pp. 69–85.

Dong, Y. *et al.* (2023) ‘Dual domestications and origin of traits in grapevine evolution’, *Science*, 379(6635), pp. 892–901.

Dornemann, R. H. (1986) ‘A Neolithic Village at Tell El Kowm in the Syrian Desert’, *Studies in Ancient Oriental Civilization Year*, 2, pp. 245–264.

Dothan, T. and Gitin, S. (1987) ‘The Rise and Fall of Ekron of the Philistines: Recent Excavations at an Urban Border Site’, *The Biblical Archaeologist*, 50(4), pp. 197–222.

Drachman, A. G. (1932) *Ancient Oil Mills and Presses*. Copenhagen: Levin and Munksgaard.

Drieu, L. *et al.* (2020) ‘Is it possible to identify ancient wine production using biomolecular approaches?’, *STAR: Science & Technology of Archaeological Research*, 6(1), pp. 16–29.

Drori, E. *et al.* (2017) ‘Collection and characterization of grapevine genetic resources (*Vitis vinifera*) in the Holy Land, towards the renewal of ancient winemaking practices’, *Scientific Reports*, 7(1), pp. 1–10.

Dudensing, R. (2023) ‘Role of Value-Added Agriculture in Promoting Regenerative Processes within a Circular Economy’, in Norton, A., Scheff, D. and Gilbertson, L. M. (eds) *ACS Symposium Series*. Washington: American Chemical Society, pp. 1–10.

Dunseth, Z. (2013) *Subsistence Practices in the Negev Highlands during the Intermediate Bronze Age: A Microarchaeological Investigation at Mashabe Sade*. MA thesis. Tel Aviv: Tel Aviv University.

Du Plat Taylor, J. (1957) *Myrtou Pigadhes*. Oxford: Ashmolean Museum.

D’Alembert, J. and Diderot, D. (1762) *Agriculture et économie rustique. Recueil de Planches sur les Sciences, les Arts Libéraux, et les Arts Mécaniques, avec leur explication [Agriculture and rustic economy. Collection of Plates on the Sciences, the Liberal Arts and the Mechanical Arts, with their explanation]*. Paris.

- Earley–Spadon, T. (2023) ‘Urartu: A Unique Case of Empire – American Research Institute of the South Caucasus’. American Research Institute of the South Caucasus.
- Edens, C. (1995) ‘Transcaucasia at the End of the Early Bronze Age’, *Bulletin of the American Schools of Oriental Research*, 299–300, pp. 53–64.
- Eichhorn, B. *et al.* (2005) ‘Desert roads and transport vessels from Late Roman–Coptic times in the Eastern Sahara’, *Journal of African Archaeology*, 3(2), pp. 213–229.
- Eisen, G. A. (1901) *The Fig: Its History, Culture and Curing: With a Descriptive Catalogue of the Known Varieties of Figs*. U.S: Government Printing Office.
- Eitam, D., Lederman, Z. and Kleiman, A. (2024) ‘Qla’: A Royal Oil– and Wine–Production Centre in the Kingdom of Israel’, *Tel Aviv*, 51(1), pp. 18–49.
- Eitam, D. (1979) ‘Olive Presses of the Israelite Period’, *Tel Aviv*, 6(3–4), pp. 146–155.
- Eitam, D. (1996) ‘The Olive Oil Industry at Tel Mique–Ekron in the Late Iron Age’, in *Oil and Wine Production in the Mediterranean Area from the Bronze Age to the end of the XVIth Century*. Toulon: Caisse d’Epargne de Toulon, pp. 167–195.
- Eitam, D. *et al.* (2015) ‘Experimental Barley Flour Production in 12,500–Year–Old Rock–Cut Mortars in Southwestern Asia’, *PLOS ONE*, 10(7), pp. 1–10.
- Ekue, M. R. *et al.* (2010) ‘Uses, traditional management, perception of variation and preferences in ackee (*Blighia sapida* K.D. Koenig) fruit traits in Benin: implications for domestication and conservation’, *Journal of Ethnobiology and Ethnomedicine*, 6(1), p. 12.
- El Hadidi, M. N. and Fahmy, A. (1996) ‘The palaeoethnobotany of locality 11C, Hierakonpolis (3800 – 3500 BC); Egypt. 1. Cultivated crops and wild plants of potential value’, *Taeckholmia*, 16, pp. 45 – 60.
- Elihu, G. and Wright, G. E. (1931) *Ain Shems excavations (Palestine)*. Haverford : Haverford College.
- Engel, T. (1993) ‘Charcoal remains from an Iron Age copper smelting slag heap at Feinan, Wadi Arabah (Jordan)’, *Vegetation History and Archaeobotany*, 2, pp. 205 – 211.
- Engel, T. (1995) ‘Holzkohlen aus dem Vorderen Orient: Jahrtausendealte Reste einstiger Wälder’, *Das Altertum*, 40, pp. 311 – 320.
- Engelmark, R. and Wennberg, B.(1985). *Palaeobotanical investigations at Hala Sultan Tekke in Cyprus. In honorem Evert Baudou*. Umeå: University of Umeå, 4, pp. 277 – 282.
- Epstein, B. S. (2014) *Brandy: A Global History*. London: Reaktion Books.
- Epstein, B. S. (2014) *Brandy: A Global History*. Reaktion Books.
- Epstein, C. (1993) ‘Oil Production in the Golan Heights During the Chalcolithic Period’, *Tel Aviv*, 20(2), pp. 133–146.

- Eren, G. (2010) *An application of depth analysis on Middle Bronze Age palaces at Acemhöyük, Tell Mardikh and Kültepe*. Doctoral thesis. Ankara: Middle East Technical University.
- Ernst, M. and Woods, T. (2011) *Adding Value to Plant Production—An Overview*. College of Agriculture: University of Kentucky.
- Esmaili, M. *et al.* (2007) ‘Grape Drying: A Review’, *Food Reviews International*, 23(3), pp. 257–280.
- Essid, M. Y. (2012) ‘History of Mediterranean Food’, in *MediTERRA: The Mediterranean Diet for Sustainable Regional Development*. Paris: Presses de Sciences Po, pp. 51–69.
- Facorellis, Y., Damiata, B.N., Vardala–Theodorou, E., Ntinou, M., Southon, J. and Trantalidou K. (2015) ‘Radiocarbon dating of Palamari on Skyros and estimation of the marine reservoir effect at the northern Sporades region during the Bronze Age’, in Parlama, L., Theochari, M., Romanou, C. and Bonatsos, S. (eds.) *The fortified settlement at Palamari, Skyros*. Athens: Ministry of Culture, pp 257–272.
- Facorellis, Y., Damiata, B.N., Vardala–Theodorou, E., Ntinou, M. and Southon, J. (2017) ‘Calculation of the regional marine reservoir effect (ca. 8th–1st century BC) based on samples from the Vryokastro site on Kythnos’, in Mazarakis–Ainian, A. (ed.) *Les sanctuaires archaïques des Cyclades*. Rennes: Universitaires de Rennes, pp 275–285.
- Fahmy, A. G., Friedmann, R. F. and Fadl, M. (2008). ‘Archaeobotanical Studies at Hierakonpolis Locality HK6: The Pre and Early Dynastic Elite Cemetery’, *Archéo–Nil*, 18, pp. 169–183.
- Fairbairn, A., Langford, C. and Griffin, B. (2002) ‘Archaeobotany at Kaman–Kalehöyük 2003’, *Anatolian Archaeological Studies*, 11, pp. 201–212.
- Fairbairn, A., Near, J. and Martinoli, M. (2005) ‘Macrobotanical Investigation of the North, South and KOPAL Area Excavations at Çatalhöyük East’, in Hodder, I (ed.) *Inhabiting Catalhöyük. Reports from the 1995–99 seasons*. Cambridge: McDonald Institute for Archaeological Research, pp. 137–201.
- Fairbairn, A. (2004). ‘Archaeobotany at Kaman–Kalehöyük 2003’, in Omura, S. (ed.) *Kaman–Kalehöyük*. Tokyo: Japanese Institute of Anatolian Archaeology, 13, pp. 108–120.
- Fairbairn, A. *et al.* (2002) ‘Macro–botanical evidence for plant use at Neolithic Çatalhöyük south–central Anatolia, Turkey’, *Vegetation History and Archaeobotany*, 11(1–2), pp. 41–54.
- Fairley, T. (1905) ‘Notes on the History of Distilled Spirits, Especially Whisky and Brandy’, *Analyst*, 30(354), pp. 293–306.
- Fakhry, A. A. (1974) ‘Geochemical studies at the fawakhir gold mine, eastern desert, egypt, 2. infrared absorption spectroscopy as a means of characterising the primary d dispersion haloes of gold deposits’, *Journal of Geochemical Exploration*, 3(3), pp. 265–275.
- Falconer, S. E. and Redman, C. L. (eds) (2022) *Polities and Power: Archaeological Perspectives on the Landscapes of Early States*. Tucson: University of Arizona Press.

- Fall, P. L., Falconer, S. E. and Lines, L. (2002) 'Agricultural Intensification and the Secondary Products Revolution Along the Jordan Rift', *Human Ecology*, 30(4), pp. 445–482.
- Fall, P.L. and Metzger, M.C. (2006) 'Economy and Subsistence at Tell el-Hayyat', in Falconer, S.V. and Fall, P.L. (eds.) *Bronze Age Rural Ecology and Village Life at Tell el-Hayyat, Jordan*. Oxford: BAR Publishing International Series 1586.
- Famiani, F. *et al.* (2020) 'Harvesting system and fruit storage affect basic quality parameters and phenolic and volatile compounds of oils from intensive and super-intensive olive orchards', *Scientia Horticulturae*, 263, p. 109045.
- Fangohr, H. (2004) 'A Comparison of C, MATLAB and Python as Teaching Languages in Engineering', in Bubak, M. *et al.* (eds) *Computational Science – ICCS 2004*. Berlin, Heidelberg: Springer, pp. 1210–1217.
- Fantalkin, A. (2004) 'The Final Destruction of Beth Shemesh and the *Pax Assyriaca* in the Judahite Shephelah: An Alternative View', *Tel Aviv*, 31(2), pp. 245–261.
- Farahani, A. *et al.* (2016) 'Paleoethnobotany at Early Iron Age Khirbat al-Mudayana al-'Aliya (KMA)', in McGeough, K. (ed.) *The Archaeology of Agro-Pastoralist Economies in Jordan*. Boston: American Schools of Oriental Research.
- Farrington, I. S. (1980) 'The archaeology of irrigation canals, with special reference to Peru', *World Archaeology*, 11(3), pp. 287–305.
- Faust, A. (2011) 'The Interests of the Assyrian Empire in the West: Olive Oil Production as a Test-Case', *Journal of the Economic and Social History of the Orient*, 54(1), pp. 62–86.
- Feinman, G. M. (2008) 'Economic Archaeology', in Pearsall, D. (ed.) *Encyclopedia of Archaeology*. New York: Academic Press, pp. 1114–1120.
- Feldman, C. (2005) 'Roman Taste', *Food, Culture and Society*, 8(1), pp. 7–30.
- Fendri, I. *et al.* (2013) 'Olive fermentation brine: biotechnological potentialities and valorization', *Environmental Technology*, 34(2), pp. 181–193.
- Fernandez, A. G., Adams, M. R. and Fernandez-Diez, M. J. (1997) *Table Olives: Production and processing*. Springer Science & Business Media.
- Ferrio, J. P. *et al.* (2012) 'Agricultural expansion and settlement economy in Tell Halula (Mid-Euphrates valley): A diachronic study from early Neolithic to present', *Journal of Arid Environments*, 86, pp. 104–112.
- Figueiral, I. *et al.* (2013) 'Bioarchaeological insights into the process of domestication of grapevine (*Vitis vinifera* L.) during Roman times in Southern France.', *Plos One*, 5(8), p.e63195.
- Figuier, L. (1877) *Les merveilles de l'industrie IV [The wonders of industry IV]*. Paris: Furne Jouvett (Industries agricoles et alimentaires).
- Finkelstein, I. and Langgut, D. (2018) 'Climate, Settlement History and Olive Cultivation in the Iron Age Southern Levant', *Bulletin of the American Schools of Oriental Research*, 379, pp.

153–169.

Fischer, P. M. and Holden, T. (2008). 'Climate, Fauna and Flora: A Synopsis', in Fischer, P. (ed.). *Tell Abu al-Kharaz in the Jordan Valley. Volume I: The Early Bronze Age*. Vienna: OAW, pp. 307–322.

Forbes, H. A. and Foxhall, L. (1978) 'The Queen of All Trees', *Expedition*, 21(1), pp. 37–47.

Forbes, R. J. (1971) *Studies in Ancient Technology, Volume 3*. Leiden: BRILL.

Foxhall, L. (1993) 'Oil extraction and processing equipment in classical Greece.' in, Amouretti, M.C. and Brun, J.P (eds.) *La Production du vin et de l'huile en Méditerranée*. Paris: Université de Provence, pp. 183–199.

Foxhall, L. (2007) *Olive Cultivation in Ancient Greece: Seeking the Ancient Economy*. Oxford: Oxford University Press.

Frangipane, A. (2016) 'From spolia to recycling: the reuse of traditional construction materials in built heritage and its role in sustainability today: a review', *Geological Society, London, Special Publications*, 416(1), pp. 23–33.

Frankel, R. (1999) *Wine and Oil Production in Antiquity in Israel and Other Mediterranean Countries*. Sheffield: Sheffield Academic Press.

Frankel, R. (2016) 'Oil and Wine Production', in *A Companion to Science, Technology and Medicine in Ancient Greece and Rome*. Hoboken: John Wiley and Sons, Ltd, pp. 550–569.

Frankel, R. (2017) 'The Winepress at Montfort', in Boas, A. and Khamisy, R.G (eds) *Monfront: History, Early Research and Recent Studies of the Principal Fortress of the Teutonic Order*. The Medieval Mediterranean 7: Leiden: BRILL.

Fraser, J. (2018) 'Khirbet Um al-Ghozlan', *Archaeology in Jordan Newsletter: 2016 and 2017 Seasons*, pp. 27–28.

French, B. C. and Matthews, J. L. (1971) 'A Supply Response Model for Perennial Crops', *American Journal of Agricultural Economics*, 53(3), pp. 478–490.

French, D. H. and Summers, G. D. (1994) 'Pre-Urartian and Urartian Pottery from the Muş Region', *Anatolian Studies*, 44, pp. 77–84.

Frey, W. and Jagiella, C. (1991) 'Holzkohlefunde in Dur-Katlimmu/Tall Šeh Hamad [Charcoal finds in Dur-Katlimmu/Tall Šeh Hamad', in Kühne, H. (ed.) *Die rezente Umwelt von Tall Šeh Hamad und Daten zur Umweltrekonstruktion der Assyrischen Stadt Dur-Katlimmu*. Berlin: Dietrich Reimer, pp. 137–161.

Fritz, V. (1987) 'Conquest or Settlement? The Early Iron Age in Palestine', *The Biblical Archaeologist*, 50(2), pp. 84–100.

Fuks, D., Avni, G. and Bar-Oz, G. (2021) 'The Debate on Negev Viticulture and Gaza Wine in Late Antiquity', *Tel Aviv*, 48(2), pp. 143–170.

- Fuks, D. (2023) 'Orphan crops of archaeology based crop history research', *Plants People Planet*, pp. 1–20.
- Fuller, D. (2003) 'Further evidence on the prehistory of sesame', *Asian Agri–History*, 7, pp. 127–137.
- Fuller, D. (2018) 'Long and attenuated: comparative trends in the domestication of tree fruits', *Vegetation History and Archaeobotany*, 27(1), pp. 165–176.
- Fuller, D. and Pelling, R. (2018) 'Plant Economy: Archaeobotanical Studies', in Fentress, E. and Limane, H. (eds.) *Volubilis après Rome*. Leiden: BRILL, pp. 349–368.
- Fuller, D. and Stevens, C. J. (2019) 'Between domestication and civilization: the role of agriculture and arboriculture in the emergence of the first urban societies', *Vegetation History and Archaeobotany*, 28(3), pp. 263–282.
- Fuller, D.Q. and Lucas, L. (2020) 'Archaeobotany', in *Encyclopedia of global archaeology* (pp. 475–480). Cham: Springer International Publishing.
- Fuller, D. Q., Denham, T. and Allaby, R. (2023) 'Plant domestication and agricultural ecologies', *Current Biology*, 33 (11), pp. 36–49.
- Gačnik, A. (2014) 'Slovenian wine stories and wine identities: From the heritage and culture of wine to wine tourism' in, Harvey, M., White, L. and Frost, W. (eds.) *Wine and Identity: Branding, Heritage, Terroir*. London: Routledge.
- Gadot, Y. (2010) 'The Late Bronze Egyptian Estate at Aphek', *Tel Aviv*, 37(1), pp. 48–66.
- Gadrat, M. *et al.* (2022) 'Sensory characterisation of Cognac eaux–de–vie aged in barrels subjected to different toasting processes', *OENO One*, 56(1), pp. 17–28.
- Gal, Z. (1985) 'Vineyard Cultivation at Emek Harod and its Vicinity 1986 during the Roman Byzantine Period', *Israel: People and Land*, 2(3), pp. 129–138.
- Gal, Z. and Frankel, R. (1993) 'An olive oil press complex at Hurbat Rōš Zayit (Rās ez–Zētūn) in Lower Galilee', *Zeitschrift Des Deutschen Palastina–vereins*, 109, pp. 128–140.
- Galebedian (2020). Face–to–face communication in Armenia.
- Galil, J. (1968) 'An Ancient Technique for Ripening Sycomore Fruit in East–Mediterranean Countries', *Economic Botany*, 22(2), pp. 178–190.
- Galil, J. and Eisikowitch, D. (1968) 'On the Pollination Ecology of Ficus Sycomorus in East Africa', *Ecology*, 49(2), pp. 259–269.
- Galili, E., Rosen, B. and Boaretto, E. (2007) 'Haifa, Kfar Samir', *Hadashot Arkheologiyot Excavations and Surveys in Israel*, 119.
- Galili, E. *et al.* (1997) 'Evidence for Earliest Olive–Oil Production in Submerged Settlements off the Carmel Coast, Israel', *Journal of Archaeological Science*, 24(12), pp. 1141–1150.

- Gallimore, S. (2013). Face-to-face communication.
- Galvez, M. C., Barroso, C. G. and Perez-Bustamante, J. A. (1994) 'Analysis of polyphenolic compounds of different vinegar samples', *Zeitschrift für Lebensmittel-Untersuchung und -Forschung*, 199(1), pp. 29–31.
- García, J. C. M. (2022) 'Trade, Statehood and Configurations of Power in Ancient Egypt (Early–Middle Bronze Age)', in *Ancient Egyptian Society*. London: Routledge.
- García-Granero, J. J. *et al.* (2020) 'A Long-Term Assessment of the Use of *Phoenix theophrasti* Greuter (Cretan Date Palm): The Ethnobotany and Archaeobotany of a Neglected Palm', *Journal of Ethnobiology*, 40(1), pp. 101–114.
- Garebedian, M. (2017) Face-to-face conversation, 3 March 2017.
- Garebedian, P. (2020) Skype conversation, 24 January 2020.
- Garfinkel, Y. *et al.* (2009) *Sha'ar Hagolan*. Oxford: Oxbow Books.
- Gasparyan, B. *et al.* (2020) 'The Vayots Dzor Project (VDP): a preliminary overview of the first three years' activities (2016–2018)', *ARAMAZD: Armenian Journal of Near Eastern Studies*, pp. 143–184.
- Gasparyan, B. *et al.* (2021) 'An Urartian Grave in Aghavnadzor, Vayots Dzor, Armenia'. Center for Open Science.
- Gattiglia, G. (2025) 'Managing Artificial Intelligence in Archeology. An overview', *Journal of Cultural Heritage*, 71, pp. 225–233.
- Gaut, B. S., Díez, C. M. and Morrell, P. L. (2015) 'Genomics and the Contrasting Dynamics of Annual and Perennial Domestication', *Trends in Genetics*, 31(12), pp. 709–719.
- Gebregziabher, S. *et al.* (2006) 'Animal drawn tillage, the Ethiopian ard plough, maresha: A review', *Soil and Tillage Research*, 89(2), pp. 129–143.
- Genz, H. (2010) 'Recent Excavations at Tell Fadous–Kfarabida', *Near Eastern Archaeology*, 73(2–3), pp. 102–113.
- Genz, H. *et al.* (2016) 'Economic and Political Organization of Early Bronze Age Coastal Communities: Tell Fadous–Kfarabida as a Case Study', *Berytus*, 55, pp. 79–119.
- Gerber, H. J. (2010) *Tree training and managing complexity and yield in fig (Ficus carica L.)*. Stellenbosch: University of Stellenbosch.
- Gering, E. *et al.* (2019) 'Getting back to nature: feralization in animals and plants', *Trends in Ecology and Evolution*, 34 (12), pp. 1137–1151.
- Germer, R. (1989) *Die Pflanzenmaterialien aus dem Grab des Tutanchamun [The plant materials from Tutankhamun's tomb]*. Hildesheim: Gerstenberg.
- Ghazzawy, H. S., Sobaih, A. E. E. and Mansour, H. A. (2022) 'The Role of Micro-Irrigation

- Systems in Date Palm Production and Quality: Implications for Sustainable Investment', *Agriculture*, 12(12), pp. 1–13.
- Ghulyan, H. *et al.* (2023) *Between the Wars: A Satellite Investigation of the Treatment of Azerbaijani Cultural Heritage in the Unrecognized Republic of Nagorno–Karabakh, 1994–2020*.
- Giddy, L., Jeffreys, D and Málek, J. (1990) 'Memphis 1989', *Journal of Egyptian Archaeology*, 76, pp. 1–15.
- Giddy, L. and Jeffreys, D. (1993) 'Memphis 1992', *Journal of Egyptian Archaeology*, 79, pp. 113–147.
- Gilboa, A. and Yasur–Landau, A. (eds) (2020) *Nomads of the Mediterranean: Trade and Contact in the Bronze and Iron Ages: Studies in Honor of Michal Artzy*. Leiden: BRILL.
- Gimbutas, M. (1963) 'European Prehistory: Neolithic to the Iron Age', *Biennial Review of Anthropology*, 3, pp. 69–106.
- Giménez–Bastida, J. A. *et al.* (2021) 'Evidence for health properties of pomegranate juices and extracts beyond nutrition: A critical systematic review of human studies', *Trends in Food Science & Technology*, 114, pp. 410–423.
- Girma Gebresenbet, Aradom, S. and Kaumbutho, P. G. (2016) 'Performance and Welfare Status of Working Donkeys', *Journal of Agricultural Science and Technology A*, 6(2), pp. 108–115.
- Giudici, P., Vero, L. D. and Gullo, M. (2017) 'Vinegars', in Gullo, M. (ed) *Acetic Acid Bacteria*. CRC Press.
- Giudici, P. *et al.* (2009) 'Technological and Microbiological Aspects of Traditional Balsamic Vinegar and Their Influence on Quality and Sensorial Properties', *Advances in Food and Nutrition Research*, 58, pp. 137–182.
- Gökce, B., Çavuşoğlu, R. and Işık, K. (2014) 'The Craftsman and Manufacturers in the Urartian Civilization', *Anatolica*, 40, pp. 23–45.
- Gökce, B (2016) 'Urartu'da yemek kültürü [View of Food culture in Urartu]', *Journal of Human Sciences*, 13(2), pp. 2656–2667.
- Goldschmidt, E. E. (2013) 'The Evolution of Fruit Tree Productivity: A Review', *Economic Botany*, 67(1), pp. 51–62.
- Goldschmidt, E. E. and Lasko, A. N. (2005) 'Fruit tree models: scope and limitations', in Gelb, E. and Offer, A. (eds.) *Information and Communication Technology (ICT) Development and Adoption: Perspectives of Technological Innovation*. Jerusalem: Hebrew University, pp. 1–19.
- González Carretero, L., Wollstonecroft, M. and Fuller, D. Q. (2017) 'A methodological approach to the study of archaeological cereal meals: a case study at Çatalhöyük East (Turkey)', *Vegetation History and Archaeobotany*, 26(4), pp. 415–432.
- Gophna, R. and M. E. Kislev (1979). 'Tel Saf (1977–1978).' *Revue Biblique* 86: 112–114.

Gordillo, M. C. L. *et al.* (2023) ‘Use of Artificial Vision during the Lye Treatment of Sevillian–Style Green Olives to Determine the Optimal Time for Terminating the Cooking Process’, *Foods*, 12(14), p. 2815.

Goulder, J. (2015) ‘Invisible donkeys in ancient Mesopotamia: new insights from modern studies in sub-Saharan Africa’, in *Archaeozoology of the Near East XII Proceedings of the 12th International Symposium of the ICAZ Archaeozoology of Southwest Asia and Adjacent Areas Working Group*. Groningen: Barkhuis Publishing and University of Groningen, pp. 79–90.

Goulder, J. (2019) ‘Transport’, in *Working Donkeys in 4th–3rd Millennium BC Mesopotamia*. London: Routledge.

Grainger, K. and Tattersall, H. (2005) ‘The Harvest’, in *Wine Production: Vine To Bottle*, pp. 44–47.

Grant, E. and Wright, G. E. (1938) *Ain Shems Excavations (Palestine): Part IV (pottery)*. Haverford: Haverford College Press.

Greenberg, R. and Cinamon, G. (2006) ‘Stamped and Incised Jar Handles from Rogem Gannim and Their Implications for the Political Economy of Jerusalem, Late 8th–Early 4th Centuries BCE’, *Tel Aviv*, 33(2), pp. 229–243.

Gregor, H.J. (1992.) ‘Paläobotanische Untersuchungen zur antiken Pflanzenwelt des Hassek Höyük im Tal des oberen Euphrat und ein Versuch zur Rekonstruktion des dortigen Ökosystems für den Übergang von der späten Urukzeit zur frühen Bronzezeit [Paleobotanical studies of the ancient flora of Hassek Höyük in the valley of the upper Euphrates and an attempt to reconstruct the local ecosystem for the transition from the late Uruk period to the early Bronze Age’, in *Hassek Höyük. Naturwissenschaftliche Untersuchungen und lithische Industrie*. Istanbul: Istanbuler Forschungen, 38, pp.34–57.

Grekyan, Y. (2013) ‘When the Gods Leave People (The Climatological Hypothesis of the Collapse of the Urartian State)’, *Armenian Journal of Near Eastern Studies*, 8 (1–2), pp. 57–94.

Grekyan, Y. (2017) ‘The Settlement Size and Population Estimation of the Urartian Cities’, in Avetisyan, P.S. and Grekyan, Y.H (eds.) *Bridging Times and Spaces. Festschrift in Honour of Gregory Areshian on the Occasion of His Sixty-Fifth Birthday*. Oxford: Archaeopress Archaeology.

Gros-Balthazard, M. and Flowers, J. M. (2020) ‘A brief history of the origin of domesticated date palms’, in Al-Khayri, M., Mohan Jain, S. and Johnson, D. *The Date Palm Genome: Phylogeny, Biodiversity and Mapping*, 2, pp. 55–74.

Gros-Balthazard, M. *et al.* (2016) ‘The Domestication Syndrome in *Phoenix dactylifera* Seeds: Toward the Identification of Wild Date Palm Populations’, in Olsen, K.M. (ed) *PLOS ONE*, 11(3), pp. 1–21.

Gros-Balthazard, M. *et al.* (2023) ‘What lies behind a fruit crop variety name? A case study of the barnī date palm from al-‘Ulā oasis, Saudi Arabia’, *PLANTS, PEOPLE, PLANET*, 5(1), pp. 82–97.

- Guasch-Jané, M. R. *et al.* (2004) 'Liquid Chromatography with Mass Spectrometry in Tandem Mode Applied for the Identification of Wine Markers in Residues from Ancient Egyptian Vessels', *Analytical Chemistry*, 76(6), pp. 1672–1677.
- Guasch-Jané, M. R. *et al.* (2006) 'First evidence of white wine in ancient Egypt from Tutankhamun's tomb', *Journal of Archaeological Science*, 33(8), pp. 1075–1080.
- Guzmán-Ardiles, R. E. *et al.* (2023) 'Genetic changes in the genus *Vitis* and the domestication of vine', *Frontiers in Plant Science*, 13, pp. 1–13.
- Hadjimitsis, D. *et al.* (2020) *Remote Sensing For Archaeology and Cultural Landscapes: Best Practices and Perspectives Across Europe and the Middle East*. Cham: Springer.
- Hadjisavvas, S. (1988) *Olive Oil Production in Ancient Cyprus*. Government Report. Report of the Department of Antiquities Cyprus, pp. 111–119.
- Hadjisavvas, S. (1990) *Windlass vs. Screw: A Case Study for the Reconstruction of an Olive Press*. Government Report. Report of the Department of Antiquities Cyprus, pp. 181–185.
- Hadjisavvas, S. (1991) 'Perforated Monoliths: Myths and Reality', in Amouretti, M. C., Brun, J. P. and Eitam, D. (eds) *Oil and Wine Production in the Mediterranean Area from the Bronze Age to the end of the XVIth Century*. Aix-en-Provence: Université de Provence, pp. 69–80.
- Hadjisavvas, S. (2012) *The Phoenician Period Necropolis of Kition I*. Nicosia. Cyprus: Department of Antiquities, Cyprus.
- Hadjisavvas, S. (2020) *The Archaeology of Wine in Cyprus*. Cyprus: Napaphos Publishers.
- Haggis, D. *et al.* (2011) 'Excavations in the Archaic Civic Buildings at Azoria in 2005–2006', *Hesperia: The Journal of the American School of Classical Studies at Athens*, 80(1), pp. 1–70.
- Haight, K. G. and Gump, B. H. (1994) 'The Use of Macerating Enzymes in Grape Juice Processing', *American Journal of Enology and Viticulture*, 45(1), pp. 113–116.
- Haldane, C. (1990) 'Shipwrecked plant remains', *Biblical Archaeologist*, 53, pp. 55–60.
- Haldane, C. (1991) 'Organic goods from the UluBurun wreck', *Institute of Nautical Archaeology – Newsletter*, 18(4), p. 11.
- Haldane, C. (1991) 'Recovery and analysis of plant remains from some Mediterranean shipwreck sites', in Renfrew, J. (ed.) *New Light on Ancient Farming*. Edinburgh: Edinburgh University Press, pp. 214–223.
- Haldane, C. (1993) 'Direct Evidence for Organic Cargoes in the Late Bronze Age', *World Archaeology*, 24(3), pp. 348–360.
- Hall, J. M. and Osborne, J. F. (2022) *The Connected Iron Age: Interregional Networks in the Eastern Mediterranean, 900–600 BCE*. Chicago: University of Chicago Press.
- Halstead, P. (2019) Face-to-face conversation, 17 October 2019.

Halstead, P. and Jones, G. (1980) 'Early Neolithic economy in Thessaly: some evidence from excavations at Prodromos', *Anthropologika*, 1, pp. 93–117.

Halstead, P. and O'Shea, J. (1989) *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge: Cambridge University Press.

Halstead, P. and O'Shea, J. (1989) *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge: Cambridge University Press.

Hamilakis, Y. (1996) 'Wine, Oil and the Dialectics of Power in Bronze Age Crete: A Review of the Evidence', *Oxford Journal of Archaeology*, 15(1), pp. 1–32.

Hamilakis, Y. (1999) 'Food technologies/technologies of the body: The social context of wine and oil production and consumption in Bronze Age Crete', *World Archaeology*, 31(1), pp. 38–54..

Hamilakis, Y. and Anagnostopoulos, A. (2009) 'What is Archaeological Ethnography?', *Public Archaeology*, 8(2–3), pp. 65–87.

Hamilton, R. W. (1934) 'Note on the Chapel and Winepress at "Ain el Jedide"', *Quarterly of the Department of Antiquities in Palestine*, 4, pp. 111–117.

Hamman, R. A. and Dami, I. E. (2000) 'Effects of Irrigation on Wine Grape Growth and Fruit Quality', *HortTechnology*, 10(1), pp. 162–168.

Hanaor, D., Gan, Y. and Einav, I. (2016) 'Static friction at fractal interfaces', *Tribology International*, 93, pp. 229–238.

Hansen, J. (1989) 'Khirokitia Plant Remains: Preliminary Report (1980 – 1981, 1983)', in LeBrun, A. (ed.) *Fouilles récentes à Khirokitia (Chypre) 1983 – 1986*. Paris: Editions Recherches sur les Civilisations Mémoire, 81, pp. 235 – 250.

Hansen, J. (1990) 'Botanical remains', in Todd, I.A. (ed.) *Vasilikos Valley Project 3: Kalavassos–Ayios Dhimitrios II. Ceramics, objects, tombs, specialist studies*. Göteborg: Paul Åströms Förlag, pp. 82–93.

Hansen, J. (1991) 'Palaeoethnobotany in Cyprus: recent research', in Renfrew, J.M. (ed.) *New light on early farming*. Edinburgh: Edinburgh University Press, pp. 225–236.

Hansen, J. (1994) 'Khirokitia Plant Remains: Preliminary Report (1986, 1988 – 1990)', in LeBrun, A. (ed.) *Fouilles récentes à Khirokitia (Chypre) 1988 – 1991*. Paris: Editions Recherches sur les Civilisations Mémoire, 3, pp. 393 – 409.

Hansen, J. (2003) 'The botanical remains', in Swiny, S., G., Rapp and Herscher, E. (eds.) *Sotira Kaminoudhia: An Early Bronze Age Site in Cyprus*, CAARI Monographs, 4, pp. 449–454.

Hansen, J.M. (1988) 'Agriculture in the Prehistoric Aegean: Data versus Speculation', *American Journal of Archaeology*, 92(1), pp. 39–52.

Hardie, W. J. and Considine, J. A. (1976) 'Response of Grapes to Water–Deficit Stress in

Particular Stages of Development’, *American Journal of Enology and Viticulture*, 27(2), pp. 55–61.

Harris, E., Brown, M. and Brown, B. (eds) (1993) *Practices of Archaeological Stratigraphy*. London: Academic Press.

Harris, E. C. (1979) ‘The laws of archaeological stratigraphy’, *World Archaeology*, 11(1), pp. 111–117.

Harris, E. C. (1989) *Principles of Archaeological Stratigraphy*. 2nd edn. London: Academic Press.

Harrower, M. J. (2008) ‘Hydrology, Ideology and the Origins of Irrigation in Ancient Southwest Arabia’, *Current Anthropology*, 49(3), pp. 497–510.

Harutyunyan, M. and Malfeito-Ferreira, M. (2022a) ‘Historical and Heritage Sustainability for the Revival of Ancient Wine-Making Techniques and Wine Styles’, *Beverages*, 8(1), pp. 10–33.

Harutyunyan, M. and Malfeito-Ferreira, M. (2022b) ‘The Rise of Wine among Ancient Civilizations across the Mediterranean Basin’, *Heritage*, 5(2), pp. 788–812.

Harutyunyan, M. *et al.* (2023) ‘Consumer acceptance of sweet wines and *piquettes* obtained by the adaptation of Ancient Wine-making Techniques’, *Journal of Sensory Studies*, 38(3), p. e12823.

Heath, D. B. (1987) ‘A decade of development in the anthropological study of alcohol use: 1970–1980’, in Douglas, M. (ed.) *Constructive Drinking*. 1st edn. London: Routledge, pp. 16–69.

Heber, D., Schulman, R. N. and Seeram, N. P. (eds) (2006) *Pomegranates: Ancient Roots to Modern Medicine*. Boca Raton: CRC Press.

Helbaek, H. (1958) ‘Plant economy in ancient Lachish’ in Tufnell, O. (ed.) *Lachish IV: The Bronze Age*. London, pp. 309 – 317.

Helbaek, H. (1961) ‘Late Bronze Age and Byzantine crops at Beycesultan in Anatolia’, *Anatolian Studies*, 11, pp. 77–97.

Helbaek, H. (1962) ‘Late Cypriot vegetable diet at Apliki’, *Opuscula Athenaes*, 4, pp. 171 – 186.

Helbaek, H. (1966a) ‘The plant remains from Nimrud’, in Mallowan, M.E (ed.) *Nimrud and its remains*. London: Collins, pp. 613–620.

Helbaek, H. (1966b) ‘What farming produced at Cypriote Kalopsidha’, in Aström, P. (ed.) *Excavations at Kalopsidha and Ayios Iakovos in Cyprus*. Lund: Studies in Mediterranean Archaeology, 2, pp. 116 – 126.

Helbaek, H. (1969) ‘Plant collecting, dry-farming and irrigation agriculture in prehistoric Deh Luran’, in Hole, K., Flannery, V. and Neely, J. A. (eds.) *Prehistory and human ecology of the*

Deh Luran plain. An early village sequence from Khuzistan, Iran. Ann Arbor: University of Michigan, 1, pp. 383–426, plates 40–41.

Heltzer, M. (1999) ‘The economy of Ugarit’, in *Handbook of Ugarit Studies*. Leiden: BRILL (Handbook of Oriental Studies, 39), pp. 423–454.

Hepper, F. N. (1990) *Pharaoh's flowers. The botanical treasures of Tutankhamun*. London: Her Majesty's Stationery Office.

Herveux, L. (2004) ‘Étude archéobotanique préliminaire de tell al–Rawda, site de la fin du Bronze ancien en Syrie intérieure [Preliminary archaeobotanical study of tell al–Rawda, a late Early Bronze Age site in interior Syria]’, *Akkadica*, 125, pp. 79–91.

Herzog, Z., Rapp, G. R. and Negbi, O. (1989) *Excavations at Tel Michal, Israel*. Tel Aviv: Tel Aviv University (Publications of the Institute of Archaeology).

Hicks, T. G. (2006) *Handbook of Mechanical Engineering Calculations*. 2nd Edition. New York: McGraw–Hill Education.

Hill, D. (2013) *A History of Engineering in Classical and Medieval Times*. London: Routledge.

Hillman, G. C. (1981) ‘The barleys from Iron Age Rifa'at’, in Matthers, J. (ed.) *The river Qoueiq, Northern Syria and its catchment: studies arising from the Tell Rifa'at survey 1977 – 79*. Oxford, 98, pp. 508 – 510.

Hirschfeld, Y. (1983) ‘Ancient Wine Presses in the Park of Ayalon’, *Israel Exploration Journal*, 33, pp. 207–217.

Hirschfeld, Y. (2004) ‘Excavations at 'Ein Feshkha, 2001: Final report’, *Israel Exploration Journal*, 54(1), pp. 37–74.

Hjelmqvist, H. (1970) ‘Some carbonized seeds and fruits from the necropolis of Salamis’, in Karageorghis, V. (ed.) *Salamis Volume 4. Excavations in the necropolis of Salamis II*. Nicosia: Department of Antiquities, pp. 329 – 335.

Hjelmqvist, H. (1979) ‘Some economic plants and weeds from the Bronze Age of Cyprus’, in Öbrink, U. (ed.) *Hala Sultan Tekke 5*. Göteborg: Paul Åströms Förlag.

Hobbs, J. J. (1992) *Bedouin Life in the Egyptian Wilderness*. Austin: University of Texas Press.

Hobosyan, S. (2011) ‘Թեղուտի 2009–2010 թթ. հնագիտական պեղումների նախնական արդյունքները [Preliminary Results of the 2009–2010 Archaeological Excavations in Teghut]’, *Historical–Philological Journal*, 2(187), pp. 199–211.

Hobosyan, S. (2014) ‘Գինեգործության ժողովրդական հմտությունները Լորու և Տավուշի մարզերում [Folk Skills of Winemaking in the Regions of Lori and Tavush]’, in *Collection of Papers of the Second International Congress on Armenian Studies*. Yerevan: Gitutyun Publishing House of the NAS RA, pp. 193–196.

Hodel, D. R. and Johnson, D. V. (2007) *Imported and American Varieties of Dates (Phoenix*

Dactylifera) in the United States. Charlotte: UCANR Publications.

Hoffner, H. A. (1967) 'Second Millennium Antecedents to the Hebrew 'ÔB.', *Journal of Biblical Literature*, 86, pp. 385–401.

Holden, T. G. (1994) *The charred plant remains from Tell Abu Kharaz in the Jordan Valley* Edinburgh, AOC, 21.

Holden, T. G. (1999) *The plant remains from Tell Esh–Shuna North, Jordan Valley*, 30.

Holland, D., Hatib, K. and Bar–Ya'akov, I. (2009) 'Pomegranate: Botany, Horticulture, Breeding', in Janick, J. (ed.) *Horticultural Reviews*. John Wiley & Sons, Ltd, pp. 127–191.

Holland, T. and Smit, B. (2010) 'Climate Change and the Wine Industry: Current Research Themes and New Directions', *Journal of Wine Research*, 21(2–3), pp. 125–136.

Hönigsberg, P. (1962) 'Römische Mühlen mahlen noch in Oberägypten [Roman mills still grinding in Upper Egypt]', *Mitteilungen der Abteilung Kairo des Deutschen Archäologischen Instituts*, 18, pp. 70–79.

Hopf, M. (1961) 'Pflanzenfunde aus Lerna / Argolis [Plant Remains from Lerna and Argolis]', *Züchter*, 31, pp. 239 – 247.

Hopf, M. (1962) 'Bericht über die Untersuchungen von Samen und Holzkohlenresten von der Argissa–Magula aus den Präkeramischen bis Mittelbronzezeitlichen Schichten [Report on the investigations of seeds and charcoal remains from the Argissa Magula from the Preceramic to Middle Bronze Age layers.]', in Milojevic, V. and Bonn, E. (eds.) *Argissa–Magula I: Das Präkeramische Neolithikum sowie die Tier– und Pflanzenreste*, pp. 101 – 109.

Hopf, M. (1978) 'Plant remains, Strata V–I', in Amiran, R. (ed) *Early Arad I*. Jerusalem: Israel Exploration Society.

Hopf, M. (1983) 'Jericho plant remains', in Kenyon, K.M. and Holland, T.A (eds), *Excavations at Jericho V. The pottery phases of the Tell and other finds*. London, pp. 576 – 621.

Hornung, E., Krauss, R. and Warburton, D. A. (2006) *Ancient Egyptian Chronology*. Leiden: BRILL.

Hovhannisyan, N. et al. (2015) Հայկական որթատունկի և գինի [Armenian Vine and Wine]. 1st edn. Yerevan: GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit,.

Huber, J. K. and Rapp, G. J.(1987) *Results of a preliminary pollen study from Troy Megaron II A*. Minnesota: University of Minnesota–Duluth Press.

Humbel, X. (1976) *Vieux pressoirs sans frontière [Old presses without borders]*. Paris: Guinegard.

Humbert, J. B. and Chambon, A. (1994) *Fouilles de Khirbet Qumrân et de Aïn Feshkha [Digs at Khirbet Qumran and Ain Feshkha]*. Freiburg: Freiburg University.

- Humbert, J.-B. and Chambron, A. (1995) 'Fouilles de Khirbet Qumrân et de Aïn Feshkha, I (NTOA, Series Archaeologica, 1; Fribourg: Editions Universitaires, 1994), pp. xv + 418. Cloth, SFr 220.00. ISBN 3-7278-0940-X', *Journal for the Study of the Old Testament*, 20(66), pp. 121-121.
- Hundley, M. B. (2014) 'The God Collectors: Hittite Conceptions of the Di-vine.', *Altorientalische Forschungen*, 41, pp. 176-200.
- Hutchinson, R. W. (1962) *Prehistoric Crete*. Harmondsworth: Penguin.
- Hutchinson, U. F. *et al.* (2019) 'Vinegar Engineering: a Bioprocess Perspective', *Food Engineering Reviews*, 11(4), pp. 290-305.
- Hutkins, R. W. (2006) *Microbiology and Technology of Fermented Foods*. John Wiley & Sons.
- Hynd, A. (1997) *A model of local continuity: The 1995 archaeobotanical assemblage from Kinet Höyük, Hatay*. Unpublished M.Sc. thesis, Sheffield: University of Sheffield.
- İkinci, A. *et al.* (2014) 'Determination of Heat Requirements and Effective Heat Summations of Some Pomegranate Cultivars Grown in Southern Anatolia', *Erwerbs-Obstbau*, 56(4), pp. 131-138.
- Immerwahr, S. (1989) 'The Pomegranate Vase: Its Origins and Continuity', *Hesperia*, 58(4), pp. 397-410.
- IOC (no date) *Olivae 127 English edition*. International Olive Council.
- Irfan, P. K. *et al.* (2013) 'Calcium chloride extends the keeping quality of fig fruit (*Ficus carica* L.) during storage and shelf-life', *Postharvest Biology and Technology*, 82, pp. 70-75.
- Iskra, M. (2021) 'Some considerations on the crisis and reconstruction of the Urartian Kingdom in the Ararat Plain', in *Interdisciplinary research on the antiquity of the Black Sea. Volume II*. Wydawnictwa Uniwersytetu Warszawskiego, pp. 259-265.
- Iskra, M. *et al.* (2024) 'Urartian Red Burnished Ware in local context: An archaeometric study of the assemblage from Metsamor (Armenia, South Caucasus)', *Journal of Archaeological Science: Reports*, 53, pp. 1-16.
- İşıklı, M. (2014) 'Reflections on Twenty Five Years of Excavations at Ayanis Castle: Past, Present and Future', *ARAMAZD: Armenian Journal of Near Eastern Studies*, 8(1-2), pp. 110-119.
- Izdebski, A. and Preiser-Kapeller, J. (2024) 'Ecology, Irrigation and Lordship in the Lake Van Region: A Long-Term View from Urartu to Vaspurakan', in *A Companion to the Environmental History of Byzantium*. Leiden: BRILL, pp. 308-345.
- Jackson, R. S. (2020) *Wine Science: Principles and Applications*. Academic Press.
- Jakobović, S. and Jakobović, M. (2015) 'Pomace brandy quality of cultivar Riesling White from Kutjevo vinegrowing region', *Bulgarian journal of agricultural science*, 21(5), pp. 917-925.

James, S. *et al.* (2024) *Landscape Histories and Terrestrial Networks in the Peloponnese: Results from the Western Argolid Regional Project (Offprint)*.

Jarvis, B. (1996) 'Cider, perry, fruit wines and other alcoholic fruit beverages', in Arthey, D. and Ashurst, P. R. (eds) *Fruit Processing*. Boston, MA: Springer US, pp. 97–134.

Jdaini, K. *et al.* (2022) 'Effect of harvesting and post-harvest practices on the microbiological quality of dates fruits (*Phoenix dactylifera* L.)', *Journal of the Saudi Society of Agricultural Sciences*, 21(8), pp. 552–559.

Joffe, A. H. (1998) 'Alcohol and Social Complexity in Ancient Western Asia', *Current Anthropology*, 39(3), pp. 297–322.

Joffe, A. H. (2019) 'Egypt and the Southern Levant in the Early Bronze Age', *Bulletin of the American Schools of Oriental Research*, 381, pp. 238–241..

Joffe, A. H. and Dessel, J. P. (1995) 'Redefining Chronology and Terminology for the Chalcolithic of the Southern Levant', *Current Anthropology*, 36(3), pp. 507–518.

Johnson, G. W. and Errington, R. (1847) *The Grape Vine: Its Culture, Uses and History*. London: R. Baldwin.

Johnson, H. (1989) *Vintage: The Story of Wine*. Simon and Schuster.

Joldersma, D. and Liu, Z. (2018) 'The making of virgin fruit: the molecular and genetic basis of parthenocarp', *Journal of Experimental Botany*, 69(5), pp. 955–962.

Jones, G and Schofield, A. (2006) 'Evidence for the use of threshing remains at the Early Minoan metallurgical workshop', in Betancourt, P.P. (ed.) *The Chrysokamino metallurgy workshop and its territory*. Athens: The American School of Classical Studies at Athens, pp. 153–154.

Jones, G. (1982). 'Cereal and pulse remains from Protogeometric and Geometric Iolkos, Thessaly.' *Anthropologika* 3: pp. 75 – 78.

Jones, G. (1983) *The use of ethnographic and ecological models in the interpretation of archaeological plant remains: case studies from Greece*. Cambridge: Cambridge University.

Jones, G. (1990) 'The application of present-day cereal processing studies to charred archaeobotanical remains', *Circaea*, 6, pp. 91–96.

Jones, G. and Halstead, P. (1993) 'Charred plant remains from Neolithic – Bronze Age Platia Magula Zarkou, Thessaly', *Annual of the British School at Athens*, 88, pp. 1 – 3.

Jonoobi, M. *et al.* (2019) 'A review on date palm tree: Properties, characterization and its potential applications', *Journal of Renewable Materials*, 7(11), pp. 1055–1075.

Jorda, G.P., Pradat, B., Rovira, N. and Alibert, P. (2004) 'Historical biogeography of olive domestication (*Olea europaea* L.) as revealed by geometrical morphometry applied to biological and archaeological material', *Journal of Biogeography*, 31, pp. 63–77.

- Joshi, V. K., Sharma, R. and Abrol, G. S. (2012) 'Stone Fruit: Wine and Brandy', in *Handbook of Plant-Based Fermented Food and Beverage Technology*. 2nd edn. CRC Press.
- Kafafi, Z. A. K. (2014) 'Early Bronze Age I–III Archaeological Evidence from the Jordan Valley: Proof of the Levantine–Egyptian Trade Route', in *Egypt and the Southern Levant in the Early Bronze Age*, pp. 145–159.
- Kailis, S. and Harris, D. J. (2007) *Producing Table Olives*. Landlinks Press.
- Kalbasis (2021) Email correspondences, 14 May 2021.
- Kalimatis (2019) Email correspondences, 19 November 2019.
- Kaniewski, D. *et al.* (2012) 'Primary domestication and early uses of the emblematic olive tree: palaeobotanical, historical and molecular evidence from the Middle East', *Biological Reviews*, 87(4), pp. 885–899.
- Kapellakis, I. E., Tsagarakis, K. P. and Crowther, J. C. (2008) 'Olive oil history, production and by-product management', *Reviews in Environmental Science and Bio/Technology*, 7, pp. 1–26.
- Kaplony, P. (1963) *Die Inschriften der ägyptischen Frühzeit [The Inscriptions of the Early Egyptian Period]*. Wiesbaden: Harrassowitz Publikation (Ägyptologische Abhandlungen).
- Karababa, E. and Develi Isikli, N. (2005) 'Pekmez: A Traditional Concentrated Fruit Product', *Food Reviews International*, 21(4), pp. 357–366.
- Karageorghis, V. (1983) *Palaepaphos–skales. An Iron Age cemetery in Cyprus*. Berlin: Deutsches Archäologisches Institut.
- Karamitrou, A., Sturt, F. and Bogiatzis, P. (2023). 'Identification of Black Reef Shipwreck Sites Using AI and Satellite Multispectral Imagery', *Remote Sensing*, 15(8), 2030.
- Karathanou, A and Valamoti, S.M. (2013) 'The archaeobotanical investigation of human activity in Late Bronze Age Greece.' *Proceedings of 16th Conference of the IWGP in Thessaloniki 2013*. Thessaloniki: University of Thessaloniki.
- Kassianidou, V. (2013) 'The production and trade of Cypriot copper in the Late Bronze Age : an analysis of the evidence', *Pasiphae : rivista di filologia e antichità egee* (7).
- Kavtaradze, G. (2014) 'On the importance of the Caucasian chronology for the foundation of the common Near Eastern–East European chronological system', in *The Proceedings of the Ivane Javakhishvili Institute of History and Ethnology XII–XIII: Dedicated to the 75th Year Anniversary of Professor Tamaz Beradze's Birth*. Tbilisi: Ivane Javakhishvili Tbilisi State University, pp. 23–45.
- Kaya, S. and Maskan, A. (2003) 'Water vapor permeability of pestil (a fruit leather) made from boiled grape juice with starch', *Journal of Food Engineering*, 57(3), pp. 295–299.
- Kaynak, L., Gözlekçi, S. and Ersoy, N. (1998) 'A Research on Storage and Pomological Properties of Some Fig (*Ficus Carica* L.) Cultivars Grown in Antalya Conditions', *Acta*

Horticulturae, (480), pp. 277–282. .

Kelly, W. W. (1983) ‘Concepts in the Anthropological Study of Irrigation’, *American Anthropologist*, 85(4), pp. 880–886.

Kempf, M. and Günther, G. (2023) ‘Point pattern and spatial analyses using archaeological and environmental data – A case study from the Neolithic Carpathian Basin’, *Journal of Archaeological Science: Reports*, 47, p. 103747.

Khachatryan, K. (2024) ‘Entrepreneurship amid armed conflicts: Insights from Artsakh’, *Business Horizons*, 67(6), pp. 727–741.

Khadivi, A. *et al.* (2020) ‘Morphological variability of wild pomegranate (*Punica granatum* L.) accessions from natural habitats in the Northern parts of Iran’, *Scientia Horticulturae*, 264, p. 109165.

Khalifa, S. A. M. *et al.* (2024) ‘Vinegar – a beneficial food additive: production, safety, possibilities and applications from ancient to modern times’, *Food & Function*, 15(20), pp. 10262–10282.

Khalil, A. A. *et al.* (2024) ‘Oleuropein: Chemistry, extraction techniques and nutraceutical perspectives—An update’, *Critical Reviews in Food Science and Nutrition*, 64(27), pp. 9933–9954.

Khan, I. *et al.* (2023) ‘Development and Storage Studies of Guava–Chiku Blended Fruit Leather’, *Jammu Kashmir Journal of Agriculture*, 3(1), pp. 1–9.

Khatchadourian, L. (2007) ‘Unforgettable Landscapes: Attachments to the Past in Hellenistic Armenia’, in *Negotiating the Past in the Past: Identity, Memory and Landscape in Archaeological Research*. Arizona: University of Arizona Press, pp. 43–75.

Khatchadourian, L. *et al.* (2022) *Silent Erasure: A Satellite Investigation of the Destruction of Armenian Cultural Heritage in Nakhchivan, Azerbaijan*. Ithaca: Cornell University.

Kilkenny, M. and Schluter, G. (2001) ‘Value–Added Agriculture Policies Across the 50 States’, *Rural America/Rural Development Perspectives*, 16 (1), pp. 12–18.

Kilmartin, P. A. and Oberholster, A. (2022) ‘Grape harvesting and effects on wine composition’, in Reynolds, A. (ed.) *Managing Wine Quality: Viticulture and Wine Quality*. London: Elsevier, pp. 705–726.

Kinzer, G. and Schreier, P. (1980) ‘Influence of Different Pressing Systems on the Composition of Volatile Constituents in Unfermented Grape Musts and Wines’, *American Journal of Enology and Viticulture*, 31(1), pp. 7–13.

Kirakosyan, A. (2020) *Current Developments in the Armenian Wine Industry*. Yerevan: Armenian National Agrarian University.

Kiritsakis, A., Kanavouras, A. and Kiritsakis, K. (2002) ‘Chemical analysis, quality control and packaging issues of olive oil’, *European Journal of Lipid Science and Technology*, 104(9–10),

pp. 628–638.

Kiritsakis, A. K. and Dugan, L. R. (1984) 'Effect of selected storage conditions and packaging materials on olive oil quality', *Journal of the American Oil Chemists' Society*, 61(12), pp. 1868–1870.

Kirleis, W. *et al.* (2021) 'ArchbotLit, the archaeobotanical literature database: an update of the search engine for literature on archaeological remains of cultivated plants since 1981', *Vegetation History and Archaeobotany*, 30(1), pp. 171–174.

Kislev, M. (1995) 'Wild olive stones at submerged Chalcolithic Kfar Samir, Haifa, Israel', *Mitekufat Haeven: Journal of the Israel Prehistoric Society*, 26, 134–135.

Kislev, M. and Mahler–Slasky, Y. (2009) 'Food remains from area X', in Kokhavi, L., Yadin, E. and Gadot, Y. (eds.) *Aphek–Antipatris II: Middle Bronze, Late Bronze and Iron Age Remains from the Acropolis*. Tel Aviv: Tel Aviv University, pp. 484–510.

Kislev, M. E., Hartmann, A. and Bar–Yosef, O. (2006) 'Early Domesticated Fig in the Jordan Valley', *Science*, 312(5778), pp. 1372–1374.

Kislev, M. E., Hartmann, A. and Galili, E. (2004) 'Archaeobotanical and archaeoentomological evidence from a well at Atlit–Yam indicates colder, more humid climate on the Israeli coast during the PPNC period', *Journal of Archaeological Science*, 31(9), pp. 1301–1310.

Kislev, M. E., Melamed, Y. and Langsam, Y. (2006) 'Plant Remains from Tel Batash. In: Timnah (Tel Batash) III: The Finds from the Second Millenium BCE. Chapter 16', in Panitz–Cohen, N. and Mazar, A. (eds.) *Qedem Monographs of the Institute of Archaeology* 45. Jerusalem: The Hebrew University of Jerusalem.

Kislev, M. E., Simchoni, O., Melamed, Y. and Maroz, L. (2009) 'Food and Industrial Crops. Chapter 17 Botanical Remains', in Panitz–Cohen, N. and Mazar, A. (eds.) *Strata in Areas N and S: Excavations at Tel Beth–Shean 1989–1996. Volume III. The 13th–11th Century BCE*. Jerusalem: The Israel Exploration Society.

Kislev, M.E. (1993) 'Food remains. Shiloh. The archaeology of a biblical site', *Tel Aviv*, pp. 354 – 361.

Kislev, M. E. (1997) 'Early agriculture and paleoecology of Netiv Hagdud', in *An Early Neolithic Village in the Jordan Valley*, pp. 203–230.

Kislev, M. E. (1998) 'The relative impact of pig husbandry versus goat browsing on ancient oak forests in Israel', in Edelstein, G., Milevski, I. and Aurant, S. (eds.) *The Rephaim Valley Project. Villages, terraces and stone mounds. Excavations at Manahat, Jerusalem, 1987–1989*. Jerusalem: Israel Antiquities Authority, pp. 113 – 118.

Kislev, M. E. (2000) *Ancient infested wheat and horse bean from Horbat Rosh Zayit. Horbat Rosh Zayit, an Iron Age storage fort and village*. Jerusalem: Israel Antiquities Authority.

Kislev, M. E. and Hopf, M. (1985) 'Food remains from Tell Qasile with special reference to *Lathyrus sativus/cicera*. Excavations at Tell Qasile', *Jerusalem*, 20, pp. 140–148.

- Kloner, A. and Sagiv, N. (1989) 'Maresha in the Shepela: Olive Oil Production in the Hellenistic Period', *Israel Land and Nature*, 15, pp. 58–65.
- Knapp, A. (2013) *The Archaeology of Cyprus: From Earliest Prehistory Through the Bronze Age*. Cambridge: Cambridge University Press.
- Knapp, A. and Demesticha, S. (2016) *Mediterranean Connections: Maritime Transport Containers and Seaborne Trade in the Bronze and Early Iron Ages*. New York: Routledge.
- Kochavi, M. (1989) חמש אלפים שנות היסטוריה: אפק – אנטיוכיה [Aphek – Antipatris: Five Thousand Years of History]. Tel Aviv: Tel Aviv University.
- Kofel, D. and Bürge, T. (2018) 'Agriculture and Storage Practices in an Early Iron Age Household: Analyses of Plant Macro Remains at Tell Abu Al-Kharaz, Jordan Valley', *Ägypten und Levante / Egypt and the Levant*, 28, pp. 291–308.
- Koh, A. J., Yasur-Landau, A. and Cline, E. H. (2014) 'Characterizing a Middle Bronze Palatial Wine Cellar from Tel Kabri, Israel', *PLoS ONE*. Edited by X. Yang, 9(8), p. e106406.
- Komonas, G. (2019) Skype conversations. September 2019.
- Korfmann, M. (1998) 'Troia, an Ancient Anatolian Palatial and Trading Center: Archaeological Evidence for the Period of Troia VI/VII.', *Classical World*, 91, pp. 369–385.
- Kotsonas, A. (2023) 'Crete: Early Iron Age to Classical', *Archaeological Reports: Archaeology in Greece 2023–2024*, 68, pp. 133–167.
- Kotzamani, G. (2009) *From gathering to cultivation: archaeobotanical research on the early plant exploitation and the beginning of agriculture in Greece (Theopetra Schisto, Sidari, Revenia)*. Doctoral thesis, Thessaloniki: University of Thessaloniki.
- Kreitzman, M. et al. (2020) 'Perennial Staple Crops: Yields, Distribution and Nutrition in the Global Food System', *Frontiers in Sustainable Food Systems*, 4, pp. 1–21.
- Kroll, H. (1981) 'Thessalische Kulturpflanzen [Cultivated plants of Thessaly]', *Zeitschrift für Archäologie*, 15, pp. 97 – 103.
- Kroll, H. (1982) 'Kulturpflanzen von Tiryns [Cultivated plants of Tiryns]', *Archäologischer Anzeiger*, 1982(3), pp. 467 – 485.
- Kroll, H. (1983). *Kastanas, Die Pflanzenfunde*. Berlin: Volker Spiess.
- Kroll, H. (1984) 'Bronze Age and Iron Age agriculture in Kastanas, Macedonia', in van Zeist, W. and Casparie, W. A. (eds.) *Plants and ancient man*. Rotterdam: Balkema, pp. 243 – 246.
- Kroll, H. (1989) 'Die Pflanzenfunde von Maadi. Maadi III', in Rizkana, I. and Seeher, J. (eds.) *The non-lithic small finds and the structural remains of the Predynastic settlement*. Mainz: Philipp von Zabern, 80, pp. 129 – 136.

Kroll, H. (1993) ‘Kulturpflanzen von Kalapodi [Crops of Kalapodi]’, *Archäologischer Anzeiger*, 2, pp. 161 – 182.

Kroll, H. and Neef, R. (1997) ‘Bohnen von Agios Mamas [Beans from Agios Mamas]’, in Becker, C., Dunkelman, M.-L. and Metzner-Nebelsick, C. (eds.) *Beiträge zur prähistorischen Archäologie zwischen Nord- und Südosteuropa. Festschrift für Bernhard Hänsel*. Espelkamp: Marie Leidorf, pp. 543 – 547.

Kroll, S. (2006) ‘Southern Armenia Survey (Syunik), 2000–2003’, *ARAMAZD: Armenian Journal of Near Eastern Studies*, 1, pp. 19–49.

Krueger, R. R. (2021) ‘Date Palm (*Phoenix dactylifera* L.) Biology and Utilization’, in Al-Khayri, J. M., Jain, S. M. and Johnson, D. V. (eds) *The Date Palm Genome, Vol. 1: Phylogeny, Biodiversity and Mapping*. Cham: Springer International Publishing, pp. 3–28.

Kucan, D. (1995) ‘Zur Ernährung und dem Gebrauch von Pflanzen im Heraion von Samos im 7. Jahrhundert v.Chr [On nutrition and the use of plants in the Heraion of Samos in the 7th century BC]’, *Jahrbuch des Deutschen Archäologischen Instituts*, 110, pp. 1 – 64.

Kühne, H. (1991) *Die Rezente Umwelt von Tall Šēḫ Ḥamad und Daten zur Umweltrekonstruktion der Assyrischen Stadt Dūr-Katlimmu*. Seiten: HW Books.

Kui, L. *et al.* (2020) ‘Identification of Selective Sweeps in the Domesticated Table and Wine Grape (*Vitis vinifera* L.)’, *Frontiers in Plant Science*, pp. 1–11.

Kuijt, I. (2009) ‘What Do We Really Know about Food Storage, Surplus and Feasting in Preagricultural Communities?’, *Current Anthropology*, 50(5), pp. 641–644.

Kunkee, R. E. (1984) ‘Selection and modification of yeasts and lactic acid bacteria for wine fermentation’, *Food Microbiology*, 1(4), pp. 315–332.

Kyllo, M. (1982) ‘The Botanical remains’, in Peltenberg EJ (ed) *Vrysi. A subterranean settlement in Cyprus. Excavations at Prehistoric Ayios Epiktitos Brysi 1969–1973*. Warminster: Aris and Phillips, pp. 90–93.

Landauer, J. *et al.* (2025) ‘Beyond the Greater Angkor Region: Automatic large-scale mapping of Angkorian-period reservoirs in satellite imagery using deep learning.’, *PLoS One*, 20(3), e0320452.

Laneri, N. (2007) ‘Burial Practices at Titriş Höyük, Turkey: An Interpretation’, *Journal of Near Eastern Studies*, 66(4), pp. 241–266.

Laneri, N. (2013) ‘Defining Residential Graves. The Case of Titris Hoyuk in Southeastern Anatolia During the Late IIIrd Millennium BC, in O. Henry (ed.) *Le mort dans la ville: Pratiques, contextes et impacts des inhumations intra-muros en Anatolie, du début de l'Âge du Bronze à l'époque romaine*. Istanbul: Institut Français d'Études Anatoliennes.

Langgut, D. (2024) ‘The core area of fruit-tree cultivation: central Jordan Valley (Levant), ca. 7000 BP’, *Palynology*, 48(4), pp. 1–15.

- Langgut, D. *et al.* (2015) 'Vegetation and Climate Changes during the Bronze and Iron Ages (~3600–600 BCE) in the Southern Levant Based on Palynological Records', *Radiocarbon*, 57(2), pp. 217–235.
- Lardos, A. and Heinrich, M. (2013) 'Continuity and change in medicinal plant use: The example of monasteries on Cyprus and historical iatrosophia texts', *Journal of Ethnopharmacology*, 150(1), pp. 202–214.
- Latour, P. (1990) 'Recherches sur la marche du progrès dans les presses [Research on the march of progress in presses', *Société historique d'archéologie et de littérature du canton de Beaune mémoires*, pp. 127–143.
- Lauer, J. P. and Laurent-Täckholm, V. (1950) 'Les plantes découvertes dans les souterrains de l'enceinte du roi Zoser à Saqqarah (IIIe dyn.) [Plants discovered in the underground passages of King Zoser at Saqqara]', *Bulletins Institutions d'Egypte*, 32, pp. 121 – 147.
- Laufner, R., Faas, K. H. and Cuppers, H. (1987) *Jahre Weinkultur an Mosel Saar Ruwer [Years of wine culture on the Mosel Saar Ruwer]*. Trier: Rheinisches Landesmuseum.
- Lastrup, M. and Seger, J. D. (1990) 'Botanical remains from Tell Halif', *Bulletin of the American Schools of Oriental Research Supplement*, 26, pp. 23 – 24.
- Lavee, S. (2000) 'Grapevine (*Vitis Vinifera*) Growth and Performance in Warm Climates', in Erez, A. (ed.) *Temperate Fruit Crops in Warm Climates*. Dordrecht: Springer Netherlands, pp. 343–366.
- Lawall, M. L. and Lund, J. (eds) (2013) *The Transport Amphorae and Trade of Cyprus*. Aarhus: Aarhus University Press.
- Lebessi, A (1969) 'Ανασκαφή τάφου στον Πόρο Ηρακλείου [Excavation of a tomb in Poros] , Πρακτικά [Proceedings] 1967, pp. 195–209.
- Legin, A. *et al.* (2005) 'Electronic tongue for quality assessment of ethanol, vodka and eau-de-vie', *Analytica Chimica Acta*, 534(1), pp. 129–135.
- Legin, A. *et al.* (2005) 'Electronic tongue for quality assessment of ethanol, vodka and eau-de-vie', *Analytica Chimica Acta*, 534(1), pp. 129–135.
- Leipe, C. *et al.* (2023) 'Archaeobotanical evidence of plant cultivation from the Sanbaopi site in south-western Taiwan during the Late Neolithic and Metal Age', *The Holocene*, 33(2), pp. 131–146.
- Lemlem, A., Alemayehu, M. and Endris, M. (2018) 'Date Palm Production Practices and Constraints in the Value Chain in Afar Regional State, Ethiopia', *Advances in Agriculture*, pp. 1–10.
- Lemonnier, P. (ed.) (2013) *Technological Choices: Transformation in Material Cultures Since the Neolithic*. London: Routledge.
- Lesko, L. H. (1996) 'Egyptian Wine Production During the New Kingdom', in *The Origins and*

Ancient History of Wine. London: Routledge.

Levi, D. (1976) *Festòs e la Civiltà Minoica I[Feasts and the Minoan civilisation]*. Rome: Edizioni dell'Ateneo.

Levin, G. M. (2006) *Pomegranate Roads: A Soviet Botanist's Exile from Eden*. Florent Press.

Levy, T. and Higham, T. (2014) *The Bible and Radiocarbon Dating: Archaeology, Text and Science*. London: Routledge.

Lev-Yadun, S. (2022) 'Remains of the Common Fig (*Ficus carica* L.) in the Archaeological Record and Domestication Processes', in Flaishman, M. A. and Aksoy, U. (eds) *Advances in Fig Research and Sustainable Production*. Great Britain: CABI, pp. 11–25.

Lewis, H. (2012) *Investigating Ancient Tillage: An experimental and soil micromorphological study*. New York: BAR Publishing.

Lewit, T. (2012) 'Oil and wine press technology in its economic context: screw presses, the rural economy and trade in Late Antiquity', *Antiquité Tardive*, 20, pp. 137–149.

Ličeli, V. (2010) *Wine-Making in Antiquity in the light of evidence from excavations at Samtskhe*. ISAW Digital South Caucasus Collection.

Liebman, M. (1996) 'Polyculture Cropping Systems', in Altieri, M (ed.) *Agroecology*. 2nd edn. Boca Raton: CRC Press.

Limbergen, D. V. (2015) 'Figuring out the balance between intra-regional consumption and extra-regional export of wine and olive oil in late antique northern Syria.', *Olive Oil and Wine Production in Eastern Mediterranean in Antiquity*, pp. 169–189.

Limier, B. *et al.* (2018) 'Documenting the history of the grapevine and viticulture: A quantitative eco-anatomical perspective applied to modern and archaeological charcoal', *Journal of Archaeological Science*, 100, pp. 45–61.

Linacre College, O. (2007) 'Oxford Expedition to Egypt: Scene-details Database'. Archaeology Data Service.

Lindsay, I. *et al.* (2014) 'Geophysical survey at Late Bronze Age fortresses: comparing methods in the diverse geological contexts of Armenia', *Antiquity*, 88(340), pp. 578–595.

Lindsay, I. *et al.* (2022) 'The Project ArAGATS Kasakh Valley Archaeological Survey, Armenia: Report of the 2014–2017 Seasons', *American Journal of Archaeology*, 126 (2), pp. 261–303.

Lipshchitz, N., Biger, B. and Gophna, R. (1991) 'The beginning of olive (*oleo Europaea*) cultivation in the world: A reassessment', *Journal of Archaeological Science*, 18, pp. 441–453.

Lipshchitz, N. (1989) 'Plant economy and diet in the Early Bronze Age in Israel: A summary of present research', in Miroshedji, P.D. (ed) *L'urbanisation de la Palestine à l'âge du Bronze Ancien. Bilan et perspectives des recherches actuelles*. Oxford: Oxford University Press, 527, pp. 269 – 277.

- Liphschitz, N. (1993) 'Palaeobotanical remains. Shiloh. The archaeology of a biblical site', *Tel Aviv*, pp. 351 – 353.
- Liphschitz, N. (1996) 'The vegetation landscape of the Negev during antiquity as evidence from archaeological wood remains', *Israel Journal of Plant Sciences*, 44, pp.161–179.
- Liphschitz, N. (2007). *Timber in Ancient Israel: Dendroarchaeology and Dendrochronology*. Monograph Series 26. Tel Aviv: Tel Aviv University.
- Liphschitz, N. (2012) 'The archaeobotanical finds.', in Fischer, M. (ed.) *Horvat Mesad: A Way Station on the Jaffa –Jerusalem Road*, 30, pp. 487–495.
- Liphschitz, N. and Bonani, G. (2001) 'Wild and Cultivated Date Palm (Phoenix Dactylifera) from Qumran Cave 24', *Tel Aviv*, 28(2), pp. 305–309.
- Liphschitz, N. and Lev–Yadun, S. (1989) 'The botanical remains from Masada: identification of the plant species and the possible origin of the remnants', *Bulletin of the American Schools of Oriental Research*, 274, pp. 27–32.
- Liphschitz, N. and Waisel, Y. (1973). 'Analysis of the botanical material of the 1969–1970 seasons and the climatic history of the Beer–Sheba region', in Aharoni, Y. (ed.) *Beersheba I. Excavations at Tel Beer–Sheba. 1969–1971 seasons*. Tel Aviv: Tel Aviv University.
- Liphschitz, N. and Y. Waisel (1983). 'Analysis of the botanical material', in Fritz, V. and Kempinski, A. (eds.) *Ergebnisse der Ausgrabungen auf der Hirbet el–Msas (Tel Masos) 1972–1975*. Wiesbaden: Otto Harrassowitz, pp. 208–213.
- Liphschitz, N. and Y. Waisel (1984). *The botanical material of Iron Age I. Beersheba II. The Early Iron Age settlements*. Tel Aviv: Tel Aviv University.
- Liphschitz, N. and Y. Waisel (1989). 'Botanical remains', in Herzog, Z., Rapp, G. and Negbi, O. (eds.) *Excavations at Tel Michal, Israel*. Minneapolis: University of Minnesota Press, pp. 219–222.
- Liphschitz, N. and Y. Waisel (1992). 'Macrobotanical remains', in de Groot, A. and Ariel, D. T. (eds.) *Excavations at the City of David 1978–1985. Volume III. Stratigraphical, environmental and other reports*. Jerusalem: Hebrew University of Jerusalem, 33, pp. 105–121.
- Liphschitz, N. and Y. Waisel (1993). 'The dendroarchaeological remains at En Boqeq', in Kastell, M., Gideon, M. and von Zabern, P. (eds.) *En Boqeq. Ausgrabungen in einer Oase am Toten Meer. Band I. Geographie und Geschichte der Oase. Das Spättrömisch–Byzantinische*, pp. 391–396.
- Liu, L. *et al.* (2018) 'Fermented beverage and food storage in 13,000 y–old stone mortars at Raqefet Cave, Israel: Investigating Natufian ritual feasting', *Journal of Archaeological Science: Reports*, 21, pp. 783–793.

Livarda, A. (2008) 'The archaeobotanical remains' in Hatzaki, E., Prent, M., Coldstream J.N., Evelyn, D. and Livarda, A. (eds.) *Knossos, the little palace north project, part I: the early Greek periods*, vol 103. Athens: Annual of the British School at Athens, pp 259–271.

Livarda, A. and Kotzamani, G. (2006) 'Plant lore in 'Dark Age' Greece: archaeobotanical evidence from Lefkandi, Euboea. Literal sources and traditional knowledge combined', in Ertuğ, Z.F. (ed.) *Ethnobotany: at the junction of the continents and the disciplines*. Istanbul: Yeditepe University Istanbul, pp 435–438.

Livarda, A. and Kotzamani, G. (2018) 'People and plant entanglements at the dawn of agricultural practice in Greece. An analysis of the Mesolithic and early Neolithic archaeobotanical remains', *Quaternary International*, 496, pp. 80–101.

Livarda, A. *et al.* (2021) 'Mediterranean polyculture revisited: Olive, grape and subsistence strategies at Palaikastro, East Crete, between the Late Neolithic and Late Bronze Age', *Journal of Anthropological Archaeology*, 61, pp. 1–14.

Livarda, A and Kotzamani, G. (2013) 'The archaeobotany of Neolithic and Bronze Age Crete: synthesis and prospects', *Annals of the British School at Athens*, 108, pp. 1–29.

Liverani, M. (2003) 'The influence of political institutions on trade in the ancient Near East (Late Bronze to Early Iron Age', *Mercanti e politica nel mondo antico*, 21, pp. 119–137.

Lloyd, S. and Mellaart, J. (1965) *Beycesultan 2. Middle Bronze Age Architecture and Pottery*. Ankara: British Institute at Ankara.

Lodolini, E. M., Ferlito, F. and Neri, D. (2021) 'Pruning fig (*Ficus carica* L.) during the early stages after planting', *Acta Horticulturae*, (1310), pp. 193–198.

Lodolini, E. M. *et al.* (2019) 'Preliminary Results about the Influence of Pruning Time and Intensity on Vegetative Growth and Fruit Yield of a Semi-Intensive Olive Orchard', *Journal of Agricultural Science and Technology*, 21(4), pp. 969–980.

Lodolini, E. M. *et al.* (2023) 'Time and type of pruning affect tree growth and yield in high-density olive orchards', *Scientia Horticulturae*, 311, p. 111831.

Lodwick, L. (2019) 'Sowing the Seeds of Future Research: Data Sharing, Citation and Reuse in Archaeobotany', *Open Quaternary*, 5, pp. 7–22.

Lodwick, L. and Rowan, E. (2022) 'Archaeobotanical Research in Classical Archaeology', *American Journal of Archaeology*, 126 (4), pp. 593–623.

Langford, C. (2015) *Plant Economy of the Kura–Araxes. A comparative analysis of agriculture in the Near East from the Chalcolithic to the Middle Bronze Age*. Doctoral thesis, Sheffield: University of Sheffield.

Lord, K.A., *et al.* (2025) 'A universally applicable definition for domestication.', in *Proceedings of the National Academy of Sciences*, 122 (22), pp. 1–9.

- Lorenz, D. h. *et al.* (1995) ‘Growth Stages of the Grapevine: Phenological growth stages of the grapevine (*Vitis vinifera* L. ssp. *vinifera*), Codes and descriptions according to the extended BBCH scale’, *Australian Journal of Grape and Wine Research*, 1(2), pp. 100–103.
- Loureiro, V. (2015) ‘Origem das lagaretas escavadas na Rocha e estilo de vinhos: conjecturas de um enólogo’, in *Lagares rupestres: aportaciones para su investigación, 2015*, ISBN 978–84–606–7006–3, págs. 223–230. *Lagares rupestres: aportaciones para su investigación*, ADRA (Asociación para el Desarrollo de Rioja Alta), pp. 223–230.
- Love, K. *et al.* (2017) *Tropical Fruit Tree Propagation Guide*. Manoa: University of Hawai’ia, College of Tropical Agriculture and Human Resources Press.
- Lozano, J. (2006) *Fruit Manufacturing: Scientific Basis, Engineering Properties and Deteriorative Reactions of Technological Importance*. Springer US (Food Engineering Series).
- Lu, R. and Dudensing, R. (2015) ‘Why are they selected?’, *Agricultural and Applied Economics Association*, 30(4), pp. 1–8.
- Luce, J.M. and Marinval, P. (2008) ‘L’alimentation végétale [Vegetation Elements]’, in Luce, J.M. (ed.) *L’aire du pilierdes Rhodiens (fouille 1990–1992) à la frontière du profane et du sacré*. Athens: École française d’Athènes.
- Luke, C. and Roosevelt, C. H. (2017) ‘The Story of a Forgotten Kingdom? Survey Archaeology and the Historical Geography of Central Western Anatolia in the Second Millennium BC’, *European Journal of Archaeology*, 20(1), pp. 120–147.
- Mabry, J. B. and Donaldson, M. L. (1995) ‘Early town development and water management in the Jordan Valley: Investigations at Tell el–Handaquq North’, *Bulletin of the American Schools of Oriental Research*, 53, pp. 115 – 147.
- MacNail, K. (2001) *The Wine Bible*. New York: Workman Publishing.
- Mafrica, R. *et al.* (2025) ‘Rooting, Growth and Root Morphology of the Cuttings of *Ficus carica* L. (cv. “Dottato”): Cutting Types and Length and Growth Medium Effects’, *Plants*, 14(2), pp. 160–181.
- Maghradze, D. *et al.* (2019) ‘Progress for research of grape and wine culture in Georgia, the South Caucasus’, *BIO Web of Conferences*. Edited by J.–M. Aurand, 12, pp. 03–13.
- Maher, L. A., Banning, E. B. and Chazan, M. (2011) ‘Oasis or Mirage? Assessing the Role of Abrupt Climate Change in the Prehistory of the Southern Levant’, *Cambridge Archaeological Journal*, 21(1), pp. 1–30.
- Mahler–Slasky, Y. and Kislev, M. E. (2012) ‘Preliminary Archaeobotanical Research at Tell es–Safi/Gath – The 1997–2002 Seasons’, in Aren, M. (ed.) *Tell es–Safi/Gath I – The 1996–2005 Seasons, Volume I*. Ägypten und Altes Testament Band 69. Wiesbaden: Harrassowitz.
- Maicas, S. and Mateo, J. J. (2020) ‘Sustainability of Wine Production’, *Sustainability*, 12(2), p. 559.

- Major, J. K. (1985) *Animal Powered Machinery*. Aylesbury: Shire Album 128.
- Makishima, H. (2005) ‘Ficus sycomorus fruit production in a semi arid land in Northern Kenya: implications for understanding a possible food resource of early hominids’, *African Study Monographs*, Supplement(32), pp. 79–86.
- Malouta, M. and Wilson, A. (2013) ‘Mechanical Irrigation: Water–Lifting Devices in the Archaeological Evidence and in the Egyptian Papyri’, in Bowman, A. and Wilson, A. (eds). Oxford University Press, pp. 273–306.
- Mandelblatt, B. (2011a) ‘Atlantic consumption of French rum and brandy and economic growth in the seventeenth– and eighteenth–century Caribbean’, *French History*, 25(1), pp. 9–27.
- Mandelblatt, B. (2011b) ‘L’alambic dans l’Atlantique. Production, commercialisation, et concurrence de l’eau–de–vie de vin et de l’eau de vie de rhum dans l’Atlantique français au XVIIe et au début du XVIIIe siècle [Atlantic consumption of French rum and brandy and economic growth in the seventeenth– and eighteenth–century Caribbean]’, *Histoire, économie & société*, 30(2), pp. 63–78.
- Mandha, J. *et al.* (2023) ‘Characterization of fruit juices and effect of pasteurization and storage conditions on their microbial, physicochemical and nutritional quality’, *Food Bioscience*, 51, p. 102335.
- Mangafa, M. and Kotsakis, K. (1996) ‘A New Method for the Identification of Wild and Cultivated Charred Grape Seeds’, *Journal of Archaeological Science*, 23(3), pp. 409–418.
- Mangafa, M. (1993) ‘Αρχαιοβοτανική μελέτη του σπηλαίου Σκοτεινής στα Θαρούνια Εύβοιας [Archaeobotanical study of the cave of Skoteini at Tharounia in Euboea]’, in Sampson, A.(ed.) *Skoteini Tharrounion: the cave, the settlement and the cemetery*. Athens: Konstantopoulos Press, pp 360–369.
- Manganaro, D. *et al.* (2024) ‘Anatomy, Bony Pelvis and Lower Limb, Foot Joints’, in *StatPearls*. Treasure Island (FL): StatPearls Publishing.
- Manning, S. (2012) ‘Chronology and Terminology’, in *The Oxford Handbook of the Bronze Age Aegean*. Oxford: Oxford University Press, pp. 11–28.
- Manning, S. W. *et al.* (2018) ‘A new chronological model for the Bronze and Iron Age South Caucasus: radiocarbon results from Project ArAGATS, Armenia’, *Antiquity*, 92(366), pp. 1530–1551.
- Marcotuli, I. *et al.* (2020) ‘Fruit Development in Ficus carica L.: Morphological and Genetic Approaches to Fig Buds for an Evolution From Monoecy Toward Dioecy’, *Frontiers in Plant Science*, 11, pp. 1–14.
- Margalit, Y. (1996) *Winery Technology & Operations A Handbook for Small Wineries*. Wine Appreciation Guild.
- Margaritis, E.(2002) ‘Αρχαιοβοτανικά δεδομένα από το νεολιθικό οικισμό της Σταυρούπολης. Μια πρώτη προσέγγιση [Archaeobotanical remains from the Neolithic Site of Stavroupoli

- Thessalonikis I: a preliminary report]’, in Grammenos, D. and Kotsos, S. (eds.) *Rescue excavations from the Neolithic site of Stavroupoli, Thessaloniki*. Thessaloniki: Archaeological Institute of Northern Greece, pp. 805–827.
- Margaritis, E. (2014) ‘Acts of destruction and acts of preservation: plants in the ritual landscape of prehistoric Greece’, in Touchais, G., Laffineur, R. and Rougemont, F. (eds.) *Physis. L’environnement naturel et la relation homme–milieu dans le monde égéen Protohistorique*. Actes de la 14e Rencontre égéenne internationale, Paris, Institut National d’Histoire de l’Art (INHA), 11–14 décembre 2012. Peeters, Leuven, pp. 279–286 (Aegaeum 37).
- Margaritis, E. and Jones, M. (2008) ‘Crop processing of *Olea europaea* L.: an experimental approach for the interpretation of archaeobotanical olive remains’, *Vegetation History Archaeobotany*, 17, pp. 381–392.
- Margaryan, K. *et al.* (2019) ‘Armenian national grapevine collection: Conservation, characterization and prospects’, *BIO Web of Conferences*. Edited by J.–M. Aurand, 12, p. 01002.
- Margaryan, K. *et al.* (2021) ‘Genetic Diversity of Armenian Grapevine (*Vitis vinifera* L.) Germplasm: Molecular Characterization and Parentage Analysis’, *Biology*, 10(12), pp. 1279–1299.
- Margaryan, K. *et al.* (2023) ‘Wild grapes of Armenia: unexplored source of genetic diversity and disease resistance’, *Frontiers in Plant Science*, 14, pp. 1–16.
- Marinatos, S. and Hirmer, M. (1960) *Crete and Mycenae*. London: Thames and Hudson.
- Mars, M. (2000) ‘Pomegranate plant material: genetic resources and breeding, a review.’, *Options Méditerranéennes*, 42, pp. 55–62.
- Marston, J. and Birney, K. (2022) ‘Hellenistic agricultural economies at Ashkelon, Southern Levant’, *Vegetation History and Archaeobotany*, 31, pp. 221–245.
- Martínez Valle, A. (2014) ‘La Solana de las Pilillas y otros testimonios de producción y consumo de vino en la Meseta de Requena–Utiel’, *Lucentum*, (33), pp. 51–72.
- Martirosyan, A. A. (1974) ‘Արցիտիხինիլի/Argishtikhinili’, *Archaeological Monuments of Armenia*, (1).
- Masalha, N. (2016) ‘The Concept of Palestine: The Conception Of Palestine from the Late Bronze Age to the Modern Period’, *Journal of Holy Land and Palestine Studies*, 15(2), pp. 143–202.
- Matilla Séiquer, G. and Rivera Núñez, D.(1994) ‘Estudio paleoetnobotánico de Tell Qara Quzaq–I [Studies of paleoethnobotanical remains from Tell Qara Quzaq–I]’, in del Olmo Lete, G. (ed.) *Tell Qara Quzaq–I. Campañas I–III (1989–1991)*. Barcelona: Editorial AUSA, 4, pp. 151–182.
- Matney, T. and Algaze, G. (1995) ‘Urban Development at Mid–Late Early Bronze Age Titriş Höyük in Southeastern Anatolia’, *Bulletin of the American Schools of Oriental Research*, (299/300), pp. 33–52.

- Mattingly, D. J. (1990) 'Paintings, Presses and Perfume Production at Pompeii', *Oxford Journal of Archaeology*, 9, pp. 71–90.
- Mau, A. (1907) *Pompeii Life and Art*. Translated by F. W. Kelsey. London: Macmillan.
- Mazar, M. (1950-1951) 'The excavations at Tell Qasile: preliminary report.' *Israel Exploration Journal*, 1, pp. 61–218.
- Mazor, G. (1981) 'The Wine Presses of the Negev', *Qadmoniot*, 14(53), pp. 51–60.
- Mazza, S. and Murooka, Y. (2009) 'Vinegars Through the Ages', in Solieri, L. and Giudici, P. (eds) *Vinegars of the World*. Milano: Springer Milan, pp. 17–39.
- Mazzotti, M. (2004) 'Enlightened Mills: Mechanizing Olive Oil Production in Mediterranean Europe', *Technology and Culture*, 45(2), pp. 277–304.
- McBean, D. M. (1976) *Drying and Processing Fruits*. Melbourne: CSIRO (CSIRO Division of Food Research).
- McCorriston, J. (1995) 'Preliminary archaeobotanical analysis in the Middle Habur valley, Syria and studies of socioeconomic change in the early third millennium BC', *Bulletin of the Canadian Society for Mesopotamian Studies*, 29, pp. 33–46.
- McCown, C. C. (1947) *Tell en-Nasbeh: Excavated Under the Direction of the Late William Frederic Badè, Vol. 1: Archaeological and Historical Results*. Berkeley and New Haven: Palestine Institute of Pacific School of Religion and American Schools of Oriental Research.
- McCreery, D. W. (1981) 'Flotation of the Bab edh-Dhra and Numeira plant remains', *Annual of the American School of Oriental Research*, 46, pp. 165 – 169.
- McGeough, K. M. (2005) *Exchange relationships at Ugarit: A study of the Ugarit economic texts*. PhD. Pennsylvania: University of Pennsylvania Press.
- McGovern, P. E., Mirzorian, A. and Hall, G. R. (2009) 'Ancient Egyptian herbal wines', *Proceedings of the National Academy of Sciences*, 106(18), pp. 7361–7366.
- McGovern, P. E. (1997) 'Wine of Egypt's Golden Age: An Archaeochemical Perspective', *The Journal of Egyptian Archaeology*, 83(1), pp. 69–108.
- McGovern, P. E. (2009) *Uncorking the Past: The Quest for Wine, Beer and Other Alcoholic Beverages*. Los Angeles: University of California Press.
- McGovern, P. E. (2013) *Ancient Wine: The Search for the Origins of Viniculture*. Princeton: Princeton University Press.
- McGovern, P. E. et al. (2004) 'Fermented beverages of pre- and proto-historic China', *Proceedings of the National Academy of Sciences*, 101(51), pp. 17593–17598.
- McGovern, P. et al. (2017) 'Early Neolithic wine of Georgia in the South Caucasus', *Proceedings of the National Academy of Sciences*, 114(48), pp. 309–318.

- McKey, D. *et al.* (2010) 'The evolutionary ecology of clonally propagated domesticated plants', *New Phytologist*, 186(2), pp. 318–332.
- McKyes, E. (1985) *Soil Cutting and Tillage*. Amsterdam: Elsevier Science Publishers.
- McMahon, G. (2002) 'Comparative Observations on Hittite Rituals.', in Yener, K. A. and Hoffner, H. A. (eds) *Recent Developments in Hittite Archaeology and History: Papers in Memory of Hans G. Güterbock*. Winona Lake: Eisenbrauns, pp. 127–135.
- Meadows, J. (1996) *The final straw: an archaeobotanical investigation of the economy of a fourth millennium BC site in the Wadi Fidan, southern Jordan*. Sheffield: University of Sheffield Press.
- Megaloudi, F. (2004) 'Funeral plant offerings from Greek historical sites: a preliminary study' in Šmejda, L. and Turek, J. (eds.) *Spatial analysis of funerary areas*. Plzeň: University of West Bohemia.
- Megaloudi, F. (2006) *Plants and Diet in Greece from Neolithic to Classic Periods: The archaeobotanical remains: The archaeobotanical remains*. Ann Arbor: University of Michigan Press.
- Melamed, Y. (2013) 'Botanical Remains from the Excavation on the Southern Beach of Ashdod', *Atiqot*, 74, pp. 127–131.
- Melgarejo, P. *et al.* (1997) 'Phenological stages of the pomegranate tree (*Punka granatum* L.)', *Annals of Applied Biology*, 130(1), pp. 135–140.
- Melgarejo–Moreno, P., Martínez–Nicolás, J. J. and Tomé, J. (2000) 'Production, processing and marketing of pomegranate in the Mediterranean region: advances in research and technology. Proceedings of the symposium jointly organized by CIHEAM and Escuela Politécnica Superior de Orihuela of the Universidad Miguel Hernández (EPSO–UMH) orihuela, Spain, 15–17 October 1'.
- Melgarejo–Sánchez, P. *et al.* (2015) 'The Pomegranate Tree in the World: New Cultivars and Uses', *Acta Horticulturae*, (1089), pp. 327–332.
- Melgarejo–Sánchez, P. *et al.* (2021) 'Pomegranate variety and pomegranate plant part, relevance from bioactive point of view: a review', *Bioresources and Bioprocessing*, 8(1), pp.1–29.
- Melik–Shahnasareants, K. K. (1885) Գործնական գինեգործության ուղեցույց [*A Guidebook on Practical Winemaking*]. Yerevan: Movses Vardanean Publishing House.
- Mellal, M. K. *et al.* (2023) 'Combined Effects of Climate and Pests on Fig (*Ficus carica* L.) Yield in a Mediterranean Region: Implications for Sustainable Agricultural Strategies', *Sustainability*, 15(7), pp. 5820–5832.
- Méndez, A. I. and Falqué, E. (2007) 'Effect of storage time and container type on the quality of extra–virgin olive oil', *Food Control*, 18(5), pp. 521–529.
- Metheny, K. B. and Beaudry, M. C. (2015) *Archaeology of Food: An Encyclopedia*. Lanham:

Rowman and Littlefield.

Metzger, M. C. (1984) 'Preliminary report of the first season of the Tell el-Hayyat Project. (Faunal and floral remains at Tell el-Hayyat. Preliminary results)', *Bulletin of the American Schools of Oriental Research*, 255, pp. 68–70.

Meyer, R. S., DuVal, A. E. and Jensen, H. R. (2012) 'Patterns and processes in crop domestication: an historical review and quantitative analysis of 203 global food crops', *New Phytologist*, 196(1), pp. 29–48.

Miguel Ramos, C. (1989) 'La agricultura tradicional en Ibiza: Introduccion al estudio de la cultura material [Traditional agriculture in Ibiza: Introduction to the study of material culture]', *Etnografia Espanola*, 7, pp. 7–58.

Milevski, I. (2011) *Early Bronze Age Goods Exchange in the Southern Levant: A Marxist perspective*. London: Equinox Publishing Ltd.

Miller, A. J. and Gross, B. L. (2011) 'From forest to field: Perennial fruit crop domestication', *American Journal of Botany*, 98(9), pp. 1389–1414.

Miller, N. F., Schwartz, G. M., Curvers, H. H., Gerritsen, F. A., McCormack, J. A. and Weber, J. A. (2000) 'Plant remains', *American Journal of Archaeology*, 104, pp. 438–447.

Miller, N. F. (1996) 'Hacinebi Tepe 1993: Archaeobotanical report', *American Journal of Archaeology*, 100, pp. 248 – 257.

Miller, N.F. (1998) 'Some plant remains from the 1996 excavation at Yarim Höyük', in Rothman, M.S. (ed.) *Yarim Höyük and the Uruk expansion Anatolica*, 2, pp. 79–88.

Miller, N. F. (1999) 'Interpreting ancient environment and patterns of land use: seeds, charcoal and archaeological context', *Tüba – Ar*, 2, pp. 15 – 29.

Miller, N. F. (2008) 'Sweeter than wine? The use of the grape in early western Asia', *Antiquity*, 82(318), pp. 937–946.

Miller, N.F. (2024) *Archaeobotanical Reports from Sites in the Near East*.

Mirheidari, F. et al. (2020) 'Phenotypic variability of naturally grown edible fig (*Ficus carica* L.) and caprifig (*Ficus carica* var. *caprificus* Risso) accessions', *Scientia Horticulturae*, 267, pp. 129–174.

Mitchel, E. et al. (2012) 'Tel Gezer, Regional Survey', *Hadashot Arkheologiyot Excavations and Surveys in Israel*, 124.

Mód, L. and Simon, A. (2023) 'Ethnography and Agricultural Production: Experiences and Opportunities for Practical Application', in Borsos, B, Cseh, F. and Mesazros, C. (eds.) *Reckoning and Framing: Current Status and Future Prospects of Hungarian Ethnography in the 21st Century*. Münster: Waxmann Verlag.

- Moffett, L. (1989) 'Appendix. Early Bronze Age plant remains from Tell Nebi Mend. A preliminary report', *Levant*, 21, pp. 29 – 32.
- Mojsov, K. *et al.* (2015) 'Enzymes and wine: The enhanced quality and yield', *Savremene tehnologije*, 4(1), pp. 94–100.
- Molist, N. *et al.* (2018) 'Medieval rock-cut wine presses and cellars in Olèrdola (Barcelona)', in *A recent discovery. Proceedings of the 24th Annual Meeting of the European Association of Archaeologists/EAA*, Barcelona: Spain.
- Mon, A. M. *et al.* (2020) 'The uses of fig (*Ficus*) by five ethnic minority communities in Southern Shan State, Myanmar', *Journal of Ethnobiology and Ethnomedicine*, 16(1), p. 55–69.
- Morato–Moreno, M. and Ramírez–Juidías, E. (2024) 'Virtual Recovery of Agricultural–Industrial Heritage. A Case Study: The Olive Oil Mill of Gines (Andalusia)', in Manchado del Val, C. *et al.* (eds) *Advances in Design Engineering IV*. Cham: Springer Nature Switzerland, pp. 451–467.
- Morris, I. (2006) 'The growth of Greek cities in the first millennium BC', in *Urbanism in the Preindustrial World: Cross–Cultural Approaches*. Tuscaloosa: University of Alabama Press.
- Murphy, A. B. (2013) 'Advancing geographical understanding: Why engaging grand regional narratives matters', *Dialogues in Human Geography*, 3(2), pp. 131–149.
- Murray, M. A. (1996) 'Archaeobotanical remains, 1995 [Jerablus–Tahtani, Syria 1995: Preliminary report]', *Levant XXVIII*, pp. 20–21.
- Murray, M. A. (1998) 'Archaeobotanical report', in Peltenburg, E. (ed.) *Excavations at Kissonerga–Mosphilia, 1979–1992. Vol. II.1A (Part I)*. Lemba Archaeological Project, Cyprus. Aström: Jonsered, pp. 215–223.
- Mushtaq, M. (2018) 'Extraction of Fruit Juice: An Overview', in Rajauria, G. and Tiwari, B. K. (eds) *Fruit Juices*. San Diego: Academic Press, pp. 131–159.
- Nafees, M. *et al.* (2020) 'Biochemical Analysis of Organic Acids and Soluble Sugars in Wild and Cultivated Pomegranate Germplasm Based in Pakistan', *Plants*, 9(4), pp. 493–509.
- Nash, S. (2019) Email correspondences, 22 January, 2019.
- Nasini, L. and Proietti, P. (2014) 'Olive harvesting', in *The Extra–Virgin Olive Oil Handbook*. John Wiley & Sons, Ltd, pp. 87–105.
- Nazaretyan, H. (2023) *More Than Just Brandy: Armenia's Exports of Alcoholic Beverages Soar*. Yerevan: EVN Report.
- Neef, R., Gebel, H. G. K., Kafafi, Z. and Rollefson, G.O. (1997) 'Status and perspectives of archaeobotanical research in Jordan', in Gebel, H.G.K., Kafafi, Z. and Rollefson, G.O (eds.) *The Prehistory of Jordan II: Perspective from 1997. Studies in Early Near Eastern Production, Subsistence and Environment*, 4. Berlin: Ex Oriente, pp. 601–609.

- Neef, R. (1985). 'Botanical remains', in Kilick, A. (ed) *Udhruh – Caravan city and desert oasis*. Hampshire: Romsey.
- Neef, R. (1988). *Les activités agricoles et horticoles. Abu Hamid. Village du 4e millénaire de la vallée du Jourdain [Agricultural and horticultural activities. Abu Hamid. 4th millennium village of the Jordan Valley, Jordan]*. Amman: Centre Culturel Français et du Département des Antiquités de Jordanie.
- Neef, R. (1989) 'Plants' in, van der Kooij, G. and Ibrahim, M. (eds.) *Picking up the threads... A continuing review of excavations at Deir Alla, Jordan*. Leiden: Archaeological Centre, pp. 30 – 37.
- Nersessian, V. N. (2007) 'Armenian Christianity', in *The Blackwell Companion to Eastern Christianity*. John Wiley & Sons, Ltd, pp. 23–46.
- Nesbitt, M. (1993) 'Archaeobotanical remains', *Iran*, 31, pp. 56–58.
- Nesbitt, M. and Samuel, D. (1996) 'Archaeobotany in Turkey: a review of current research', *Orient Express*, 3, pp. 91 – 96.
- Netzer, E. (1989) 'תעלות מים ואחוזת מלכותית מהתקופה החמונאית במערב יריחו' [Water Channels and a Royal Estate from the Hasmonean Period in the Western Plains of Jericho], in Amit, D., Hirschfeld, Y. and Patrich, J. (eds) *The Aqueducts of Ancient Palestine*. Jerusalem: Yad Izhak Ben Zvi, pp. 273–282.
- Netzer, E. (2002) 'Date winepresses in the Royal Estate at Jericho', *Judea and Samara Research Studies 11*, pp. 69–80.
- Neuweiler, E. (1935) 'Nachträge urgeschichtlicher Pflanzen [Addendums to prehistoric plants]', *Vierteljahrsschr Naturforsch Ges Zürich*, 80, pp. 98–122.
- Newport, J. (2016) *A Fruity Subject: Fruit Availability and their Uses in the Mesolithic of Northwest Europe*. Masters thesis. Durham: Durham University.
- Nigro, L. and Spagnoli, F. (2018) 'Pomegranate (*Punica granatum* L.) from Motya and its deepest oriental roots', *Vicino Oriente*, 24, pp. 49–90.
- Oeconomou, A. (1996) 'Προβιομηχανικές τεχνικές παραγωγής ελαιολάδου στην περιοχή Πετρίνα Λακωνίας [Pre-industrial olive oil production techniques in the Petrina region, Laconia]', in *Olives and Olive Oil (ΕΛΙΑ ΚΑΙ ΛΑΔΙ) Proceedings of Conference at Kalamata in May 1993*. Athens: Cultural and Technological Institute of ETBA Bank, pp. 396–422.
- Ohnefash-Richter, M. A. (1913) *Griechische Gebrauche auf Zypern [Greek Usages in Cyprus]*. Berlin: Dietrich Reimer Ernst Vohsen.
- Oladoja, E. O. et al. (2021) 'Wine produced from date palm (*Phoenix dactylifera* L.) fruits using *Saccharomyces cerevisiae* X01 isolated from Nigerian locally fermented beverages', *Archives of Microbiology*, 203(1), pp. 193–204.
- Omar, S. (2010) 'Oleuropein in Olive and its Pharmacological Effects', *Scientia Pharmaceutica*,

78(2), pp. 133–154.

Onozuka, T. (2012) ‘Keeping Up with the Demand for Oil? Reconsidering the Unique Oil Presses from Late Bronze Age IIB to Iron Age IIA in the Southern Levant’ *orient*, 47(0), pp. 67–90.

Orendi, A. and Deckers, K. (2018) ‘Agricultural resources on the coastal plain of Sidon during the Late Iron Age: archaeobotanical investigations at Phoenician Tell el–Burak, Lebanon’, *Vegetation History and Archaeobotany*, 27(5), pp. 717–736.

Orendi, A. *et al.* (2017) ‘The Agricultural Landscape of Tel Burna: Ecology and Economy of a Bronze Age/Iron Age Settlement in the Southern Levant’, *Journal of Landscape Ecology*, 10(3), pp. 165–188.

Orsingher, A. *et al.* (2020) ‘Phoenician lime for Phoenician wine: Iron Age plaster from a wine press at Tell el–Burak, Lebanon’, *Antiquity*, 94(377), pp. 1224–1244.

Outram, A. K. and Bogaard, A. (2019) *Subsistence and Society in Prehistory: New Directions in Economic Archaeology*. Cambridge: Cambridge University Press.

Özdoğan, M. (2023) ‘Emergence and Dispersal of Neolithic Lifeways: From Core to Peripheries’, in Richter, T. and Darabi, H. (eds) *The Epipalaeolithic and Neolithic in the Eastern Fertile Crescent*. 1st edn. London: Routledge.

Pagnoux, C. (2019) ‘Fruitiers connus et cultivés en Grèce du Néolithique à l’époque romaine. Confrontation des données archéobotaniques et des sources écrites [Fruit trees known and cultivated in Greece from the Neolithic to Roman times. Comparison of archaeobotanical data and written sources]’, *ArchéoSciences*, 43, pp. 27–52.

Pagnoux, C. *et al.* (2021) ‘Local domestication or diffusion? Insights into viticulture in Greece from Neolithic to Archaic times, using geometric morphometric analyses of archaeological grape seeds’, *Journal of Archaeological Science*, 125, p. 105263.

Palanjyan, R. (2018) ‘Towards some problems of ancient wine–making of the Armenian highlands’, in *Archaeological Studies in Memory of Telemek Khachatryan*. Yerevan: Publishing House Gitutyun, pp. 1–24.

Palumbo, G. (1991) *The early Bronze age IV in the southern Levant: settlement patterns, economy and material culture of a ‘Dark Age’*. Roma: Università degli studi di Roma “La Sapienza (Contributi e materiali di archeologia orientale, 3).

Papasavvas, G. and Kassianidou, V. (2012) *Eastern Mediterranean Metallurgy in the Second Millennium BC*. Oxford: Oxbow Books.

Parker, B. *et al.* (2011) ‘In the Shadow of Ararat Intensive Surveys in the Araxes River Region, Naxçıvan, Azerbaijan’, *Anatolica*, 37, pp. 187–200.

Pascual, I. *et al.* (2022) ‘Grape berry transpiration influences ripening and must be composed in cv. Tempranillo (*Vitis vinifera* L.)’, *Physiologia Plantarum*, 174(4), pp. 1–11.

Pasternak, R. (1997) 'Zwischenbericht über die Arbeiten an den botanischen Funden aus Oylum Höyük: Chalkolithische Fundschichten [Interim report on the work on the botanical finds from Oylum Höyük: Chalcolithic find layers]', *Istanbuler Mitteilungen*, 47, pp. 68 – 70.

Pasternak, R. (1998) 'Übersicht über die Ergebnisse der archäobotanischen Arbeiten in Kusakli 1994 – 1997 und ein Interpretationsansatz zu den Befunden [Overview of the results of the archaeobotanical work in Kusakli 1994 – 1997 and an interpretation approach to the findings]', *Mitteilungen der Deutschen Orient-Gesellschaft zu Berlin*, 130, pp. 160–174.

Pasternak, R. (2000) "Archäobotanische Arbeiten 1999: Die Bearbeitung eines Massenfundes von Gersten im Nordflügel des Gebäudes [Archaeobotanical work 1999: Processing a mass find of barley in the north wing of Building]", *Mitteilungen der Deutschen Orient-Gesellschaft zu Berlin*, 132, pp. 348 – 351.

Pasteur, L. (1868) *Études sur le Vinaigre [Studies on Vinegar]*. Kessinger Publishing.

Pecci, A. *et al.* (2020) 'Wine consumption in Bronze Age Italy: combining organic residue analysis, botanical data and ceramic variability', *Journal of Archaeological Science*, 123, p. 105256.

Peña-Chocarro, L. *et al.* (2015) 'Storage in traditional farming communities of the western Mediterranean: Ethnographic, historical and archaeological data', *Environmental Archaeology*, 20(4), pp. 379–389.

Peña-Neira, A. *et al.* (2000) 'A survey of phenolic compounds in Spanish wines of different geographical origin', *European Food Research and Technology*, 210(6), pp. 445–448.

Pereira, C. *et al.* (2017) 'Evaluation of agronomic and fruit quality traits of fig tree varieties (*Ficus carica* L.) grown in Mediterranean conditions', *Spanish journal of agricultural research*, 15(3), pp. 1–10.

Pérez Jordà, G. *et al.* (2013) 'Stone winepress and cellars in the Iberian territory of Kelin (Utiel-Requena) (6th–2nd centuries BC)' in, Martínez Valle, A. (ed.) *Paisajes y patrimonio cultural del vino y de otras bebidas psicotrópicas: Requena, Valencia, España, del 12 al 15 abril de 2011*. Valencia: M.I Ayuntamiento de Requena, pp. 149–158.

Perold, A. I. (1911) 'The Manufacture, Properties and Uses of Brandy', *Agricultural Journal of the Union of South Africa*, 7(2).

Pessin, H. (2004) *Stratégies d'approvisionnement et utilisation du bois dans le Moyen Euphrate et la Damascène. Approche anthracologique comparative de sites historiques et préhistoriques*. Paris: Paris University of Paris.

Petrakis, C. (2006) 'Olive Oil Extraction', in Boskou, D. (ed.) *Olive Oil (Second Edition)*. AOCS Press, pp. 191–223.

Petrosyan, A. and Dan, R. (2017) 'The Kotayk Survey Project. Preliminary Report on 2015 Fieldwork Activities', *Annali Sezione Orientale*, 77(1–2), pp. 294–317.

Petrovic, A. (2005) 'Possibilities of producing grape-based alcoholic drinks from newly created

grapevine varieties’, *Journal of Agricultural Sciences*, 50 (2), pp. 183–191.

Phalanjyan, R. (2015) Խաղողագործությունը և արդյունաբերական մեղակաբույսերի մշակումը հին Հայաստանում (մ.թ.ա. VI դար – մ.թ.ա. IC դար) [*Viniculture and Processing of Industrial Crops in ancient Armenia (VI Century BCE –IC Century AD)*]. Yerevan: Institute of Archaeology and Ethnography of NAS RA.

Pinhasi, R. *et al.* (2010) ‘First Direct Evidence of Chalcolithic Footwear from the Near Eastern Highlands’, *PLoS ONE*. Edited by M. D. Petraglia, 5(6), p. E10984.

Piotrovsky, B. (1969) *Ванское царство/Kingdom of Van*. Moscow: Izdatel’stvo Oriental Literature.

Pisciotta, A., Barone, E. and Di Lorenzo, R. (2022) ‘Table–Grape Cultivation in Soil–Less Systems: A Review’, *Horticulturae*, 8(6), p. 553

Piscopo, A. and Poiana, M. (2012) ‘Packaging and Storage of Olive Oil’, in Muzzalupo, I. (ed.) *Olive Germplasm: The Olive Cultivation, Table Olive and Olive Oil Industry in Italy*. BoD – Books on Demand.

Platon, L. and Kopaka, K. (1993) ‘Ληνοί Μινωτικοί. Installations minoennes de traitement des produits liquides’, *Bulletin de correspondance hellénique*, 117(1), pp. 35–101.

Platon, N. (1971) *Zakros: the discovery of a lost palace of ancient Crete*. New York: Scribner.

Pliny (1949) *Naturalis Hlstoriae* (10 vol). Edited by H. Rackman. London: Loeb.

Polat, A. A. and Caliskan, O. (2008) ‘Fruit characteristics of table fig (*Ficus carica*) cultivars in subtropical climate conditions of the Mediterranean region’, *New Zealand Journal of Crop and Horticultural Science*, 36(2), pp. 107–115.

Poo, M. (2013) *Wine & Wine Offering In The Religion Of Ancient Egypt*. 0 edn. London: Routledge.

Popov, V. L. (2010) *Contact Mechanics and Friction: Physical Principles and Applications*. Berlin, Heidelberg: Springer Berlin Heidelberg.

Porqueddu, M.–E., Sciuto, C. and Lamesa, A. (2023) ‘Reconsidering the Chaîne Opératoire: At the Crossroad Between People and Materials’, *Open Archaeology*, 9(1), pp .220–296.

Pötl, C. (2021) *Volcanic tuffs as natural building stones: Mineralogy, technical properties, deterioration and conservation strategies*. Georg–August, University Göttingen Press.

Prabha, A. V. N. K. (2018) ‘A Short Review: Production and Characterization of Wine from Fig Fruit (*Ficus Carica*)’, *International Journal of Research*, 6(30), pp. 134–139.

Pratt, C. (2021) *Oil, Wine and the Cultural Economy of Ancient Greece: From the Bronze Age to the Archaic Era*. Cambridge: Cambridge University Press.

Pratt, C. E. (2014) *Critical Commodities: Tracing Greek Trade in Oil and Wine from the Late Bronze Age to the Archaic Period*. Los Angeles: UCLA.

- Preziuso, S. M. *et al.* (2010) 'Influence of olive crushing methods on the yields and oil characteristics', *European Journal of Lipid Science and Technology*, 112(12), pp. 1345–1355.
- Prive, J. (2003) *Иллюстрированная энциклопедия вина [Wine Illustrated Encyclopedia]*. Moscow: AO Publishing House.
- Puebla, M., Toribio, F. and Montes, P. (2003) 'Determination of Fruit Bearing Pruning Date and Cutting Intensity in "San Pedro"(Ficus carica L) Type Fig Cultivars', *Acta Horticulturae*, (605), pp. 147–157.
- Rackham, O. and Moody, J. (1996) *The Making of the Cretan Landscape*. Manchester: Manchester University Press.
- Raspuzzi, D. (2024) Email correspondences, 30 March 2024.
- Reddy, L. v. a. and Reddy, O. v. s. (2009) 'Effect of Enzymatic Maceration on Synthesis of Higher Alcohols During Mango Wine Fermentation', *Journal of Food Quality*, 32(1), pp. 34–47.
- Reed, G. and Nagodawithana, T. W. (1988) 'Technology of Yeast Usage in Winemaking', *American Journal of Enology and Viticulture*, 39(1), pp. 83–90.
- Reed, G. and Nagodawithana, T. W. (1990) 'Distiller's Yeasts', in Reed, G. and Nagodawithana, T. W. (eds) *Yeast Technology*. Dordrecht: Springer Netherlands, pp. 225–259.
- Regev, J. *et al.* (2012) 'Chronology of the Early Bronze Age in the Southern Levant: New Analysis for a High Chronology', *Radiocarbon*, 54(3–4), pp. 525–566.
- Renfrew, C. (1972) *The Emergence of Civilisation: The Cyclades and the Aegean in the Third Millennium B.C.* Methuen: Methuen Publishing.
- Renfrew, C. and Margaritis, E. (2011) 'Minoan olive oil: the first extensive production in the eastern Mediterranean. Current World Archaeology, 48, pp. 42, 46.
- Renfrew, J. (1970) *Carbonized seeds and fruits from the Necropolis of Salamis. Salamis. Excavations in the Necropolis of Salamis II (text)*, in Karageorghis, V. (ed.) Nicosia, 4, pp. 318 – 335.
- Renfrew, J. M. (1996) 'Palaeoethnobotanical Finds of Vitis from Greece', in McGovern, P., Fleming, S. and Katz, S. (eds) *The Origins and Ancient History of Wine*. Oxford: Routledge.
- Renfrew, J. M. (2002) 'Archaeology and the origins of wine production', in Sandler, M. and Pinder (eds) *Wine*. 1st edn. London: CRC Press.
- Reynier, P. (1910) 'Broyeurs et meules préhistoriques [Prehistoric crushers and millstones]', *Bulletin de la Société préhistorique française*, 7(5), pp. 284–286.
- Rice, P. M. (1996) 'The Archaeology of Wine: The Wine and Brandy Haciendas of Moquegua, Peru', *Journal of Field Archaeology*, 23(2), pp. 187–204.
- Riehl, S. (1999a) *Vorläufiger Bericht über die botanischen Funde aus Emar [Preliminary report on the botanical finds from Emar]*. Tübingen: University of Tübingen.

- Riehl, S. (1999b) 'Archäobotanik in der Troas [Archaeobotanicals of Troy]', *Studia Troica*, 9, pp. 367–409.
- Riehl, S. (2000) 'Erste Ergebnisse der archäobotanischen Untersuchungen am Tall Mozan/Urkesch [First results of the archaeobotanical investigations at Tall Mozan/Urkesch]', *Mitteilungen der Deutschen Orient-Gesellschaft zu Berlin*, 132, pp. 229–238.
- Riehl, S. (2004) 'Archaeobotany at the Early Bronze Age settlement of Hirbet ez-Zeraqon: a preliminary report', *Zeitschrift des Deutschen Palästina-Vereins*, 120(2), pp. 102–122.
- Riley, F.R. (2002) 'Olive oil production on bronze age Crete nutritional properties, processing methods and storage life of Minoan olive oil', *Oxford Journal of Archaeology*, 21(1), pp. 63–75.
- Ripoche, A. *et al.* (2011) 'Changing the soil surface management in vineyards: immediate and delayed effects on the growth and yield of grapevine', *Plant and Soil*, 339(1), pp. 259–271.
- Ristvet, L. (2018) 'Negotiation, Violence and Resistance', in *The Archaeology of Imperial Landscapes: A Comparative Study of Empires in the Ancient Near East and Mediterranean World*. Cambridge University Press, pp. 175–205.
- Riyahi, R. *et al.* (2011) 'Some physical characteristics of pomegranate, seeds and arils', *Journal of Agricultural Technology*, 7(6), pp. 1523–1537.
- Roby, C. A. (2023) *The Mechanical Tradition of Hero of Alexandria*. Cambridge: Cambridge University Press.
- Rojas Sola, J. I. and Ramírez-Arrazola, C. (2011) 'Engineering graphics applied to the study of old methods of olive oil production', *Scientific research and essays*, 6, pp. 2379–2388.
- Rollefson, G. O. (1986) 'Neolithic 'Ain Ghazal (jordan): Ritual and Ceremony, Ii', *Paléorient*, 12(1), pp. 45–52.
- Rosenthal, P. (1994) 'How on Earth Does an Olive Branch Mean Peace?', *Peace and Change*, 19(2), pp. 165–179.
- Rosianski, Y. *et al.* (2016) 'Advanced analysis of developmental and ripening characteristics of pollinated common-type fig (*Ficus carica* L.)', *Scientia Horticulturae*, 198, pp. 98–106.
- Rossiter, J. J. (1998) 'Pressing issues: wine- and oil-production', *Journal of Roman Archaeology*, 11, pp. 597–602.
- Rowan, E. (2015) 'Olive Oil Pressing Waste as a Fuel Source in Antiquity', *American Journal of Archaeology*, 119(4), pp. 465–482.
- Runnels, C.N. and Hansen, J. (1986). 'The olive in the prehistoric Aegean: the evidence for domestication in the Early Bronze Age', *Oxford Journal of Archaeology*, 5, pp. 299–308.
- Rytönen, P. (2024) 'The Armenian Wine Industry: Entrepreneurship, History, Legacy', in *New Perspective on Swedish Economic History: Institutions, Infrastructure and Finance* edited by Susane Fellman and Jan Otonson. Cham: Palgrave Macmillan, pp. 299–322.

Rytönen, P. (2024) 'The Armenian Wine Industry: Entrepreneurship, History, Legacy', in *New Perspective on Swedish Economic History: Institutions, Infrastructure and Finance* edited by Susane Fellman and Jan Otonson. Cham: Palgrave Macmillan, pp. 299–322.

Sable, P. A. (2020) 'Propagation by Sexual and Budding (Asexual) Methods in Horticulture Crops', *Indian Journal of Pure & Applied Biosciences*, 8(2), pp. 259–266.

Sáez Fernández, P. (1987) *Agricultura romana de la Bética. I*. S.l.: P. Sáez (Monografías del Departamento de Historia Antigua de la Universidad de Sevilla).

Sakai, M, *et al.* (2024) 'AI-accelerated Nazca survey nearly doubles the number of known figurative geoglyphs and sheds light on their purpose', *Proceedings of the National Academy of Sciences of the United States of America*, 121(40), e2407652121

Salavert, A. (2008) 'Olive cultivation and oil production in Palestine during the early Bronze Age (3500–2000 B.C.): the case of Tel Yarmouth, Israel', *Vegetation History and Archaeobotany*, 17(S1), pp. 53–61.

Saleh, E. (2013) 'Eating and Drinking Kefraya: The Karam in the Vineyards', in Abbots, E. and Lavis, A. (ed.) *Why We Eat, How We Eat*. London: Routledge.

Saleh, E. (2014) *Trade-marking Tradition: An Ethnographic Study of the Lebanese Wine Industry*. Doctoral Thesis. London: University of London.

Sallon, S. *et al.* (2020) 'Origins and insights into the historic Judean date palm based on genetic analysis of germinated ancient seeds and morphometric studies', *Science Advances*, 6(6), p. eaax0384

Salomón–Torres, R. *et al.* (2021) 'Date Palm Pollen: Features, Production, Extraction and Pollination Methods', *Agronomy*, 11 (504), pp. 1–23.

Sarpaki, A. (1987) *The palaeoethnobotany of the West House Akrotiri, Thera : a case study*. phd. University of Sheffield.

Sarpaki, A. (1992) 'A palaeoethnobotanical study of the West House, Akrotiri, Thera', *The Annual of the British School at Athens*, 87, pp. 219–30.

Sarpaki, A. (1995) 'Toumba Balomenou, Chaeronia: plant remains from the early and middle Neolithic levels', in Kroll, H. and Pasternak, R. (Eds.) *Res archaeobotanicae. International Work Group for Palaeoethnobotany*. Proceedings of the ninth Symposium Kiel, Kiel: Oetker–Voges, pp. 281 – 300.

Sarpaki, A. (1999) 'The archaeobotanical study of Tzambakas House, Rethymno, Crete', in Tzedakis, Y. and Martlew, H. (eds) *Minoans and Mycenaeans, Flavours of their Time*. Athens.

Sarpaki, A. (2007) 'Résultats archéobotaniques préliminaires dans divers secteurs de Malia [Preliminary archaeobotanical results in various sectors of Malia]', *Bulletin de Correspondance Hellénique*, 131, pp. 882–884.

Sarpaki, A. (2012) ‘Re-visiting the Visibility of the Grape, Grape Products, By-products and some Insights of its Organization from the Prehistoric Aegean, as Guided by New Evidence from Monastiraki, Crete’, *Interdisciplinaria Archaeologica – Natural Sciences in Archaeology*, III(2/2012), pp. 211–220

Sarpaki, A. (2016) ‘The archaeobotanical remains from EM to LMIIC at the Greek–Swedish excavations’ in Hallager, E. and Hallager, P. (eds.) *The Greek–Swedish excavations at the Agia Aikaterini Square Kastelli, Khania 1970–1987, 2001, 2005 and 2008. vol 5: The Late Minoan IIIA: I and II settlements*. Stockholm: Åströms Förlag, pp 418–446.

Sarpaki, A. (2019) ‘Akrotiri, Thera: Glimpses of the Countryside as Seen Through the Archaeological and Bioarchaeological Data. Whispers of a Dialogue’, in Garcia, D. orgeolet, R., Pomadere, M. and Zurbach, J. (eds.) *Country in the City: Agricultural Functions of Protohistoric Urban Settlements (Aegean and Western Mediterranean)*. Archaeopress, pp. 77–92.

Sarpaki, A. and Kanta, A. (2011) ‘Monastiraki, in the Amari region of Crete: some interim archaeobotanical insights into Middle Bronze Age subsistence’ *Proceedings of the 10th International Cretological Conference, Chania (1–8 October 2006)*. Chani: The Philological Society Chrysostomos, pp 247–270.

Sauvage, C. (2017) ‘The development of maritime exchange in the Bronze Age Eastern Mediterranean’, in Buchet, C., Arnaud, P. and de Souza, P. (eds) *The Sea in History – The Ancient World*. Boydell & Brewer, pp. 151–164.

Schell, C.J. (2018) ‘Urban evolutionary ecology and the potential benefits of implementing genomics’, *Journal of Heredity*, 109 (1), pp. 138–151.

Schipper, B. U. (2012) ‘Egypt and Israel: The Ways of Cultural Contacts in the Late Bronze Age and Iron Age (20th – 26th Dynasty)’, *Journal of Ancient Egyptian Interconnections*, 4(3), pp. 30–47.

Schultze–Motel, J. (1994) ‘Literature on archaeological remains of cultivated plants’, *Vegetation History and Archaeobotany*, 3(1), pp. 33–6.

Schweinfurth, G. (1884) ‘Further Discoveries in the Flora of Ancient Egypt 1’, *Nature*, 29(744), pp. 312–315.

Segal, O. (2000). ‘Rishon Le-Ziyyon’ *Excavations and Surveys in Israel*, 20, pp 66–67.

Segschneider, M. (1995) ‘Pflanzliche Großreste’, in Müller–Karpe, A. (ed.) *Untersuchungen in Kusakli 1992 – 94*, 127, pp. 27 – 30.

Segura-Borrego, M. del P. *et al.* (2024) ‘Impact of fig maceration under various conditions on physicochemical and sensory attributes of wine vinegar: A comprehensive characterization study’, *Journal of Food Science*, 89(12), pp. 8945–8968.

Seidl, U. (2004) *Bronzekunst Urartus*. Mainz am Rhein: von Zabern.

Senol, K. and Aydinoglu, U. (2010) *Olive Oil and Wine Production in Anatolia During Antiquity*. Istanbul: Ege Yayinlari.

Sethi, V. and Sethi, S. (2006) *Processing of Fruits and Vegetables for Value Addition*. Indus Publishing.

Sevak, P. (1982) Դու քի խաղողի պէս էիր [*You were like your grapes*]. Yerevan: Sovetakan Grogh Publishing House.

Sevak, P. (1982) Դու քի խաղողի պէս էիր [*You were like your grapes*]. Yerevan: Sovetakan Grogh Publishing House.

Shaheen, J., Fseha, Y. H. and Sizirici, B. (2022) ‘Performance, life cycle assessment and economic comparison between date palm waste biochar and activated carbon derived from woody biomass’, *Heliyon*, 8(12), pp.1–13.

Shanshiashvili, L. *et al.* (2024) ‘Citruillinated isomer of myelin basic protein can induce inflammatory responses in astrocytes’, *IBRO Neuroscience Reports*, 16, pp. 127–134.

Sharaf, L., El Hadidi, N. M. N. and Saber, W. E. I. A. (2022) ‘Preliminary study for the evaluation of basil essential oil in the preservation of Ficus sycomorus wood’, *Advanced Research in Conservation Science*, 3 (1), pp. 1–12.

Sharif, M. K., Zahid, A. and Shah, F.–H. (2018) ‘Role of Food Product Development in Increased Food Consumption and Value Addition’, *Food Processing for Increased Quality and Consumption*, pp. 455–479.

Sharma, A. and Thakur, N. (2018) ‘Wild pomegranate (*Punica granatum* L.): A review on physical and chemical attributes of himalayan wild pomegranate fruit’, *Journal of Pharmacognosy and Phytochemistry*, 7(4), pp. 1518–1524.

Shaw, I. and Nicholson, P. T. (2000) *Ancient Egyptian Materials and Technology*. Cambridge: Cambridge University Press.

Shaw, P. E. (2000) ‘Fruit Juices’, in *Kirk–Othmer Encyclopedia of Chemical Technology*. John Wiley & Sons, Ltd.

Shaw, S. J. (1975) ‘The Nineteenth–Century Ottoman Tax Reforms and Revenue System’, *International Journal of Middle East Studies*, 6(4), pp. 421–459

Shay, C. T. *et al.* (2014) ‘The Modern Flora and Plant Remains from Bronze Age Deposits at Kommos’, in Shaw, J. W. and Shaw, M. C. (eds) *Kommos: An Excavation on the South Coast of Crete, Volume I, Part I: The Kommos Region and Houses of the Minoan Town. Part I: The Kommos Region, Ecology and Minoan Industries*. Princeton: Princeton University Press, pp. 91–162

Shay, J., Shay, T. and Kapinga, M. (1998) ‘Appendix 4. The Bronze Age plant and insect remains and modern vegetation’, in Wahlberg, G. (ed.) *Excavations on the Acropolis of Midea: results of the Greek–Swedish Excavations, vol 1.1: the excavations on the Lower Terraces 1985–1991*. Stockholm: Åströms Förlag, pp 299–357.

- Shay, J. and Shay, T. (1978) 'Modern vegetation and fossil plant remains' in Rapp, G. and Aschenbrenner, S.E. (eds.) *Excavations at Nichoria in southwest Greece, vol I: Site, environs and techniques*. Minneapolis: University of Minnesota Press, pp 41–59.
- Shay, T. and Shay, J. M. (1995) 'The modern flora and plant remains from Bronze Age deposits at Kommos', in Shaw, J. and Shaw, M. (eds.) *Kommos I, part I. An excavation on the South coast of Crete*, Princeton: Princeton University Press, pp. 91–162.
- Shelef, O. *et al.* (2016) 'Domestication of plants for sustainable agriculture in drylands: Experience from the Negev Desert', *Arid Land Research and Management*, 30(2), pp. 209–228..
- Sheridan, A. and Bailey, G. (1981) *Economic Archaeology: Towards an Integration of Ecological and Social Approaches*. Oxford: BAR Publishing.
- Sherratt, A. (1981) 'Plough and Pastoralism: Aspects of the Secondary Products Revolution', in Sherratt, A. (ed.) *Economy and Society in Prehistoric Europe: Changing Perspectives*. Edinburgh: Edinburgh University Press, pp. 158–198.
- Sherratt, A. (1999) 'Cash–crops before cash: organic consumables and trade', in Gosden, C. and Hather, J. (eds.) *The Prehistory of Food*. London: Routledge.
- Sherratt, S. and Sherratt, A. (1993) 'The Growth of the Mediterranean Economy in the Early First Millennium BC', *World Archaeology*, 24(3), pp. 361–378.
- Shonkwiler, W. D. (1953) 'Preparation of Brandy for Bottling', *American Journal of Enology and Viticulture*, 4(1), pp. 123–127.
- Simaan, J. (2017) 'Olive growing in Palestine: A decolonial ethnographic study of collective daily–forms–of–resistance', *Journal of Occupational Science*, 24(4), pp. 510–523.
- Simchoni, O., Kislev, M. E. and Melamed, Y. (2007) 'Beth–Shean as a Trade Center For Crops in the Bronze Age: Botanical and Entomological Evidence. Chapter 15 Botanical Remains', in Mazar, A. and Mullins, R. A. (eds.) *Excavations at Tel Beth–Shean 1989–1996. Volume II. The Middle and Late Bronze Age Strata in Area R*. Jerusalem: The Hebrew University of Jerusalem.
- Simchoni, O. and Kislev, M. (2012) 'Food and Fodder in Early Bronze Age Strata in Area M. Chapter 12 Botanical Remains', in Mazar, A. (ed.) *Excavations in Tel Beth–Shean 1989–1996. Volume IV. The 4th and 3rd Millenia BCE. Mazar*. The Israel Exploration Society: The Hebrew University of Jerusalem.
- Simchoni, O. and Kislev, M. E. (2006) 'Charred By–Products of Olive–Oil Production in the Iron Age. Chapter 24', in Mazar, A. (ed.) *Excavations at Tel Beth–Shean 1989–1996. Volume I. From the Late Bronze Age IIB to the Medieval Period*. The Israel Exploration Society: The Hebrew University of Jerusalem.
- Singh, A. *et al.* (2023) 'Phenological growth and development stages of common fig (*Ficus carica* L.) under arid climate of India', *Folia Horticulturae*, 35(2), pp. 395–402.
- Skourtanioti, E. *et al.* (2020) 'Genomic History of Neolithic to Bronze Age Anatolia, Northern Levant and Southern Caucasus', *Cell*, 181(5), pp. 1158–1175.

- Sladonja, B. (ed.) (2013) *The Mediterranean Genetic Code – Grapevine and Olive*. Croatia: InTech.
- Smith, A. (2005) *Climate, culture and agriculture: examining change in the Near East during the Bronze and Iron Ages*. Doctoral thesis, Boston: Boston University.
- Smith, A. *et al.* (2014) ‘Late Chalcolithic and Medieval Archaeobotanical Remains from Areni-1 (Birds’ Cave)’, in *Stone Age of Armenia*. Center for Cultural Resource Studies, Kanazawa University, Kanazawa, Japan, pp. 233–260.
- Smith, A. T. (2000) ‘Rendering the Political Aesthetic: Political Legitimacy in Urartian Representations of the Built Environment’, *Journal of Anthropological Archaeology*, 19(2), pp. 131–163.
- Smith, A. T. and Kafadarian, K. (1996) ‘New Plans of Early Iron Age and Urartian Fortresses in Armenia: A Preliminary Report on the Ancient Landscapes Project’, *Iran*, 34, pp. 23–37.
- Smith, R., Dabney, A., Kotzamani, G., Livarda, A., Tsartsidou, G. and J., Wright. (2014) ‘Plant use in Mycenaean mortuary practices’, in Touchais, G., Laffineur, R. and Rougemont, F. (eds.) *Physis. L’environnement naturel et la relation homme-milieu dans le monde égéen Protohistorique*. Leuven: Peeters, pp 265–270.
- Smith, S. A. and Donoghue, M. J. (2008) ‘Rates of Molecular Evolution Are Linked to Life History in Flowering Plants’, *Science*, 322(5898), pp. 86–89
- Soles, J. and Davaras, C. (1994) ‘Excavations at Mochlos 1990–1991’, *Hesperia*, 63, pp. 391–436.
- Soles, J. and Davaras, C. (1996) ‘Excavations at Mochlos 1992–1993’, *Hesperia*, 65, pp. 175–230.
- Soloklui, A. A. G. *et al.* (2017) ‘Chilling and Heat Requirements of 20 Iranian Pomegranate Cultivars and Their Correlations with Geographical and Climatic Parameters, as well as Tree and Fruit Characteristics’, 52(4), pp. 560–565.
- Sommer, M. (2009) ‘Networks of Commerce and Knowledge in the Iron Age: The Case of the Phoenicians’, in Malkin, I., Constantakopoulou, C. and Panagopoulou, K. (eds) *Greek and Roman Networks in the Mediterranean*. Routledge.
- Sordinas, A. (1971) *Old Olive Oil Mills and Presses on the Island of Corfu*. Memphis: Memphis State University Anthropological Research Centre (Occasional Papers, 5).
- South, A. K. (1980) *Kalavassos–Ayios Dhimitros: A Summary Report*. Report of the Department of Antiquities Cyprus, pp. 22–53.
- Soyer, Y., Koca, N. and Karadeniz, F. (2003) ‘Organic acid profile of Turkish white grapes and grape juices’, *Journal of Food Composition and Analysis*, 16(5), pp. 629–636.
- Sparkes, B. and Talcott, L. (1974) *Athenian Agora XII: Black and Plain Pottery of the 6th, 5th and 4th Centuries B.C.* Athens: American School of Classical Studies at Athens.

- Spiegel–Roy, P. (1986) ‘Domestication of Fruit Trees’, in *Developments in Agricultural and Managed Forest Ecology*. Elsevier, pp. 201–211.
- Squitieri, A. and Eitam, D. (eds) (2019) *Stone Tools in the Ancient Near East and Egypt: Ground stone tools, rock-cut installations and stone vessels from Prehistory to Late Antiquity*. Archaeopress Publishing Ltd (Archaeopress Ancient Near Eastern Archaeology).
- Srinivas, M. S. *et al.* (2020) ‘A Review on the Preparation Method of Fruit Leathers’, *International Journal of Current Microbiology and Applied Sciences*, 9(5), pp. 773–778.
- Stager, L. E. (1985) ‘The Firstfruits of Civilization’, in Tubb, J.(ed.) *Palestine in the Bronze and Iron Ages*. London: Routledge.
- Stager, L. E. (2011) *Ashkelon 3: The Seventh Century B.C.* Pennsylvania: Penn State University
- Stager, L. E. 1943–2017 (1996) ‘Ashkelon and the archaeology of destruction: Kislev 604 BCE’, *Joseph Aviram volume*, pp. 61–74.
- Stager, L. E. and Wolff, S. R. (1981) ‘Production and Commerce in Temple Courtyards: An Olive Press in the Sacred Precinct at Tel Dan’, *Bulletin of the American Schools of Oriental Research*, 243, pp. 95–102.
- Stancin, I. and Jovic, A. (2019) ‘An overview and comparison of free Python libraries for data mining and big data analysis’, in *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*. 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia: IEEE, pp. 977–982
- Stancin, I. and Jovic, A. (2019) ‘An overview and comparison of free Python libraries for data mining and big data analysis’, in *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*. 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia: IEEE, pp. 977–982.
- Steel, L. (2018) ‘Shifting Relations in Bronze Age Gaza: An Investigation into Egyptianizing Practices and Cultural Hybridity in the Southern Levant During the Late Bronze Age’, *Journal of Ancient Egyptian Interconnections*, 20, pp. 15–20.
- Steiner, M. L. and Killebrew, A. E. (eds) (2014) ‘The Northern Levant During the Neolithic Period’, in Akkerman, P., *The Oxford Handbook of the Archaeology of the Levant: C. 8000–332 BCE*. OUP Oxford.
- Steiner, B.L., Antolin, F. and Jacomet, S. (2015) ‘Testing of the consistency of the sieving (wash-over) process of waterlogged sediments by multiple operators’, *Journal of Archaeological Science: Reports*, 2, pp. 310–320.
- Stepanyan, A. (2008) *Мотив граната в раннесредневековом изобразительном искусстве Армении [Pomegranate motif in early medieval fine art of Armenia]*.
- Stepanyan–Gandilyan, N. (2009) ‘On identification of wild relatives of cultivated plants by the

example of *Punica granatum* L. (Punicaceae). Flora, Vegetation and Plant Resources of Armenia.’, *Institute of Botany of the Armenian National Academy of Sciences*, 17, pp. 84–88.

Stepanyan–Gandilyan, N. (2012) ‘The status of cultivars and wild relatives of pomegranate (*Punica granatum* L.) in Armenia’, *Institute of Botany of the Armenian National Academy of Sciences*, pp. 164–166.

Stepanyan–Gandilyan, N. (2014) ‘Հայաստանում նուրբ հնագիտական և էթնոբուսաբանական հետազոտությունները [Archaeo and Ethnobotanical Studies of the Pomegranate in Armenia]’, in *Ethnology and Archaeology of Armenia and Neighboring Countries*. Yerevan: NAS RA Gitutyun Publishing House (Habitus: Studies in Anthropology and Archaeology), pp. 358–375.

Stepanyan–Gandilyan, N. (2020) Email correspondences, 2 September 2020.

Stern, B. *et al.* (2008) ‘New investigations into the Uluburun resin cargo’, *Journal of Archaeological Science*, 35(8), pp. 2188–2203.

Stevens, C. J. and Clapham, A. J. (2014) ‘Botanical Insights into the Life of an Ancient Egyptian Village. Excavation Results from Amarna’, in Stevens, C.J., Nixon, S., Murray, M.A and Fuller, D.Q. (eds.) *Archaeology of African Plant Use*. Walnut Creek: Left Coast Press, pp. 151–164.

Stevens, C. J. and Clapham, J. J. (2010) ‘The Botanical Samples’, in Kemp, B. and Stevens, A. (eds) *Busy Lives at Amarna: Excavations in the Main City (Grid 12 and the House of Ranefer, N49.18). Volume I: The Excavations, Architecture and Environmental Remains*. London: Egypt Exploration Society and Amarna Trust, pp. 427–444.

Stewart, N. and Warwick, S. (2005) ‘Crops Come from Wild Plants , How Domestication, Transgenes and Linkage Together Shape Fertility’, in *Crop Fertility and Volunteerism*. CRC Press, pp. 9–30.

Stewart, R. T. (1974) ‘Paleobotanical investigation: 1972 season’, in Stager, L., Walker, A. and Wright, G. E. (eds.) *American expedition to Idalion, Cyprus*. The Bulletin of the American Schools of Oriental Research, 18, pp. 123 – 129.

Stika, H.–P. (1997) ‘Pflanzenreste aus dem archaischen Milet. Vorbericht zur Kampagne 1992’, *Archäologischer Anzeiger*, 2, pp. 157 – 163.

Still, D. W. (2006) ‘Pomegranates: A Botanical Perspective’, in *Pomegranates*. CRC Press.

Stol, M. (1994) ‘Beer in Neo–Babylonian Times’, in Milano, L. (ed.) *Drinking in Ancient Society (Padova)*. Sargon, pp. 155–183.

Stone, D. (2017) *Pomegranate: A global history*. Reaktion Books.

Stratouli, G *et al.* (2014) ‘Dialogues between bioarchaeological, geoarchaeological and archaeological data: approaches to understanding the Neolithic use of Drakaina Cave, Kephallonia island, western Greece’, in Touchais, G., Laffineur, R. and Rougemont, F. (eds.) *Physis. L’environnement naturel et la relation homme–milieu dans le monde égéen Protohistorique*. Leuven: Peeters, pp 23–32.

- Tadevosyan, N. (2019). Skype call. April 2019.
- Tadovosyan, G. (2020). Skype call. April 2020.
- Taiz, Lincoln and Taiz, Lee (2017) *Flora Unveiled: The Discovery and Denial of Sex in Plants*. Oxford University Press.
- Tan, S. C. (2005) *Vinegar fermentation*. Master of Science. Louisiana State University and Agricultural and Mechanical College.
- Taylor, B. (2004) 'Fruit and Juice Processing', in Ashurst, P. R. (ed.) *Chemistry and Technology of Soft Drinks and Fruit Juices*. 1st edn. Wiley, pp. 35–67.
- Telak, L. J. et al. (2020) 'Short-Term Impact of Tillage on Soil and the Hydrological Response within a Fig (*Ficus Carica*) Orchard in Croatia', *Water*, 12(11), pp. 1–16.
- Temin, P. (2006) 'The Economy of the Early Roman Empire', *Journal of Economic Perspectives*, 20(1), pp. 133–151.
- Tengberg, M. (2012) 'Beginnings and early history of date palm garden cultivation in the Middle East', *Journal of Arid Environments*, 86, pp. 139–147.
- Tepper, Y. (1987) 'בתי הבד באזור מרשה [The Oil Presses at the Maresha Region]', in Heltzer, M. and Eitam, D. (eds) *Olive Oil in Antiquity*. Haifa: Haifa University, pp. 25–52.
- Terral, J. et al. (2012) 'Insights into the historical biogeography of the date palm (*Phoenix dactylifera*) using geometric morphometry of modern and ancient seeds', *Journal of Biogeography*, 39(5), pp. 929–941.
- Terral, J.-F. et al. (2010) 'Evolution and history of grapevine (*Vitis vinifera*) under domestication: new morphometric perspectives to understand seed domestication syndrome and reveal origins of ancient European cultivars', *Annals of Botany*, 105(3), pp. 443–455.
- Thakur, D. S., Sood, R. and Chawla, R. (2023) *Recent Trends in Agriculture Sciences*. India: Kripa–Drishti Publications.
- Thanaphon Charoensri et al. (2017) 'The Effects of Pressure and Temperature on Cold-Pressed Sesame–Oil Recovery Yield', *RMUTL Engineering Journal*, 13 (10), pp. 1–9.
- Thanassekos, S. and Scheld, A. M. (2020) 'Simulating the effects of environmental and market variability on fishing industry structure', *Ecological Economics*, 174, p. 106687.
- Thanheiser, U. (1992) 'Plant–food at Tell Ibrahim Awad: preliminary report', in van den Brin, E. (ed.) *The Nile delta in transition; 4th – 3rd millennium BC proceedings of the seminar held in Cairo, 21.–24. October 1990, at the Netherlands Institute of Archaeology and Arabic Studies*. Jerusalem, Israel Exploration Society, pp. 117– 122.
- Thanheiser, U. (1997) *Die Pflanzenfunde. Tell el-Fara'in – Buto*. Mainz :Philipp von Zabern, pp. 238 – 250.
- Thanheiser, U. (2006) 'Tell el Dab'a: The Provision of an Expanding Settlement with Plant

- Food', in Czerny, E. et al. (eds) *Timelines. Studies in Honour of Manfred Bietak*. Leuven/Paris/Dudley: Uitgeverij Peeters en Departement Oosterse Studies (Orientalia Lovaniensia Analecta).
- Theodossopoulos, D. (1999) 'The Pace of the Work and the Logic of the Harvest: Women, Labour and the Olive Harvest in a Greek Island Community', *The Journal of the Royal Anthropological Institute*, 5(4), pp. 611–626.
- This, P., Lacombe, T. and Thomas, M. R. (2006) 'Historical origins and genetic diversity of wine grapes', *Trends in Genetics*, 22(9), pp. 511–519.
- This, P. et al. (2007) 'Wine grape (*Vitis vinifera* L.) color associates with allelic variation in the domestication gene *VvmybA1*', *Theoretical and Applied Genetics*, 114(4), pp. 723–730.
- Thurmond, D. L. (2016) *From Vines to Wines in Classical Rome: A Handbook of Viticulture and Oenology in Rome and the Roman West*. Leiden: BRILL.
- Tontul, I. and Topuz, A. (2018) 'Production of pomegranate fruit leather (pestil) using different hydrocolloid mixtures: An optimization study by mixture design', *Journal of Food Process Engineering*, 41(3), p. 12–57.
- Trad, M., Renard, C. and Harbi, M. (2021) 'Key Descriptors for Sugars and Acids to Evaluate *Vitis sylvestris* Grapevines', *Agricultural and Food Sciences*, 3(103).
- Trad, M. et al. (2017) 'The Glucose–Fructose ratio of wild Tunisian grapes', *Cogent Food & Agriculture*. Edited by Y. Fatih, 3(1), pp. 1–10.
- Trainor, C. (2021) 'The late Hellenistic wine press excavations from Knossos: the early Iron Age, Hellenistic and early Roman contexts', *Annual of the British School at Athens*, 116, pp. 235–290.
- Tripler, E. et al. (2011) 'Long-term growth, water consumption and yield of date palm as a function of salinity', *Agricultural Water Management*, 99(1), pp. 128–134.
- Tsakiris, A., Kallithraka, S. and Kourkoutas, Y. (2014) 'Grape brandy production, composition and sensory evaluation', *Journal of the Science of Food and Agriculture*, 94(3), pp. 404–414.
- Tsetskhladze, G. R. (eds.) (2021) *Archaeology and History of Urartu (Biainili)*. Leuven: Peeters Leuven Publishing.
- Tsuneki, A. et al. (2006) 'The Early PPNB in the North Levant : A New Perspective from Tell Ain el-Kerkh, Northwest Syria', *Paléorient*, 32(1), pp. 47–71.
- Tumanyan, G. S. (2008) Հայաստանի գինեգործների մշակույթը [*The Culture of Winepresses of Armenia*]. Yerevan: Zangak-97 Publishing House.
- Tuna, N. (2020) 'Hellenistic–Roman Wine and Olive Oil Presses from the Knidian Territorium', *Anatolia Antiqua*, 28, pp. 47–67.
- Turker, N. and Alaeddinoglu, F. (2015) 'Viniculture in Urartu Civilization', *Enometrics Conference Proceedings*, pp. 7–16.

Turner, N. J. *et al.* (2009) 'Cultural Management of Living Trees: An International Perspective', *Journal of Ethnobiology*, 29(2), pp. 237–270.

Tyree, E. L. and Stefanoudaki, E. (1996) 'The Olive Pit and Roman Oil Making', *The Biblical Archaeologist*, 59(3), pp. 171–178.

Underwood, D. (2012) 'Reuse as Archaeology in Ostia: A Test Case for Late Antique Building Chronologies in Ostia', *Late Antiquity Archaeology*, 9(1), pp. 383–409.

Üngör, U. Ü. (2015) 'Cultural genocide : Destruction of material and non–material human culture', in *The Routledge History of Genocide*. Routledge, pp. 241–254.

Unwin, T. (1991) *Wine and the Vine: An Historical Geography of Viticulture and the Wine Trade by Unwin, Tim: (1991) | Wonderland Books*. 1st edn. London: Routledge.

Ussishkin, D. (1975) 'Hollows, "Cup–Marks," and Hittite Stone Monu–ments.', *Anatolian Studies*, 25, pp. 85–103.

Uylaşer, V. and Yildiz, G. (2014) 'The Historical Development and Nutritional Importance of Olive and Olive Oil Constituted an Important Part of the Mediterranean Diet', *Critical Reviews in Food Science and Nutrition*, 54(8), pp. 1092–1101.

Valaer, P. (1939) 'Brandy', *Industrial & Engineering Chemistry*, 31(3), pp. 339–353.

Valamoti, S. (2004) *Plants and People in Late Neolithic and Early Bronze Age Northern Greece. An archaeobotanical investigation*. British Archaeological Reports International Series 1258. Oxford: Archaeopress.

Valamoti, S. M. (1997) 'Αρχαιοβοτανικά κατάλοιπα από τον οικισμό του Αρχοντικού: ανασκαφική περίοδος Σεπτεμβρίου 1993 [Archaeobotanical remains from the settlement of Archondiko: excavation period of September 1993]' *To Archaeologiko Ergo sti Makedonia kai Thraki*, 7, pp.155–158.

Valamoti, S. M. *et al.* (2007) 'Grape–pressings from northern Greece: the earliest wine in the Aegean?', *Antiquity*, 81(311), pp. 54–61.

Vallejo–Marín, M. (2019) 'Buzz pollination: studying bee vibrations on flowers', *New Phytologist*, 224(3), pp. 1068–1074.

Van, W. S. C. L. (2006) 'An Archaeological investigation into the production of olive oil in Israel/Palestine during Iron Age I and II', *Journal for Semitics*, 15(2), pp. 564–589.

van den Brink, E. C. M. *et al.* (2001) 'Chalcolithic Dwelling Remains, Cup Marks and Olive (*Olea europaea*) Stones at Nevalat', *Israel Exploration Journal*, 51(1), pp. 36–43.

Van Limbergen, D. (2017) 'Changing perspectives on roller presses in Late Antique Northern Syria', *Syria. Archéologie, art et histoire*, (94), pp. 307–323.

Van W. Scheepers, C. L. (2006) 'An archaeological investigation into the production of olive oil in Israel and Palestine during Iron Age I and II', *Journal of Semitics*, 15(2), pp. 564–589.

- Van W. Scheepers, L. (2006) 'The olive oil industry at Ekron and co-existence under New-Assyrian dominion : a socio-economic model for South Africa', *Journal for Semitics*, 15(2), pp. 590–616.
- van Zeist, W., de Roller, G. J. (2003). 'The Çayönü Archaeobotanical Record' in van Zeist, W. (ed.) *Reports on Archaeobotanical Studies in the Old World*. Groningen: The Groningen Institute of Archeology, University of Groningen.
- van Zeist, W. (1984) 'Palaeobotanical investigations of Tell ed-Der', in de Meyer, L. (ed.) *Tell ed-Der IV. Progress reports (Second Series)*. Leuven: Peeters, pp. 119–133.
- van Zeist, W. (1988) 'Paleobotanical remains from Ikiztepe', in Alkim, U. B., Alkim, H. and Bilgi, Ö. (eds.) *Ikiztepe I. The first and second seasons' excavations (1974–1975)*. Ankara: Türk Tarih Kurumu, pp. 257–260.
- van Zeist, W. (1994) 'Some notes on second millenium BC plant cultivation in the Syrian Jazira'. *Mesopotamian history and environment*. Leuven: Peeters, 2, pp. 541 – 553.
- van Zeist, W. (1999/2000 (2001)) 'Third to first millennium BC plant cultivation on the Khabur, North-Eastern Syria', *Palaeohistoria*, 41/42, pp. 111–125.
- Van Zeist, W. (2000) 'Third to first millennium BC plant cultivation on the Khabur, north-eastern Syria', *Palaeohistoria*, pp. 111–125.
- van Zeist, W. and Bakker-Heeres, J.A.H. (1973) 'Palaeobotanical Studies of Deir'Alla, Jordan', *Paléorient*, 1, pp. 21 – 37.
- van Zeist, W. and Bakker-Heeres, J.A.H. (1985) 'Archaeobotanical studies in the Levant 4. Bronze Age sites on the north Syrian Euphrates', *Palaeohistoria*, 27, pp. 247–316.
- van Zeist, W. and de Roller, G. J. (1995) 'Plant remains from Asikli Hoyük, a pre-pottery Neolithic site in central Anatolia', *Vegetation History and Archaeobotany*, 4, pp. 179–185.
- Van Zeist, W. and Waterbolk-Van-Rooijen, W. (1985) 'The Palaeobotany of Tell Bouqras, Eastern Syria', *Paléorient*, 11(2), pp. 131–147.
- van Zeist, W. and Waterbolk-van Rooijen, W. (1988) 'Some notes on the plant husbandry of Tell Hammam et-Turkmen', in van Loon, M.N. (ed.) *Hammam et-Turkmen*. Report of the University of Amsterdam's 1981–84 excavations in Syria II. Istanbul: Nederlands Historisch-Archeologisch Instituut te Istanbul, pp. 705–715.
- van Zeist, W. and Waterbolk-van Rooijen, W. (1995a) 'Floral remains from Late Neolithic Ilipinar', in Roodenberg, J. (ed.) *The Ilipinar excavations I. Five seasons of fieldwork in NW Anatolia*. Istanbul: Nederland Historical-Archaeological Institute, pp. 159–166.
- van Zeist, W. and Waterbolk-van Rooijen, W. (1995b) 'The cultivated and wild plants', in Akkermans, P.M.M.G. (ed.) *Tell Sabi Abyad. The late Neolithic settlement*, 2, pp. 521–550.
- Varro (1979) 'Marcus Terentius Varro: Rerum Rusticarum', in Hooper, W. D. (ed.) *Cato and*

Varro. London: Loeb.

Veberic, R. and Mikulic–Petkovsek, M. (2016) ‘Phytochemical Composition of Common Fig (*Ficus carica* L.) Cultivars’, in *Nutritional Composition of Fruit Cultivars*, pp. 235–255.

Viecelli, C. (2022) *Crafting Alternatives through Wine: An Ethnography of Female Natural Winegrowers in Italy*. Doctoral Thesis, Southampton: University of Southampton.

Vincent, L. and Meena, S. (2025) ‘Genetic Diversity of Pomegranate (*Punica granatum* L.) and Sustainable Utilization’, in *Genetic Diversity of Fruits and Nuts*. CRC Press.

Vincze, I. (1959) ‘Ungarische Weinkelter [Hungarian Wine Press]’, *Acta Ethnographica Academiae Scientiarum Hungaricae*, 8(2), pp. 99–129.

Viola, F. *et al.* (2012) ‘Olive yield as a function of soil moisture dynamics’, *Ecohydrology*, 5(1), pp. 99–107.

Vossen, P. (2013) ‘Growing Olives for Oil’, in Aparicio, R. and Harwood, J. (eds) *Handbook of Olive Oil*. Boston, MA: Springer US, pp. 19–56.

Wachter–Sarkady, C. (1995) ‘Ebla e le condizioni materiali della produzione agricola nell’antico Orient [Ebla and the material conditions of agricultural production in the ancient Orient]’, in Matthiae, P., Pinnock, F. and Matthiae, G. S. (eds) *Ebla: Alle origini della civiltà urbana*. Milan: Electa, pp. 242–251.

Wachter–Sarkady, C. (1998) ‘Archaeobotanical investigations’, in Cecchini, S. M. and Mazzoni, S. (eds.) *Tell Afis (Siria). Scavi sull’acropoli 1988 – 1992*. Pisa: Edizioni ETS, pp. 451–480.

Wachter–Sarkady, C. (2013). ‘Consuming Plants. Archaeobotanical Samples from Royal Palace G and Building P4’, in Matthiae, P. and Marchetti, N (eds.) *Ebla and its Landscapes. Early State Formation in the Ancient Near East*.

Walker, A. (2008) *Bronze Age and Iron Age charred plant remains from Tell Nebi Mend, Syria*. MSc Thesis, Sheffield: University of Sheffield.

Wallace, M. *et al.* (2018) ‘Origins of agriculture: archaeobotanical database’. Archaeology Data Service.

Walsh, C. E. (2018) *The Fruit of the Vine: Viticulture in Ancient Israel*. Leiden: BRILL.

Ward, C. (2003) ‘Pomegranates in eastern Mediterranean contexts during the Late Bronze Age’, *World Archaeology*, 34(3), pp. 529–541.

Warinner, C. and D’Alpoim Guedes (2014) ‘Digitizing the Archaeobotanical Record’, in Marston, J., Guedes, J. and Warinner, C. (eds.) *Method and Theory in Paleoethnobotany*. Boulder: University Press of Colorado.

Warnock, P. (2007) *Identification of Ancient Olive Oil Processing Methods Based on Olive Remains*. Oxford: BAR Publishing.

Waterhouse, A. L., Sacks, G. L. and Jeffery, D. W. (2024) *Understanding Wine Chemistry*. John

Wiley and Sons.

Weiberg, E. *et al.* (2019) 'Mediterranean land use systems from prehistory to antiquity: a case study from Peloponnese (Greece)', *Journal of Land Use Science*, 14(1), pp. 1–20.

Weiss, E. (2011). 'Plant Remains', in Faust, A. and Erlich, A. (eds.) *The Excavations of Khirbet er-Rasm, Israel. The Changing Faces of the Countryside*. BAR International Series 2187. Oxford: BAR Publishing.

Weiss, E. (2015) "'Beginnings of Fruit Growing in the Old World" – two generations later', *Israel Journal of Plant Sciences*, 62, pp. 75–85.

Weiss, E. and Kislev, M. E. (2007) 'Plant remains as a tool for reconstruction of the past environment, economy and society: Archaeobotany in Israel', *Israel Journal of Earth Sciences*, 56(2), pp. 163–173.

Weiss, E and Kislev, M. E. (2004). 'Plant Remains as Indicators for Economic Activity: A Case Study from Iron Age Ashkelon.', *Journal of Archaeological Science*, 31, pp 1–13.

Western, A. C. (1971) 'The ecological interpretation of ancient charcoals from Jericho.', *Levant* 3, pp. 31 – 40.

Wheeler, M., (1954) *Archaeology from the earth*. Oxford: Clarendon Press.

White, C. E., Chesson, M. S. and Schaub, R. T. (2014) 'A recipe for disaster: emerging urbanism and unsustainable plant economies at Early Bronze Age Ras an-Numayra, Jordan', *Antiquity*, 88(340), pp. 363–377.

White, C. E., Chesson, M. S. and Schaub., T. (2014) 'A Recipe for Disaster: Emerging Urbanism and Unsustainable Plant Economies at Early Bronze Age Ras an-Numayra, Jordan', *Antiquity*, 88(340), pp. 363–377.

White, C. E. and Makarewicz, C. A. (2012) 'Harvesting practices and early Neolithic barley cultivation at el-Hemmeh, Jordan', *Vegetation History and Archaeobotany*, 21(2), pp. 85–94.

White, C. E. and Miller, N. F. (2018) 'The Archaeobotany of Grape and Wine in Hittite Anatolia', *Die Welt des Orients*, 48(2), pp. 209–224.

Whitlam, J., Finlayson, B., Bogaard, A., Charles, M. and Makarewicz, C.A. (2023) 'Processing and storage of tree fruits, cereals and pulses at PPNA Sharara, southern Jordan.', *Vegetation History and Archaeobotany*, 32, pp. 501-516.

Wiersma, C. W. and Voutsaki, S. (eds) (2016) *Social Change in Aegean Prehistory*. Oxbow Books.

Willcox, G. (1981) 'Plant remains' in Helms, S.W. (ed.) *Jawa, lost city in the Black Desert*. London: Methuen, pp. 247–248.

- Willcox, G. (1999) 'Charcoal analysis and Holocene vegetation history in southern Syria.' Quaternary Science Reviews INQUA symposium Ankara, *The late Quaternary in the Eastern Mediterranean*, pp. 711–716.
- Willerding, U. (1973) *Bronzezeitliche Pflanzenreste aus Iria und Synoro [Bronze Age plant remains from Iria and Synoro]*. Mainz: P von Zabern (Tiryns : Forschungen und Berichte 6).
- Willerding, U. and Wolf, G. (1991) 'Paläoethnobotanische Untersuchungen von Pflanzenresten aus dem 1. Jahrtausend v.Chr. von Elephantine [Paleoethnobotanical studies of plant remains from the 1st millennium BCE from Elephantine]', *Mitteilungen des Deutschen Archäologischen Instituts Kairo*, 46, pp. 263–267.
- Williams, L. E., Dokoozlian, N. K. and Wample, R. (1994) 'Grape', in *Handbook of Environmental Physiology of Fruit Crops*. CRC Press.
- Winkler, J. A. *et al.* (2013) 'Understanding the Impacts of Climate on Perennial Crops', in *Climate Vulnerability*. Elsevier, pp. 37–49.
- Winter, M. and Herrmann, K. (1986) 'Esters and glucosides of hydroxycinnamic acids in vegetables', *Journal of Agricultural and Food Chemistry*, 34(4), pp. 616–620.
- Woolley, C. L. (1914) *Carchemish* (3 vol). Oxford: British Museum.
- Wright, G. E. (no date) *Shechem: The Biography of a Biblical City*. London: Duckworth.
- Wright, K. (1991) 'The Origins and development of ground stone assemblages in Late Pleistocene Southwest Asia', *Paléorient*, 17(1), pp. 19–45.
- Wulff, H. E. (1966) *The Traditional Crafts of Persia*. Cambridge: MIT Press.
- Xin, H. *et al.* (2013) 'The effects of artificial selection on sugar metabolism and transporter genes in grapes', *Tree Genetics & Genomes*, 9(5), pp. 1343–1349.
- Yalcin, O., Bassil, N. V. and Kafkas, N. E. (2022) 'Wild Edible Small Fruits in Turkey and their Fruit Characteristics', *Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact and Applied Sciences.*, 76(4), pp. 417–423.
- Yannai, E. and Marder, O. (2000) 'Lod' *Hadashot Arkheologiyot: excavations and surveys in Israel*, 112, pp. 63–65.
- Yasuda, Y. (1997) 'The rise and fall of olive cultivation in north–western Syria: Palaeoecological study of Tell Mastuma', *Nichibunken Japan Review: Bulletin of the International Research Center for Japanese Studies*, 8, pp. 251–273.
- Yasur-Landau, A. *et al.* (2018) 'The Wine Storage Complexes at the Middle Bronze II Palace of Tel Kabri: Results of the 2013 and 2015 Seasons', *American Journal of Archaeology*, 122(2), pp. 309–338.
- Yateem, A. A. (2009) 'Agriculture and pastoralism in the Hajar mountains of the Emirates: a historical ethnography', *Journal of the Gulf and Arab Peninsula Studies*, 35, p. 17–85.

- Yengibaryan, N. (2011) 'The Urartian Pithos Burial of Agarak', 101(1), pp. 152–155.
- Yokotsuka, K. (1990) 'Effect of press design and pressing pressures on grape juice components', *Journal of Fermentation and Bioengineering*, 70(1), pp. 15–21.
- Zahedi, S. M. *et al.* (2022) 'Evaluation of drought tolerance in three commercial pomegranate cultivars using photosynthetic pigments, yield parameters and biochemical traits as biomarkers', *Agricultural Water Management*, 261(25), pp. 107357.
- Zaid, A. and de Wet, P. F. (2002) 'Origin, Geographical Distribution and Nutritional Values of Date Palm', in *Date Palm Cultivation*. Rome: Food and Agriculture Organisation of the United Nations.
- Zaitschek, D. V. (1961) 'Remains of cultivated plants from the caves of Nahal Mishmar.' *Israel Exploration Journal*, 11, pp. 70 – 72.
- Zeder, M. A. (2008) 'Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion and impact', *Proceedings of the National Academy of Sciences*, 105(33), pp. 11597–11604.
- Zemer, A. (1978) *Storage jars in Ancient Sea trade*. Haifa: National Maritime Museum.
- Zhang, R. *et al.* (2014) 'Effect of water stress in different growth stages on grape yield and fruit quality under delayed cultivation facility', *Transactions of the Chinese Society of Agricultural Engineering*, 30(24), pp. 105–113.
- Zhang, S. Y., Ren, H. and Jiang, Z. (2021) 'Wood density and wood shrinkage in relation to initial spacing and tree growth in black spruce (*Picea mariana*)', *Journal of Wood Science*, 67(1), pp. 30–40.
- Zhang, X. *et al.* (2022) 'Identification, Analysis and Gene Cloning of the SWEET Gene Family Provide Insights into Sugar Transport in Pomegranate (*Punica granatum*)', *International Journal of Molecular Sciences*, 23(5), p. 24–71.
- Zhang, Y. and Keller, M. (2015) 'Grape Berry Transpiration Is Determined by Vapor Pressure Deficit, Cuticular Conductance and Berry Size', *American Journal of Enology and Viticulture*, 66(4), pp. 454–462.
- Zhou, Y., Muyle, A. and Gaut, B. S. (2019) 'Evolutionary Genomics and the Domestication of Grapes', in Cantu, D. and Walker, M. A. (eds) *The Grape Genome*. Cham: Springer International Publishing (Compendium of Plant Genomes), pp. 39–55.
- Zimansky, P. (1998) *Ancient Ararat: A Handbook of Urartian Studies*. New York: Caravan Books.
- Zimansky, P. (2011) 'Urartu and Urartians', in Steadman, S. and McMahon, G. (eds) *The Oxford Handbook of Ancient Anatolia*. Oxford: Oxford University Press.
- Zimansky, P. (2021) 'An Overview Of Urartian Studies: The Philological Recovery and Archaeological Exploration of Urartu', in Tsetschladze, G. *et al.* (eds) *Archaeology and History*

of Urartu (*Biainili*). Leuven: Peeters Publishers.

Zoecklein, B. W. (2012) *Production Wine Analysis*. Springer Science and Business Media.

Zohary, D., Hopf, M. and Weiss, E. (2012) *Domestication of Plants in the Old World: The origin and spread of domesticated plants in Southwest Asia, Europe and the Mediterranean Basin*. Oxford University Press.

Zohary, D. (1995) ‘Olive. *Olea europaea* (oleaceae)’, in: Smart, J. and Simmons, N.W. (eds.) *Evolution of Crop-Plants*. London: Longmans, pp. 279–382.

Zohary, D. and Spiegel–Roy, P. (1975) ‘Beginnings of fruit growing in the old world’, *Science* (New York, N.Y.), 187(4174), pp. 319–327.

Zois, A. (1992) ‘Βασιλική Ιεράπετρας [Vasiliki Ierapetras]’, *Archaeological Society of Athens*, pp. 109–111.

Zuiderhoek, A. (2013) ‘Economy, Hellenistic and Roman Period’, in *The Oxford Encyclopedia of the Bible and Archaeology*. Oxford University Press.

Сборник сведений по виноградарству и виноделию на Кавказе. Эриванская губерния [Collection of Information on Viticulture and Winemaking in the Caucasus. Erivan Governorate] (1896). Tiflis: Ministry of Agriculture and State Property in the Caucasus K.P. Kozlovski Publishing House (The Publication of the Caucasian Pylloxera Committee).

‘ADEMNES– Archaeobotanical database of Eastern Mediterranean and Near Eastern sites’ (2010). Tübingen: DFG–Deutsche Forschungsgemeinschaft.

‘Electronic Corpus of Urartian Texts (eCUT)’ (2020). Munich: LMU Munich.

‘Integrated Archaeobotanical Research Project’ (2009). Sheffield: University of Sheffield.

‘Literature database ArchbotLit’ (2018). Germany: Niedersächsisches Institut für historische Küstenforschung.

‘Mapping Ancient Urartu’ (2023). Brown University’s Center for Digital Scholarship: Brown University.

‘mec Engineering Spreadsheets’(2024) mec Engineering Spreadsheets.

‘Հայաստանի Հանրապետության 2011 թվականի մարդահամարի արդյունքները/ The results of the 2011 population census of the Republic of Armenia’ (2011). Երևան, Հայաստան: Հայաստանի Հանրապետության վիճակագրական կոմիտե.

Appendices Explanation

Appendix 10 was formatted in a more conventional style but is still provided as a hyperlink and contains links to the sensitivity analyses. In contrast, Appendices 1–9 and 11–12 were intentionally left in spreadsheet form and provided as spreadsheets as a strategic choice. This format was chosen for several reasons:

Clarity, Simplicity and Organisation:

Spreadsheets excel at organising large volumes of data. Their clearly displayed rows and columns preserve the structure and context of the raw data, helping readers quickly understand how the data is arranged and analysed.

Data Integrity and Reproducibility:

Maintaining the data in its original spreadsheet format preserves its exact details and structure, minimising the risk of misinterpretation or errors that could arise from reformatting it into text or tables. Direct access to the data facilitates verification of results, replication of analyses and further exploration, key aims of this research.

Accessibility and Ease of Use:

Providing the data in spreadsheets makes it more accessible to a wide audience. Readers can view and interact with the data directly, which enhances transparency and user-friendliness. This approach eliminates the need for peers and researchers to recreate or reformat the data, ensuring a more efficient research experience. Furthermore, modern spreadsheet applications support screen readers and other accessibility tools, allowing individuals with visual impairments or other disabilities to interact with and understand the data effectively. Integrating spreadsheet data directly into academic work and appendices has become increasingly common over the past decade. For example, see Fuller and Stevens (2019).

Together, these factors ensure the chosen format is clear, reliable and accessible to all users. Below is a list of appendices with hyperlinks to their corresponding spreadsheets.

List of Appendices

Appendix 1 - New chronology of the time periods under study

Appendix 2 - Armenian Ethnographic Project Data

Appendix 3 - Effectiveness and Benefits of a Basket Press, Single-Screw Press, Double-Screw Press and Feet Treading

Appendix 4 - Archaeobotanical Dataset of Vitis

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Appendix 9a - Archaeological Data of SLWPs (Niches)

Appendix 9b - Archaeological Data of SLWPs (Weights)

Appendix 9c - Archaeological Data of SLWPs (Press Beds)

Appendix 10 - Effectiveness of Processing Methods Using Mechanical Engineering and Maths

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Appendix 12 - Archaeological Data for Prehistoric and Historic Armenian Wine Presses