Agriculture in Transition: An Archaeobotanical Study of Bronze Age Sites in the Southern Levant

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"Se tu segui tua stella,
non puoi fallire a glorioso porto,
se ben m'accorsi nella vita bella"

Contents

Abbreviations

BCE	Before Common Era
CA	Correspondence Analysis
CCA	Canonical Correspondence Analysis
CE	Common Era
CO_2	Carbon dioxide
CRC	Collaborative Research Centre
DCA	Detrended Correspondence Analysis
EBA	Early Bronze Age
GIS	Geographic information system
HCI	Hydrochloric acid
LBA	Late Bronze Age
Km	Kilometer
MBA	Middle Bronze Age
Mm	Millimeter
SFB	(see CRC)

Abstract

The archaeobotanical research presented in this dissertation focuses on the study of plant macro remains from archaeological Bronze Age sites (3600 BCE – 1200 BCE) in the southern Levant. Although the Levant has been and is the subject of numerous scientific studies, several gaps still exist, including those related to archaeobotanical research. Numerous sites, including those extensively studied, lack systematic botanical sampling, environmental data, or even a comprehensive archaeobotanical investigation. Additionally, there is a scarcity of regional diachronic syntheses that compare the findings of these archaeobotanical studies. This deficiency hinders a comprehensive understanding of agricultural development and resources within specific chronological ranges.

The work presented here thus concerns the analysis of plant macro remains from two significant sites in the southern Levant: Lachish, one of the most influential cities during the Late Bronze Age, where previous botanical investigations were limited to charcoal remains and handpicked materials, and Tel Kabri, previously unexplored in terms of carpological studies, renowned for its Middle Bronze Age palace that houses the earliest known wine cellar in the ancient Near East. Plant macro remains from various contexts, encompassing both wild species and cultivated crops, were retrieved and analyzed from approximately 6500 liters of sediment collected. These analyses have been complemented and integrated with other types of research, such as environmental, isotopic, iconographic studies and multivariate statistics. Indeed, Correspondence Analyses were utilized to compare the results of the botanical assemblages with those of other coeval sites in the Levant.

The results enhanced our knowledge of the agricultural resources at both sites and have provided deeper insights into the nature of the archaeological contexts from which the samples originated. The botanical assemblages at both sites are predominantly characterized by fruit crop taxa, with olive being the most prevalent, indicating a common trend among southern Levant sites that initiated intensified horticulture and vineyard cultivation from the Early Bronze Age onwards. Through the comprehensive analysis of the evolution of agrarian resources throughout the Bronze Age, it becomes evident that agricultural practices in the southern Levant were influenced not only by climatic changes but also by cultural and economic factors. The results underscore the value of this archaeobotanical research in filling research gaps and serving as an essential tool to reconstruct crucial archaeological information at the individual sites. Moreover, it contributes to reconstructing the agricultural resources transition within a broader regional context.

Zusammenfassung

Diese archäobotanische Forschung konzentriert sich auf die Untersuchung von Pflanzenmakroresten aus archäologischen Bronzezeitstätten (3600 v. Chr. - 1200 v. Chr.) im südlichen Levante. Obwohl der Levant Gegenstand zahlreicher wissenschaftlicher Studien war und ist, bestehen immer noch mehrere Lücken, darunter solche im Zusammenhang mit archäobotanischer Forschung. Zahlreiche Stätten, einschließlich derjenigen, die umfangreich untersucht wurden, weisen keine systematische botanische Probenahme, Umweltdaten oder sogar eine umfassende archäobotanische Untersuchung auf. Darüber hinaus gibt es einen Mangel an regionalen diachronen Synthesen, die die Ergebnisse dieser archäobotanischen Studien vergleichen. Diese Lücke behindert ein umfassendes Verständnis der agrarischen Entwicklung und Ressourcen innerhalb bestimmter chronologischer Bereiche. Die hier vorgestellte Arbeit betrifft daher die Analyse von Pflanzenmakroresten aus zwei bedeutenden Stätten im südlichen Levante: Lachisch, einer der einflussreichsten Städte während der Spätbronzezeit, wo frühere botanische Untersuchungen auf Holzkohlereste und handverlesene Materialien beschränkt waren, und Tel Kabri, bisher noch unerforscht in Bezug auf karpologische Studien, bekannt für seinen Palast aus der Mittelbronzezeit, der den ältesten bekannten Weinkeller im antiken Nahen Osten beherbergt. Pflanzenmakroreste aus verschiedenen Kontexten, die sowohl wilde Arten als auch kultivierte Kulturen umfassen, wurden aus etwa 6500 Litern gesammeltem Sediment extrahiert und analysiert. Diese Analysen wurden durch andere Arten von Forschung wie Umwelt-, Isotopen-, ikonografische Studien und multivariate Statistiken ergänzt und integriert. Tatsächlich wurden Korrespondenzanalysen verwendet, um die Ergebnisse der botanischen Assemblagen von diesen beiden Stätten mit denen anderer zeitgenössischer Stätten im Levant zu vergleichen.

Die Ergebnisse erweiterten unser Wissen über die agrarischen Ressourcen an beiden Stätten und lieferten tiefere Einblicke in die Natur der archäologischen Kontexte, aus denen die Proben stammten. Die botanischen Assemblagen an beiden Stätten sind überwiegend durch Fruchtpflanzentaxa gekennzeichnet, wobei Oliven am häufigsten sind, was auf einen gemeinsamen Trend bei Stätten im südlichen Levante hinweist, der seit der frühen Bronzezeit eine intensivierte Gartenbau- und Weinbaukultur initiiert. Durch die umfassende Analyse der Entwicklung der agrarischen Ressourcen während der Bronzezeit wird deutlich, dass landwirtschaftliche Praktiken im südlichen Levante nicht nur von klimatischen Veränderungen, sondern auch von kulturellen und wirtschaftlichen Faktoren beeinflusst wurden. Die Ergebnisse unterstreichen den Wert dieser archäobotanischen Forschung bei der Schließung von

Forschungslücken und als unverzichtbares Instrument zur Rekonstruktion wichtiger archäologischer Informationen an den einzelnen Stätten. Darüber hinaus trägt sie zur Rekonstruktion des agrarischen Übergangs im breiteren regionalen Kontext bei.

List of Publications:

1.Nicoli’ M, Riehl S, Webster L, Streit K, Höflmayer F (2022) Agriculturalresources in the Bronze Age city of Tel Lachish. Veget Hist Archaeobot 31, 559–577

2.Nicoli’ M, Riehl S, Cline E H, Yasur-Landau A (2023) From Early Bronze Age domestic plant production to Middle Bronze Age regional exchange economy: the archaeobotanical assemblages from Tel Kabri. Archaeol Anthropol Sci 15:128

3.Grasso A M, D’Aquino S, Vacca E, Nicoli’ M, Primavera M, Fiorentino G (2021) Innovation: Turning Something Old into Something New. Vicia faba var. major. In Grau Sologestoa I, Albarella U (eds.) The Rural World in the Sixteenth Century, Turnhout

Personal Contributions

A declaration of the significance of the own part according to § 6, 2 of PromO2, together with the "Declaration concerning Collaborative Publications."

I am the first and corresponding author of the first and second publication provided here. I conceptualized the project ideas, conducted all the archaeobotanical and statistical analyses, created graphs and maps. In the third publication I collected evidences and analyzed part of the research.

Manuscript 1 and 2: Simone Riehl helped with conceptualization, review and editing. Assistance with botanical identifications and interpretations. For manuscript 2 she also provided stable isotope analysis and writing of the chapter.

Manuscript 1 Katharina Streit and Felix Höflmayer are directors of the Tel Lachish excavations and provided editorial input.

Manuscript 2 Eric Cline and Assaf Yasur-Landau are directors of the Tel Kabri excavations and provided editorial input.

Manuscript 3 Anna Maria Grasso is the corresponding author and main researcher. Girolamo Fiorentino helped designing the research and collected evidences. Eligio Vacca helped analyzing the data. Silvia D'Aquino and Milena Primavera, collected evidences and analyzed part of the research.

1. Introduction

Archaeobotanical research plays a crucial role in comprehending the evolution of ancient societies. Investigating the impact of the environment on the transformative processes that societies undertook to meet their needs is essential for forming a comprehensive understanding of the intricate relationship between humanity and the environment, individual dietary practices, economic strategies, and agricultural production. Archaeobotany directs its research toward these aspects, exemplifying the significance of amalgamating a scientific approach with humanities studies within its interdisciplinary framework.

The study of plant remains is considered fundamental, as corroborated by a recent published review outlining the primary challenges in archaeology (Kintigh et al. 2014). In addressing some of the listed "grand challenges" for archaeology, archaeobotany emerges as a crucial tool for finding answers, particularly in challenges related to the resilience, persistence, transformation, and collapse of societies (Kintigh et al. 2014). These issues are intricate and would be challenging to resolve through alternative approaches, as they are connected to understanding how diverse human groups engage with their environment, climatic fluctuations and social pressure, through changes in their subsistence strategies (e.g. Riehl 2009, Primavera et al. 2017, Clarke et al. 2016)

It is important to acknowledge that the findings of an archaeobotanical study provide only a partial representation of the actual plant resources present in a given time and location. One must recognize that botanical remains are recovered from anthropogenic sediments, reflecting the choices made by humans during that period. The results are influenced by preservation conditions and specific taphonomic processes. However, investigations into plant remains provide a distinctive and invaluable source of information, yielding unique insights and results that would be otherwise unattainable.

As one of the hubs for plant domestication, the Near East has consistently been one of the most extensively excavated and studied regions in the world. Over the years, numerous studies and archaeobotanical analyses have been conducted, primarily focusing on the reconstruction of plant exploitation at archaeological sites.

However, several research gaps persist, including the absence of systematic sampling for many sites, a scarcity of stable isotope analyses across various periods, resulting in incomplete environmental data, and a lack of syntheses on the diachronic regional development of crop cultivation. Addressing these gaps is crucial for a more comprehensive understanding of the historical dynamics in the Near East.

This dissertation concentrates on the southern Levant region, employing archaeobotanical analyses to study Bronze Age sites. The research involves the identification and interpretation of plant macro-remains, and a diachronic study is conducted to compare various results.

The southern Levant (Figure 1) indicate the area corresponding to modern-day Jordan, Israel, Palestine and southern Lebanon. It is characterized by different climate areas and includes four north-south geographical features: the coastal plain, distinct by its Mediterranean climate; the western mountains ranging from Mediterranean climate on the west side to desert and semi-desert on the east side; the rift valley composed by desert areas on the south and Mediterranean wood climate on the north, the Transjordan Plateau delimited by the Jordan river on the west and the desert on the east (Zohary 1962).

The framework of this dissertation will range within the southern Levant Bronze Age and it will adopt the chronology of Kamlah and Riehl (in press) (table 1). This follows the southern Levant chronology developed by Sharon (2014) for the "Oxford Handbook of the Archaeology of the Levant" (Steiner und Killebrew 2014).

Chronological Period	Absolute Dating
Early Bronze Age (EBA)	3600 – 2000 BCE
- Early Bronze Age I (EBA I)	3600 – 3000 BCE
- Early Bronze Age II (EBA II)	3000 – 2850 BCE
- Early Bronze Age III (EBA III)	2850 – 2400 BCE
- Early Bronze Age IV (EBA IV)	2400 – 2000 BCE
Middle Bronze Age (MBA)	2000 – 1550 BCE
Late Bronze Age (LBA)	1550 – 1200 BCE

Table 1 Southern Levant Bronze Age chronology and abbreviations used in this dissertation.

Fig. 1 Map of southern Levant with the location of two sites discussed in this dissertation (Google Earth).

1.1 Objectives of Study

Studying plant assemblages within archaeological sites offers a means to enhance our understanding of agricultural resource utilization. As such, the initial phase of this study involved the examination of plant macro-remains collected from two sites situated in modern-day Israel (see Figure 1):

- Lachish, whose contexts analyzed belongs to Middle and Late Bronze Age layers;
- Tel Kabri, with a focus on the Middle and Early Bronze Age deposits;

Earlier archaeobotanical investigations in both sites predominantly focused on charcoal remains (Liphschitz 2002 and 2004). While Tel Kabri has never undergone analysis for its seed remains, Lachish did have a carpology study conducted, but it primarily focused on general proportions and ubiquity (Helbæk 1958). This approach is consistent with the historical tendency to exclusively collect larger seeds, leading to their overrepresentation in the assemblages, at the expense of smaller-seeded and wild taxa. This limited approach does not facilitate comparative studies over time or across different regions. The botanical assemblages from these sites and their contexts have been investigated to fill these gaps and understand the use of site-specific agricultural resources.

A subsequent step involves comparing botanical assemblages within the contemporary regional context. Archaeobotanical analyses provide insight into the changes in various crops in the southern Levant and their implications for the social dynamics of different societies. By employing Correspondence Analysis (CA), local botanical assemblages can be compared within a broader regional context, facilitating an analysis of the diachronic development of agricultural production during the Bronze Age.

Furthermore, the archaeobotanical analyses have been supplemented with various data sources, encompassing ethnographic, iconographic references and residues analysis, as well as palaeoclimatological and ecological data. It is established indeed that the transition from the Early to Middle Bronze Age marked an extraordinary climatic shift in the Near East (Langgut 2015). Studies involving stable carbon isotope analysis of ancient plant remains from the onset of the Middle Bronze Age indicate a decline in precipitation, aligning with a global climatic change during that era, resulting in drier conditions (Riehl 2008). To enhance the information database for the Early and Middle Bronze Age, stable isotope analyses have been conducted on new samples collected in Tel Kabri.

1.2 Collaborative Research Centre 1070

This dissertation is part of the CRC 1070 Resource Cultures (or SFB 1070 RessourcenKulturen) second phase, which focuses on the study of social and cultural dynamics dealing with resources. Through an interdisciplinary approach involving close cooperation between different topics such as Archaeology, Social and Cultural Anthropology, History, Geography, Philology, and so on, the CRC 1070 aims to:

- renew of the notion of resources in cultural studies;
- identify diachronic socio-cultural and political developments (developments);
- comprehend the formation of identities in relation to human migrations (movements);
- understand the symbolic dimension of resources (valuations);

Defining the concept of resources is not a straightforward task, as it is heavily influenced by the cultural context in which it is being considered. The perception of resources often varies depending on the time period and specific context. However, resources can generally be seen as fundamental elements or instruments that play a role in creating, sustaining, and shaping social relationships, groups, and identities. In defining the concept of resources, it is essential to consider resource complexes, as resources typically do not exist in isolation but rather in combination with other resources within a complex. These resource complexes often encompass a range of elements, including objects, individuals, knowledge, and practices that work together as an interconnected resource network.

This dissertation is a component of the project division A that focuses on the "developments" question, exanimating resources within the context of cultural and social transformations as they evolve as a result of historical developments. More specifically this study belongs to the sub-project A05 "The Land Flowing with Milk and Honey" which investigate the changes and advancements in the management of agrarian resources in the southern Levant, spanning from the Early Bronze Age to the conclusion of the Iron Age (3600 BCE to 586 BCE).

The agricultural resources are made not only of the plant material itself but also of the farming knowledge, climate, water, technology, tools, vessel, trades and so on that combining form the "agrarian ResourceComplex". Resource complexes have a unique historical pattern of emergence and distribution, involving their allocation and utilization in relation to one another. A comprehensive understanding of the "agrarian ResourceComplex" can be achieved by examining its complexity and development through an exploration of the interconnections and dynamics within it

1.3 Environmental background

The southern Levant, situated on the eastern flank of the Mediterranean basin, encompasses a diversity of vegetation zones. These range from a Mediterranean climate along the coast and northern hills to semi-arid and desert zones in the eastern and southern portions of the region

(Zohary 1962, Langgut 2015). As a result, there is a significant variability in mean annual precipitation across both west-east and north-south gradients (Figure 2).

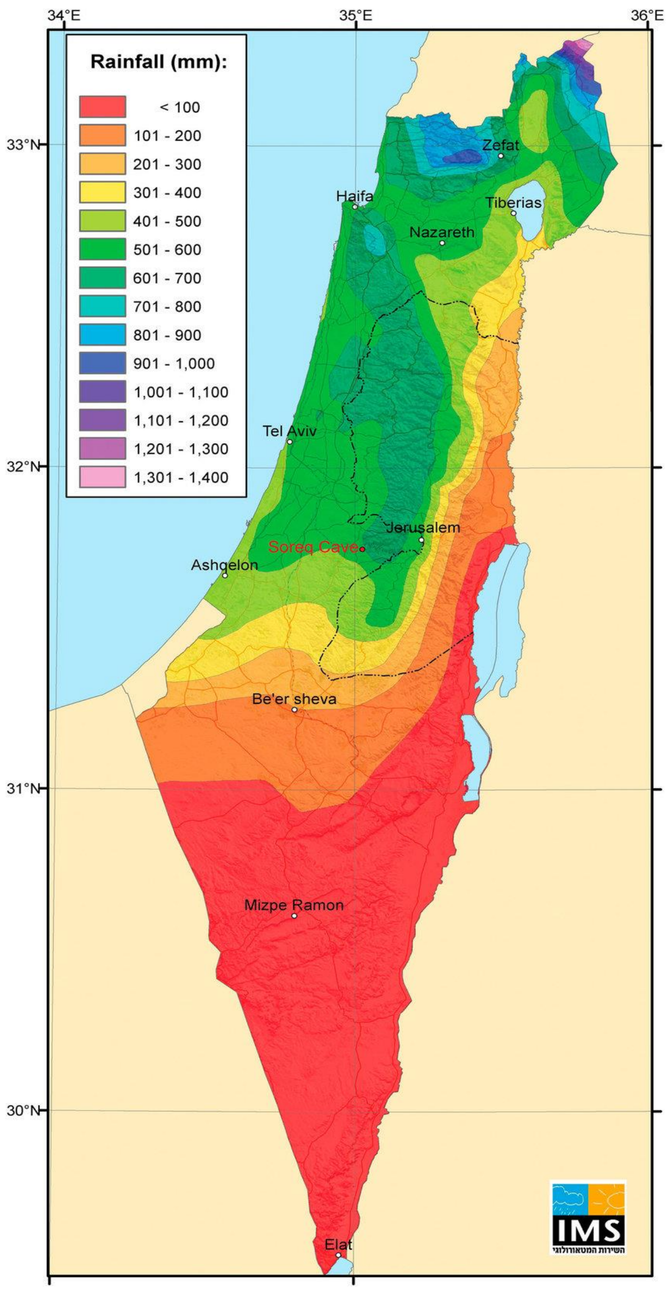

Fig. 2 Mean annual precipitation in modern Israel (1981-2010 Israeli Meteorological Service). From Fuks et al. 2017

To illustrate this variability, consider the annual precipitation disparities between the two study sites: Tel Kabri registers approximately 500mm, while Lachish records 350mm. Thanks to these characteristics, the southern Levant is perceived as an area highly susceptible to climatic variations. Historically, the region's climate has not been constant, prompting numerous studies aimed at reconstructing its paleoenvironment. The interplay between environmental shifts and cultural transformations is direct and mutual. While civilizations have undeniably been influenced by these climatic shifts, human activities have applied a profound impact on the region's vegetation over the centuries.

Recent years have seen an increase in efforts to reconstruct the paleoclimate of the southern Levant, with primary emphasis on the northern and eastern portions of the region (Rambeau 2010). Given the climatic sensitivity of the southern Levant, these analyses have some limits. Environmental conditions can vary markedly over short distances, making it vital to account for these limitations when interpreting the results (Rambeau 2010). Nevertheless, these analyses offer a varied perspective on the region's environmental evolution, which is pivotal to comprehending the paleoclimate and its implications for historical contexts.

The initial stages of the EBA witnessed the highest humidity levels throughout the entire Bronze Age. Pollen records from the Sea of Galilee reveal that during this period, olive trees, along with other Mediterranean vegetation, reached peak frequency (Schiebel and Litt 2017; Langgut et al. 2015). Speleothem data from the Nahal Qanah cave, situated on the western edge of the central highlands, show wet climate conditions persisting from EBA I through EBA IV (Frumkin et al 1999).Speleothem analyses from the Soreq Cave, which is located in the Judean Hills approximately 26 km northeast of Lachish, highlight a heightened wet phase spanning the EBA II to EBA III periods (Bar-Matthews and Ayalon 2004 and 2011). Interestingly, this peak is not registered by pollen records from the Sea of Galilee (Langgut et al. 2015).

The EBA IV phase documented drier intervals in pollen diagrams, which have been correlated with a receding Dead Sea level (Kagan et al. 2015; Migowski et al. 2006) and diminishing rainfall (Bar-Matthews and Ayalon 2011). The transition from the Early to Middle Bronze Age marked a profound climatic shift in the Near East (Langgut et al. 2015). Research focusing on the stable carbon isotope of ancient plant remnants from the onset of the Middle Bronze Age indicates a dip in precipitation. This aligns with the broader global climate alterations of that era, culminating in arid conditions (Riehl 2008).

The onset of the MBA was marked by a brief dry event, evidenced by a decline in Mediterranean tree pollen counts (Langgut et al. 2013 and 2015) and shifts in the isotopic composition of plankton within Mediterranean sea cores along the coastal plain (Schilman et al. 2002). Subsequently, a more humid phase emerged, which was wetter than current conditions, a fact also corroborated by the stable oxygen data from the mineral deposits in the Soreq cave (Bar-Matthews and Ayalon 2004).

Research from the Dead Sea indicates a prolonged dry period starting around 1500 BCE in the region (Migowski et al. 2006; Kagan et al. 2015). However, these findings have yet to be chronologically aligned through correlative dating.

During the LBA, evidence suggests a predominant wet climate. This is manifested in pollen diagrams that depict the presence of trees and shrubs, pointing to Mediterranean woodlands or maquis scrub, with a peak in evergreen Quercus and Pistacia around 1350 BCE (Langgut et al. 2015). This moist climate phase is also documented by results from the Nahal Qanah cave (Frumkin et al 1999) and local pollen samples sourced from Lachish (Drori and Horowitz 1989).

The end of the LBA witnessed a pronounced dry climatic event in the Levant. Indicators of this shift include a decline in arboreal pollen, along with significant elevations in $\delta^{18}O$ and $\delta^{13}C$ values found in the speleothems of the Soreq cave (Bar-Matthews and Ayalon 2004). Further evidence of increased aridity is derived from studies of the Dead Sea, which highlight prevailing dry conditions in the area (Migowski et al. 2006; Kagan et al. 2015).

1.4 Historical Background

The Early Bronze Age I (3600 – 3000 BCE) witnessed a notable increase in settlement compared to the preceding era, with formerly uninhabited areas in the southern Levant, like the Central Highlands and Northern Negev, now hosting villages (de Miroschedji 2014). The departure from the late Chalcolithic era is marked by a new material culture, incorporating advancements in pottery and metallurgy (de Miroschedji 2014, Milevski 2013), with implications for agriculture, such as the introduction of the plough. Food processing also saw advancements in tool technology within urban centers, particularly with the adoption of basalt grinding stones. These grinding stones exhibited a standardized shape and size across the entire southern Levant region (Hruby and Rosenberg 2023). Meanwhile it has been observed that other food processing implements, such as mortars and pestles, are typically locally produced in rural areas using easily accessible raw materials, resulting in a higher variability of morphologies (Hruby and Rosenberg 2023).

There is also a shift in subsistence methods towards an agropastoral economy, encompassing agriculture (especially emmer, barley, and legumes), horticulture (olive and grapes), and animal husbandry (de Miroschedji 2014, Philip 2003).

The new villages of the EBA I are generally considered no larger than five hectares (de Miroschedji 2014) practicing then a small-scale agriculture. However, certain settlements, particularly those in the southwestern part of the southern Levant, display clear evidence of Egyptian influence and a keen interest in local agricultural products, potentially leading to surplus production (Miroschedji 2014). There are exceptions to the small-scale pattern, such as the case of Megiddo, which likely evolved into a complex society with monumental architecture and structures, necessitating extensive agricultural production (Kamlah and Riehl 2020).

The Early Bronze Age II-III (3000 – 2400 BCE) has marked an acceleration of the urbanization process which led into the abandonment of some rural EBA I settlements to establish fortified urban centers (Miroschedji 2014). Since the beginning of the EBA II but also during the EBA III these urban centers built a fortification around their settlement, underlining the rivalry and conflicts that arose among these city-states during these periods (Miroschedji 2014). As these city-states developed, the influence of Egypt in the southern part of the Southern Levant gradually decreased, and their trade interests shifted towards other commodities like wood and resins found in the northern regions of the Southern Levant (de Miroschedji 2014; Genz 2014). The possibility to create such urban centers was possible thanks to the expansion and intensification of agriculture (Kamlah and Riehl 2020). This phenomenon is closely linked to the construction of new structures, including monumental buildings, within these centers (Genz 2010). The ability to store agricultural products in these structures contributed to the generation of surplus yields, promoting the potential for further expansion (Kamlah and Riehl 2020, Philip 2003).

During the Early Bronze Age IV (2400 – 2000 BCE), also called Intermediate Bronze Age period, the urbanization process ceased. Many settlements in the Southern Levant (including Lachish) were abandoned and only a few with an architecture existed (Prag 2014). A distinct disruption in material culture from the preceding period is evident, accompanied by a shift in rural subsistence strategies that vary regionally in the Southern Levant. In the northern regions, there is an emphasis on agricultural potential, while in the southern regions, a focus on pastoralism is observed (de Miroschedji 2014 and 2009, Prag 2014). In Lachish, excavations demonstrated the existence of nomadic tribes living on the slope beneath the large mound that was once occupied by a settlement and almost completely abandoned during this period (Ussishkin 2004).

The debate surrounding the reasons for these societal and settlement changes remains open, and various explanations and discussions have been suggested. While none can be definitively confirmed, the most plausible explanation likely involves a combination of factors: 1) Military campaigns by Egypt and a decline in trade with the southern Levant; 2) Political events and environmental changes; 3) The natural recurring cycle of the urbanization/de-urbanization process (Prag 2014).

The Middle Bronze Age (2000 – 1550 BCE) was a period of another rise of the urbanization cycle (Figure 3). This phase did not happen at the same timeframe in the whole region but it was focused at first along the coastal plains and the east-west wadi systems to spread only in later times in the southern part of the southern Levant (Cohen 2014).

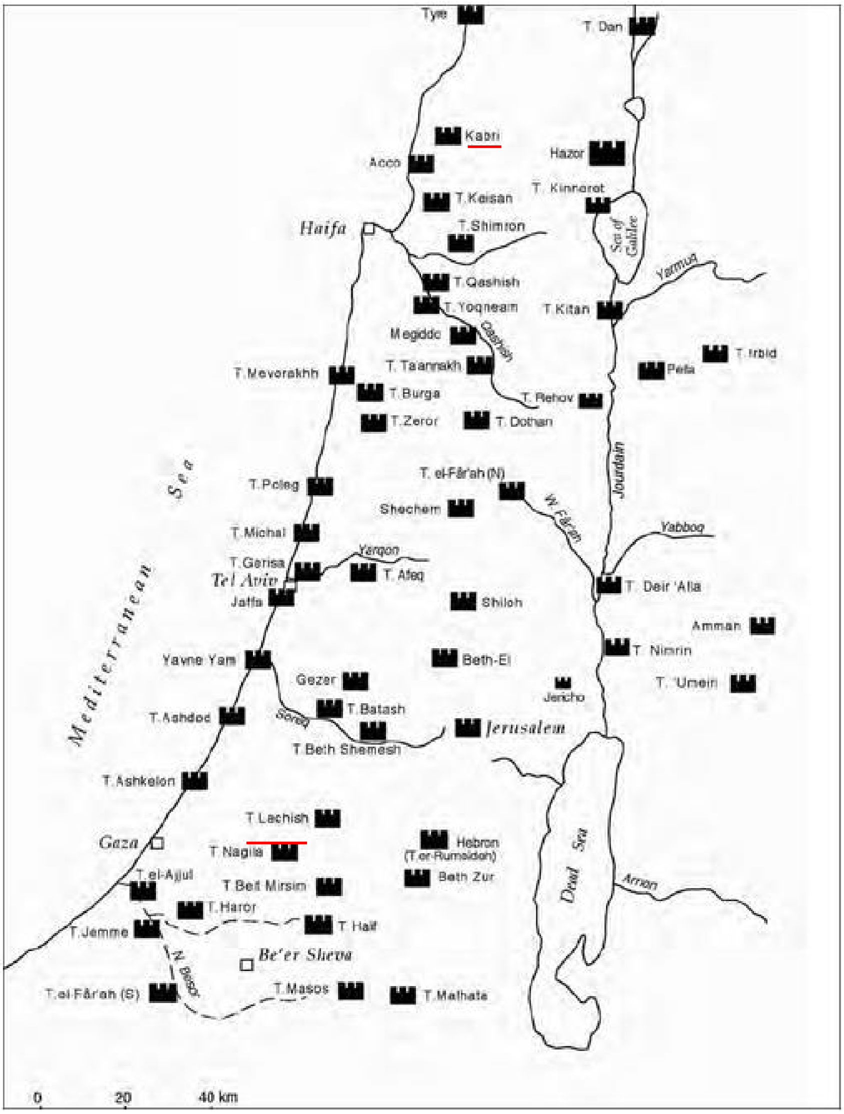

Fig. 3 Southern Levant settlements during the Middle Bronze Age (from de Miroschedji 2009)

This new urbanization process is remarked by the development of heavily fortified cities with public structures and palace architecture, forming a centralized palace economy controlling the settlements in the hinterland (Cohen 2014).

Despite being a multi-period site, it is during the MBA that Tel Kabri reached its greatest power, when one of the largest palaces in the levant was built and includes multiple wings and rooms for a total area of circa 2000 m^2 (Lazar et al. 2020, Oren 2002).
The same happened in Lachish during the MBA, where a renewed urbanization occurred and massive structures, including a mudbrick building interpreted as a palace, were built.
The influence of Egypt raised in the Levant, especially toward the end of the MBA period and trades (in both directions) contributed to the development of cities along the Levantine coast (Bourke 2014, Cohen 2014).
The Late Bronze Age (1,550 – 1,200 BCE) in the Southern Levant is chiefly associated with the expansion of Egyptian influence in the region (Figure 4).

Fig. 4 Map of the southwest Levant during the LBA (from Koch 2019)

Forts were established, and the city-states became vassals to the Egyptian rulers. These rulers aimed to maintain control of the region, which was flourishing due to new trade routes (Panitz-Cohen 2014). Lachish too entered the Egyptian sphere of influence. Upon its reconstruction, it was regarded as one of the most significant kingdoms in the region, as textual evidence suggests (Rainey 2015). The Amarna Letters provide insight into the diplomatic relationships, illustrating the extent of Egyptian power in the region (Pfoh 2019). Some contexts in Lachish discussed in this dissertation have been dated using the radiocarbon method. They were found to be contemporary with both the Amarna Letters and Papyrus Hermitage 1116A (Webster et al. 2019 a, b).

Egyptian influence became even more pronounced during the 19th Dynasty. There was not only an increase in military campaigns but also in the construction of governors' residences and garrisons in the Southern Levant. The locals adopted new Egyptian burial customs, there was a surge in the production of Egyptian pottery and artifacts, and more temples were dedicated to Egyptian deities. An example of this is the Fosse Temple in Lachish, which was rebuilt in the Egyptian style (Koch 2019, Panitz-Cohen 2014).

2. Research Methods

The archaeobotanical material was collected during on-site fieldwork throughout the excavation seasons of 2018 and 2019 at Tel Kabri and Lachish. Samples from another site, Tel Keisan, were also collected and processed during these seasons, but the analyses from this site will not be included in this dissertation. The volume of sediment retrieved at each site aimed for the standard of 30 litres, with the actual amount largely depending on the archaeological context and the status of the layers (i.e., loci). Typically, botanical findings endure in the vast majority of archaeological sites. However, their discovery is contingent upon the application of requisite sampling and processing techniques (Lancelotti and Madella 2023, Weiss and Kislev 2007). Flotation, the method used to obtain plant remains through the water separation process of the soil, was conducted on site using a flotation machine. This machine was built shortly before the first excavation season and was transported to different fieldwork sites.

The flotation machine consisted of three barrels of varying dimensions connected by a series of tubes. These, along with a pump, created a water recycling system. To avoid contamination between samples, the barrels were emptied each time sediments from a new locus were processed. Fractions were collected using sieves of different mesh sizes: 1 mm for the heavy fraction and 0.2 mm for the light fraction. The samples were dried on-site using cloths made of natural materials, primarily linen or cotton, and were later sent to the archaeobotanical laboratory in Tübingen.

Fig. 5 Flotation machine built and used in loco to process the sediments analyzed in this dissertation

The plant remains were identified using a Euromex stereoscopic microscope with up to 30x magnification and the Senckenberg seed reference collection (SeSam), which contains more than 15,000 specimens primarily from Mediterranean and Near Eastern floras. The identification was assisted by the resources available in the archaeobotanical lab of Tübingen University, including relevant identification literature and a Zeiss Stereo Discovery V8 digital microscope for photographs.

During the quantification of the plant remains, two halves and four quarters of cereal grains were considered one seed but when only one fragment was found in a sample, it was counted as one seed. Weighing was used to quantify highly fragmented seeds and fruit stones, particularly olives, and then converted these weights to represent the equivalent number of whole seeds based on the weight of a single intact seed.

The archaeobotanical data was assessed in conjunction with the archaeological information furnished by each site. To gain a comprehensive understanding aligned with the study's objectives, additional data sources were incorporated, encompassing GIS and geographical maps, ethnographic sources, and iconography.

2.1 Macro-remains

The plant remains identified in this dissertation are categorized as macro-remains. The term "macro-remains" refers to plant remains visible to the naked eye, generally larger than 0.25 mm. However, a microscope is still necessary for their identification (Fuller and Lucas 2014). This study identified seeds, fruits, and chaff remains from two sites.

Macro-remains are distinct from "micro-remains." Although both require a microscope for identification, micro-remains necessitate higher magnification. They include phytoliths, pollen, and starch grains (Fuller and Lucas 2014, Neumann et al. 2017). Analyzing macro-remains aids in reconstructing life at and around the site. Through the examination of botanical remains, a spectrum of questions ranging from food, diet, economy, and environment, to seasonality, lifestyle changes, social organization, food preparation, technology, and specific uses of buildings or possible trades can be answered (Weiss and Kislev 2007, Johnston 2023). Many of these questions have been posed and addressed in the course of studying the sites discussed in this thesis.

The majority of the macro-remains collected for this dissertation were charred. Charred remains are the most common botanical findings in the Southern Levant and globally (Weiss and Kislev 2007). Exposure to a burning process—without extreme temperatures and in anaerobic conditions—transforms botanical remains into charcoal. While they lose their original color, in most instances, they retain their original features and morphological properties. This transformation preserves their presence in archaeological sites, as biological decomposers cannot utilize charcoal remains.

Another preservation type of botanical material found in this study is the so-called mineralized plant remains. This preservation occurs when cells of organic botanical material are replaced by inorganic molecules during an exchange that occurs in the soil under specific conditions. Some plants produce seeds with a high mineral content. In some cases, it becomes challenging to discern whether the seeds belong to the archaeological context or are modern contaminants. This is often the case with representatives of the Boraginaceae family, such as Lithospermum (Pustovoytov et al. 2004).

During the identification process, efforts were made to classify macro-remains to the most specific level possible (species or variety). However, due to the poor preservation of some botanical material, identification was occasionally limited to the family level.

2.2 Correspondence analysis

In order to contextualize the collections from the two sites studied within the regional framework, Correspondence Analyses (CA) were employed to evaluate the extensive datasets of botanical remains sourced from archaeological sites in the Levant.

CA serves as a robust analytical tool, adept at structuring and interpreting expansive datasets (e.g. Jones et al. 2000; Smith and Munro 2009). It is a multivariate statistical method that facilitates the representation of a dataset in a two-dimensional graphic format, having the purpose to represent underlying structures within the multivariate configuration of the data table through a biplot. In this study, it arranges sites along axes delineated by plant species, facilitating a comprehensive examination of the agrarian resources' evolution throughout the Bronze Age and seamlessly incorporating these findings into comparative analyses with the investigated sites. These sites and their botanical assemblages are interconnected based on the counts of the plant taxa, considered as variables. Sites that are more similar to each other appear closer to the origin of the axes. The horizontal axis, representing the first axis, captures instead the highest variance within the data.

To initiate a CA, it is needed to procure appropriate data (Jones 1991). Botanical data from archaeological sites were sourced from published articles and reports, with a substantial portion extracted from the ADEMNES database (https://www.ademnes.de/). The focus was exclusively on macro-remains data. Even though various crop plants can vary significantly in the number of seeds they produce per plant or per fruit (e.g. a single fig can yield hundreds of seeds), it is important to define the single agricultural resource and its presence in the regional evolution. While the contexts from these external sites may also differ from those examined in this dissertation, the information obtained has been proven beneficial both in comparative analyses and in elucidating the evolution of agrarian resources in the region within the study's designated timeframe. For efficiency in handling expansive datasets, specific chronological phases such as EBA I, EBA II-III, EBA IV and so on, were consolidated into broader categories: EBA, MBA, and LBA.

After gathering the data the next step is to proceed with a selection of the right data (Jones 1991), cleaning it from the possibility of giving results that could conceal real patterns. In the CA evaluations, sites analyzed exclusively on presence/absence data were excluded. Additionally, sites with a limited number of taxa were also removed to prevent skewed results and to eliminate any "noise" on the graph that might obscure genuine patterns. A minimum

threshold for taxa occurrence was set, and taxa present in fewer than four sites were not incorporated.
The results are visually represented in a biplot graph. Essentially, a biplot offers a low-dimensional representation of certain information from the original data table. The horizontal axis (first axis) captures the most significant variance within the data and the cumulative variation, as indicated in the graph's legend, provides insight into the proportion of variation explained by the two axes.
To plot the graph using the data gathered and "cleaned" it has been used CANOCO 5 software (Leps and Smilauer 2014). This software offers all statistical methods including CA and its variants, including detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA), using data that can be easily imported from Excel files. CANOCO also offers the possibility to modify the design of the graphs plotted with a series of visualization tools that can improve their readability and pattern recognition.
While the CA method can encounter issues with the so-called "arch effect", a distortion that might result in misinterpretation of the first and second axes, as per Jongman et al. 1995, the results derived in this dissertation from our dataset are reliably interpretable, given that this specific distortion is absent from our graph.

2.3 Stable isotopes

Stable carbon and nitrogen isotope analysis on the plant remains allow a possible reconstruction of ancient environmental conditions in which those plants have grown: climate, soil nutrients, manuring, irrigation, etc. In this way it is possible to understand the human or the natural effects on the growing plants obtaining palaeoclimatological and ecological data.
Particularly successful were the stable carbon and nitrogen analyses on well-preserved crop seeds from Tel Kabri, that were conducted at the Institute of Geosciences of the University of Tübingen, Germany, on a FinniganMAT252 gas source mass spectrometer with a ThermoFinnigan GasBench II/CTC Combi-Pal autosampler.
Plant material recovered from archaeological sediments usually carries soil substances which can alter the stable isotopes analyses. Depending on the soil properties, most commons contaminants are carbonate precipitates and humic/fulvic acids (Fiorentino et al. 2015, Ferrio et al. 2020) which are removed prior to analysis following different methods (DeNiro and Hastorf 1985). For our study, the carbonized seeds from Tel Kabri the carbonized were reacted with 5% HCl to eliminate sedimentary carbonate.

Considering that most plants take their carbon from atmospheric CO_2 and that $\delta^{13}C_{air}$ then is not constant over time, it is needed to estimate its past value before comparing modern and archaeological data (Fiorentino et al. 2015, Ferrio et al. 2020). Antarctic ice-cores provide a direct and extensive record of global atmospheric changes in $\delta^{13}C_{air}$ even though they lack local values. Ferrio et al. (2005, 2006) set a $\delta^{13}C_{air}$ curve from 16100 BCE to 2010 CE by interpolating data from Antarctic ice-cores, together with modern data from Antarctic stations of the CU-INSTAAR/NOAA-CMDL network for atmospheric CO_2.

For our Tel Kabri samples, these changes were transferred into $\Delta^{13}C$ by using AIRCO2_LOESS (Ferrio et al. 2012, https://data.mendeley.com/datasets/btwpwh8292/2).

3. Results and discussions

3.1 Lachish and Tel Kabri

Lachish is a multi-period archaeological site, with its history dating back to the Neolithic period. As previously discussed, the site underwent a cyclical process of urbanization from the Middle Bronze Age to the Late Bronze Age and Iron Age. This tell, situated in the Shephelah region of Israel (Figure 1), between the Mediterranean coast and the Judaean mountains, ranks among the largest in the southern Levant. Botanical investigations were conducted in two distinct areas of the tell: Area S, a trench located on the western periphery of the site, with samples originating from LBA deposits, and Area P, situated on the top of the mound in the palace area, containing samples spanning from the MBA to LBA. In the excavation seasons of 2018 and 2019, a total of 89 archaeobotanical samples were gathered, for approximately 2,530 liters of sediment. While samples from the Iron Age IIA and IIB periods were processed, they were not evaluated due to their limited sample size. The comprehensive botanical assemblage comprises 58 distinct taxa: 20 of these represent cultivated plants (Figure 6), totaling 9,714 remains, and the remaining 38 taxa are associated with wild plants (Figure 7), accounting for 3,920 remains (Appendix 1, Nicoli' et al. 2022).

Tel Kabri, situated in the Western Galilee of northwestern Israel (Figure 1), reached the height of its power during the MBA. However, it's noteworthy that Tel Kabri also represents multiple archaeological periods. The archaeobotanical specimens examined in this dissertation are sourced, in fact, from two distinct periods and area of this tell: the MBA palace in Area DW and the EBA domestic deposits in Area L.

Samples from Tel Kabri were procured over three separate excavation seasons in 2015, 2017, and 2019, amounting to an approximate total sediment volume of 3961 liters. Twentynine taxa were identified. Of these, 16 pertain to cultivated plants, amounting to 495 remains. The remaining taxa are wild plants, comprising 294 seeds (Figure 8).

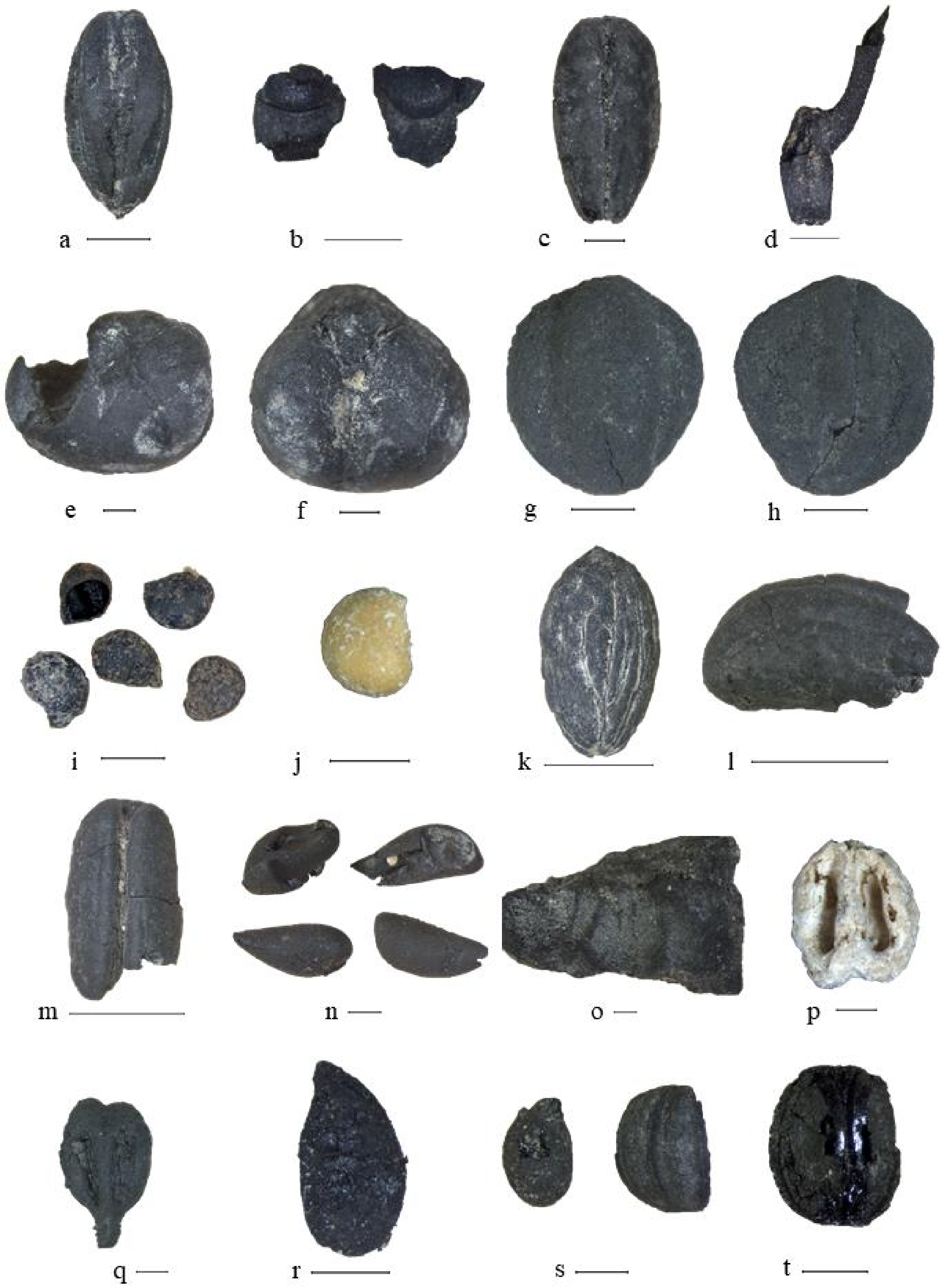

Fig. 6 *Hordeum vulgare* (barley), a grain, b rachises; *Triticum dicoccum* (emmer wheat), c grain, d glume base; *Vicia faba* var. *minor* (faba bean), e lateral view, f front view; *Crataegus azarolus* (azarole), g top view, h bottom view; *Ficus carica* (fig), i seeds, j mineralized seeds; k *Olea europaea* (olive); *Phoenix dactylifera* (date), l lateral view, m top view; *Punica granatum* (pomegranate), n

seeds, o exocarp fragment; *Vitis vinifera* (grape), p mineralized pip, q pip ; *Linum usitatissimum* (flax), r seed, s seed and capsule, t capsule detail; scale bars=1 mm except for a, g, h=2 mm and k, l, m=5 mm (from Appendix 1, Nicoli' et al. 2022)

Fig. 7 a *Capparis spinosa* (caper) seeds; b *Cephalaria* cf. *syriaca* (L.2049); c Chenopodium (L.1197); d *Lolium* cf. *temulentum* (darnel); e *Malva* (mallow); *Plantago lanceolata* (ribwort plantain), f seed, g seed including a modern specimen; h Polygonaceae (L.2049); i *Pistacia terebinthus* (terebinth) (L.); j *Thymelaea passerine* (L.1122); *Torilis leptophylla* (L. 2049), k front view; l back view; m, n *Tribulus terrestris* (L.1187); scale bars=1 mm (from Appendix 1, Nicoli' et al. 2022)

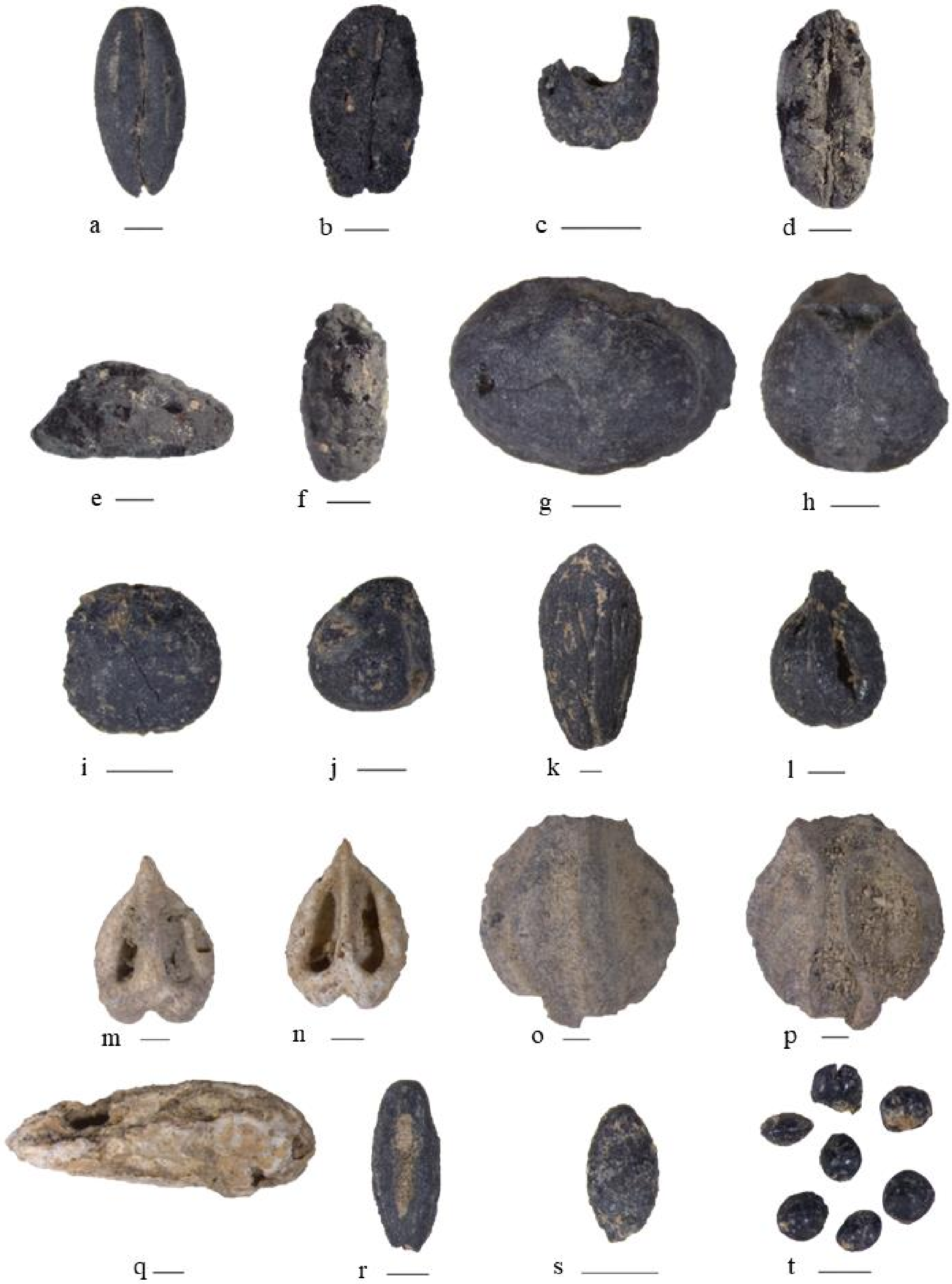

Fig. 8 a Emmer wheat, Triticum dicoccum (Area L); b emmer wheat, Triticum dicoccum (Area DW); c emmer wheat glume base, Triticum dicoccum (Area L); d emmer wheat, Triticum dicoccum (Area L); e emmer wheat lateral view, Triticum dicoccum (Area L); f emmer wheat dorsal view, Triticum dicoccum (Area L); g faba bean lateral view, Vicia faba var. minor (Area L); h faba bean frontal view, Vicia faba var. minor (Area L); i lentil, Lens culinaris (Area DW; j bitter vetch, Vicia ervilia (Area DW) k olive, Olea europaea (Area DW); l grape, Vitis vinifera(Area DW); m mineralized grape, Vitis vinifera (Area L); n mineralized grape (Area DW); o jujube dorsal view, Ziziphus cf. spinachristi (Area L); p jujube frontal view, Ziziphus cf. spina-christi (Area L); q mineralized pomegranate (Area DW); r ryegrass, Lolium (Area L); s canarygrass, Phalaris (Area DW); t weld, Reseda (Area DW). Scale bars=1 mm (from Appendix 2, Nicoli' et al. 2023)

3.1.1 EBA domestic deposits in Tel Kabri

Area L, situated west of the MBA palace and north of one of the two perennial springs encompassing Tel Kabri, was excavated with the intent of uncovering non-palatial, residential MBA structures. However, the excavation led to the discovery of EBA deposits.

Despite the limited number of samples taken from this area, the count of charred botanical remains is remarkably high. Across six samples, totaling approximately 121 L, 269 plant macro-remains have been identified (see Appendix 2, Table 1 and 2, Nicolì et al. 2023). In what is characterized as a domestic context—evidenced by the discovery of a stone installation identified as either a storage container or an apsidal house—a diverse array of remains was uncovered, primarily associated with the identification of kitchen waste. Alongside a relative substantial quantity of emmer wheat, emmer glume bases were also identified, marking the sole cereal chaff discovery in Tel Kabri. Noteworthy in this area is the presence of various legume remains, including lentil, grass pea, and faba bean. While olive is the most prevalent taxon across Tel Kabri, its proportional significance is diminished when compared to the Middle Bronze Age assemblage. Concerning other fruits, both grape pips and jujube seeds were found.

3.1.2 The MBA assemblages from Tel Kabri and Lachish: the palaces area

Both the MBA assemblages from Tel Kabri and Lachish comes from palatial contexts. Tel Kabri hosts one of the most expansive palaces from the MBA period, as previously mentioned (Lazar et al. 2020).

During the revitalized settlement and urbanization of the MBA, as Canaanite city-states started to emerge, Lachish showcased extensive fortifications and a significant mudbrick structure interpreted as a palace (Ussishkin 2004).

Macro-remains from these contexts have also been collected and identified.

For Tel Kabri Area DW, encompassing the wine cellar in the palace area, 185 samples were processed using the flotation machine, totaling around 3,840 liters of sediment (Appendix 2, Nicolì et al. 2023).

As anticipated based on the context's nature, only a limited number of cereal grains were identified, including a solitary free-threshing wheat grain. The few cereal seeds of emmer wheat and barley were discovered in conjunction with certain cereal crop weeds, such as *Phalaris* and *Lolium*. Certain layers, owing to their proximity to the topsoil, produced wild plant seeds that are exclusively of modern origin. This contamination was inevitable and affected these layers.

The botanical assemblage of this area also included some legumes, in particular lentils and bitter vetch but in terms of both quantity and ubiquity, olive and grape are the predominant findings. The majority of grapes in these contexts were discovered in a mineralized state, whereas the vast majority of olive remains were fragmented. The high abundance of grapes is, of course, linked to the specific context (Appendix 2, Nicolì et al. 2023).

For Lachish 65 samples were collected from the palace area (Area P), with a sediment volume of approximately 2,022 liters (Appendix 1, Nicoli’ et al. 2022). These contexts were significantly impacted by modern contamination. In numerous instances, complete identification to the species level could not be accomplished.

In the MBA layers of Lachish, barley is the most common taxon, followed by the remains of figs and olives, and then emmer. No chaff remains have been found in Area P. Approximately three-quarters of the total charcoal remains found at the site were retrieved from this area, as expected also due to the fiery destruction of the MBA palace.

3.1.3 LBA assemblages from Lachish

A total of 24 samples, amounting to roughly 508 liters of sediment, were collected from Area S. Remarkably, this area yielded an exceptionally high density of plant remains, amounting to eight times the number of remains found in the MBA context of Area P (for detailed data, please see Table 2 and 3 in Appendix 1, Nicoli' et al. 2022).

The samples were collected along a fortification wall and both outside and inside a monumental building, intercepted in the deep section of Area S. This led to the recovery of substantial quantities of remains, which were partially associated with waste contexts. In the LBA botanical assemblage, the most abundant taxa are figs, followed by emmer and barley (both including few chaff remains), free-threshing wheat, and subsequently olive and grape. It's worth noting that olive remains exhibit a notably high level of ubiquity. Distinctive discoveries in this context, not encountered elsewhere in Lachish, include pomegranate and azarole among the fruit taxa. Other taxon include flax, which is concentrated in a few LBA samples and also comprise of a whole capsule.

Wild taxa are also present in this LBA assemblage, and it is primarily characterized by the prevalence of darnel, a common weed often found in association with cereal remains. In some cases, it was identified in exceptionally high densities within the samples, indicating that the context may have been a working or storage area.

The LBA samples obtained from Area P, which was interpreted as an offering pit, are particularly intriguing. In addition to complete vessels and other ceramics discovered in situ, a significant number of plants remains were recovered, constituting more than 80% of the entire area. Notably, emmer, free-threshing wheat, and olives are the most abundant remains, and it is remarkable that over 85% of all the flax found in Lachish was recovered from this pit. Furthermore, a substantial quantity of wild plant seeds was identified, including a significant amount of canarygrass and ribwort plantain, as well as a large quantity of darnel seeds.

3.1.4 Stable isotope measurements for Tel Kabri

A total of 37 seeds sourced from EBA and MBA contexts in Tel Kabri were subjected to an analysis of their isotopic carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) composition, as detailed in Table 4 of Appendix 2 (Nicolì et al. 2023). The seeds were prepared and analyzed using the methodology described in paragraph 2.3. Barley and emmer showed the lowest values for $\Delta^{13}C$ indicating the probability of a drought stress while the other seeds showed no signals of drought. The majority of the $\delta^{15}N$ values fall within a range indicating low to moderate levels of manuring, with emmer wheat emerging as the most plausible candidate for having been subject to manuring practices (see fig. 10, Appendix 2, Nicolì et al. 2023).

3.2 Discussion

3.2.1 Lachish

In the context of agricultural resources in Lachish, the MBA primarily relied on barley and fruit remains (figs and olive). Throughout the LBA more taxa appeared and the general amount of remains increased exponentially. In an initial phase of the LBA, barley was the primary cereal crop, but in a later stage, emmer wheat came to dominate the botanical assemblage (see Table 4 in Appendix 1, Nicolì et al. 2022). Significantly, this transition in the later LBA phase, dated coeval with the Amarna period based on radiocarbon dating (see fig. 5 in Appendix 1, Nicolì et al. 2022), aligns with the crop production strategy that was employed in Egypt during that specific historical period (Nesbitt and Samuel 1996). During this same LBA phase, the presence of flax becomes evident in the botanical material, and it is often found in conjunction with ribwort plantain seeds, a wild plant species associated with environments having ample moisture. This observation confirms that flax cultivation occurred in an area with convenient access to water resources.

Other frequent type of wild seeds identified in the LBA botanical assemblage are darnel, which is a noxious weed found in cereal crops, canary ryegrass and cephalaria. These wild plants, found mainly during the first LBA phase, are commonly associated with winter rain fed type of crops, very frequent in the Shephelah region (Frumin et al. 2019).

The findings from Lachish serve as confirmation that the Shephelah region was indeed well-suited for agriculture.

Numerous lines of evidence substantiate the emphasis on horticulture and orchards around the tell at Lachish. Firstly, it's important to note that olive stands out as the most prevalent taxon in the assemblage. Together with fig and pomegranate, these elements form a characteristic fruit assemblage that mirrors what is found in coeval sites throughout the Shephelah region. (Frumin et al. 2019). In Lachish are also present grape, date and azarole. Another evidence is the famous Lachish relief: was crafted during a period subsequent to the contexts examined in this dissertation, provides strong indications that fruits held a significant cultural value and that fruit cultivation was firmly established in Lachish (Figure 9). This is further underscored by the Assyrians, who associated this fruit-centric identity with the city.

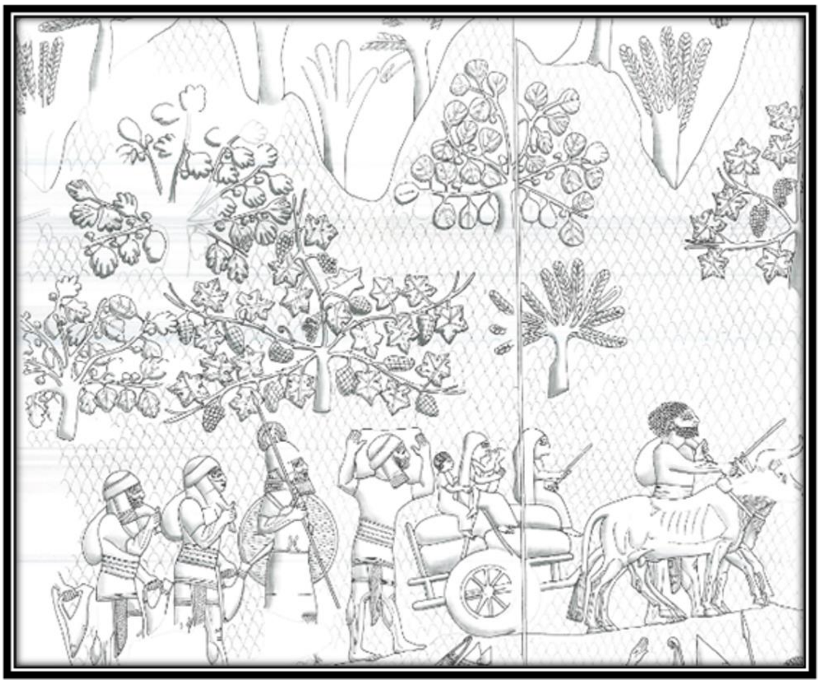

Fig. 9 Lachish relief. From Ussishkin 1982

An hypothesis has been put forth suggesting that the substantial presence of fig remains might also be linked to evidences of dung utilization, even though direct evidence of dung in Lachish has not yet been discovered. Numerous other sites in the vicinity, characterized by a high concentration of fig seeds and a botanical assemblage resembling that of Lachish, have yielded dung remains. It is worth highlighting that in the specific location where sediment was collected in Area S, a tabun oven was found. As detailed by Dalman in his ethnographical publication "Leben und Sitte in Palästina," focusing on the customs and work practices of the inhabitants of the region during the early decades of the 20th century, it is noted that dung cakes continued to be employed as a means to fuel ovens for baking bread during that period (Dalman 1935).

As previously mentioned, noteworthy temporal shift is evident in Lachish, as there is an increase in the number of cultivated plant taxa and a general rise in the quantity of remains observed in the LBA samples when compared to those from the MBA. Certainly we can argue that Area S, exclusively representing LBA, and Area P exhibit distinct structural, contextual, and taphonomic differences and this has inevitably influenced the composition of the botanical assemblage.

Area P, placed on the top of the mound was affected by heavy modern contamination due to the continue human exploitation of the soil and it also explained the total absence of chaff remains. Area S, being a deep trench on one side of the mound, had a better preservation of remains resulting in an high density of remains in its samples but still having a very small quantity of chaff remains compared to the amount of macro-remains. The scarcity of chaff in these contexts is likely attributed to the specific nature of the context. It is plausible that cereal processing occurred at a considerable distance from the deposition area of Area S. Additionally, in the case of Area P, the absence of chaff may be due to its status as an elite location, associated with a palatial context, where such agricultural remains might not have been present.

3.2.2 Tel Kabri

In Tel Kabri, the primary agricultural resources are predominantly centered around olives, which are abundantly present since the EBA assemblage, along with grapes. The results of the botanical samples predominantly mirror their respective context types.

Specifically concerning Area L and its EBA context, emmer wheat emerges as the principal cereal crop. Notably, it's worth mentioning that the $\Delta^{13}C$ values indicate a high level of drought stress for emmer.

In contrast, emmer displays a relatively high $\delta^{15}N$ compared to the other crops recovered from the site, indicating that it was likely the only crop that received manure application. Various hypotheses have been suggested to explain why emmer, despite being manured, exhibited such high drought stress: it may imply that emmer was not irrigated and possibly indirectly received nutrients from browsing ruminants; could be the result of trade coming from a naturally fertile cultivation area; or it could be a result of a single harvest taking place during an exceptionally dry year.

Fairly similarly to emmer, also barley resulted having high level of drought stress, even more pronounced than what is observed in other sites when considering their lower mean annual precipitation levels for comparison. Notably, similar $\Delta^{13}C$ values were observed in darnel seeds. While weed species are generally infrequently analyzed for their stable isotopes, it became evident that darnel was indeed a weed associated with barley cultivation.

An important finding in Area L is the abundance of legume remains, particularly lentils, grass peas, and faba beans, which are notably more frequent when compared to MBA Area DW. Furthermore, it's worth noting that these legume remains did not exhibit any stress signals and had similar water availability conditions.

In the MBA botanical assemblage of Area DW, it is not surprising that there is a notable absence of cereal chaff and, in general, a reduced presence of cereal crops remains when compared to Area L. This is likely due to the original functionality of Area DW as wine cellar. Most of the remains belongs to fruit taxa, including charred olive, grape (all mineralized), and a mineralized pomegranate seed.

The mineralized preservation status of the grape seeds has given rise to two potential hypotheses: one suggesting the presence of unfiltered stored wine and the other linked to the collapse of the palace, leading to the subsequent spillage of wine that enveloped the seeds. The wine, containing syringic acid, acted as a preservative for the grape seeds.

In Area DW, the identification of a *Pistacia* seed among the wild taxa is intriguing. The fruit, leaves, or mastic from this plant could have been utilized for the preservation or flavor enhancement of wine (Hansson and Foley 2008; Stern et al. 2008). Although only one seed was discovered, residue analysis has confirmed the presence of Pistacia terebinth resin traces in the jars recovered from the MBA palace (Koh et al. 2014).

The numerous fragments of olive remains could be instead associated with oil extraction, although it's noteworthy that no oil press has been found in Kabri so far. Much more likely they were used as fuel sources considering also that significant quantity of olive charcoal has been identified in Tel Kabri, making it one of the most prevalent types of charcoal in the assemblage. Significantly, the presence of grapevine in the charcoal assemblage may suggests the existence of vineyards in the vicinity of the tell (Lorentzen 2023).

3.2.3 *Vicia faba* and its varieties: an innovation process

Both in Lachish and in Tel Kabri whole faba beans seeds have been found. The substantial quantity of legume remains in Tel Kabri is notably higher, which is indicative of the Galilee region's strong inclination towards legume cultivation. *Vicia faba* has been cultivated in the region since the Neolithic period (Caracuta et al. 2015). The numerous springs in the vicinity of Tel Kabri indeed ensured a consistent water supply, a fact further supported by stable isotopic evidence. This strongly indicates that the cultivation of faba beans most likely took place in the proximity of the site during the EBA.

The faba bean variety identified in Lachish and Tel Kabri, much like all the other instances of *Vicia faba* var. *minor* found, is characterized by morphometric features such as small dimensions and a sub-circular shape.

The cultivation of faba beans has held significant importance across the entire Mediterranean region. In fact, legumes in general, not only played an important role in the human diet but also had a vital role as they enhance soil productivity. This is due to the nitrogen-fixing abilities of symbiotic bacteria in the plant's roots, which enable them to thrive in nutrient-poor soils and make these soils more fertile.

Throughout the botanical assemblages recovered from archaeological sites dating up to the Roman period, it is consistently the *minor* variety of faba beans that has been identified. It was not until after the twelfth/eleventh century CE that a larger variety started to appear in the botanical samples, suggesting a gradual process of varietal improvement in *Vicia faba*, eventually leading to the emergence of the *major* cultivar.

A study conducted subsequent to the completion of the Master's thesis indicates that in southern Puglia, Italy, there may have been evidences of gradual processes marked by micro-changes. These processes are observed through variations in the historical record, which highlight the adaptation of pre-existing forms to address evolving needs and preferences in the context of new varieties. Through biometric analysis, evidences prove that in the twelfth century CE, a new morphotype of the faba bean started to appear in the Salento peninsula (see Appendix 3, Grasso et al. 2021).

3.3 The botanical assemblages and the Bronze age regional context

3.3.1 Lachish

Following the completion of the macro-remains identifications for Lachish, an initial attempt to compare a botanical assemblage using correspondence analysis was conducted (see fig. 8, Appendix 1, Nicoli' et al. 2022). This analysis centered on the substantial evidence recovered from the LBA context in Lachish. Archaeobotanical data was collected from coeval published sites in the Shephelah region and the southern Levant, utilizing the previously described methodology (see paragraph 2.2).

The promising results showed a few clusters of sites, drawn by different types of taxa. Lachish is located in the positive sides of the graph, inside quadrant 1, concentrated together with some other sites that exhibit similarities in terms of fruit taxa, legumes and emmer. The other sites that clustered around Lachish are Pella, which share also a similar modern mean annual rainfall as Lachish (Wilcox 1992) and Sidon, sharing affinities in the botanical assemblage, and in particular regarding the frequency of olive remains (De Moulins 2015).

3.3.2 Tel Kabri

Following the completion of the macro-remains identification process for Tel Kabri and an initial application of Correspondence Analysis in Lachish, a more extensive analysis was conducted, which involved a comparative study of other coeval Levantine sites (Figure 10).

Data pertaining to the botanical assemblages from these sites were gathered for a new CA that included EBA, MBA and LBA periods (see list in Appendix 2, Table 3, Nicolì et al. 2023).

Once the CA was plotted using CANOCO, the same software was utilized to fine-tune and optimize the graph for enhanced readability.Patterns highlight the congruence of data from Tel Kabri with other Levantine sites.

Specifically, the EBA botanical composition at Tel Kabri seems to align closely with that of other sites from the same period. These sites cluster together, indicating that they typically demonstrate a high similarity in the frequency of a specific taxon found in close proximity in the graph. The pattern reveal that the botanical assemblage of Tel Kabri during the EBA is predominantly linked to the cultivation of olive and grape.

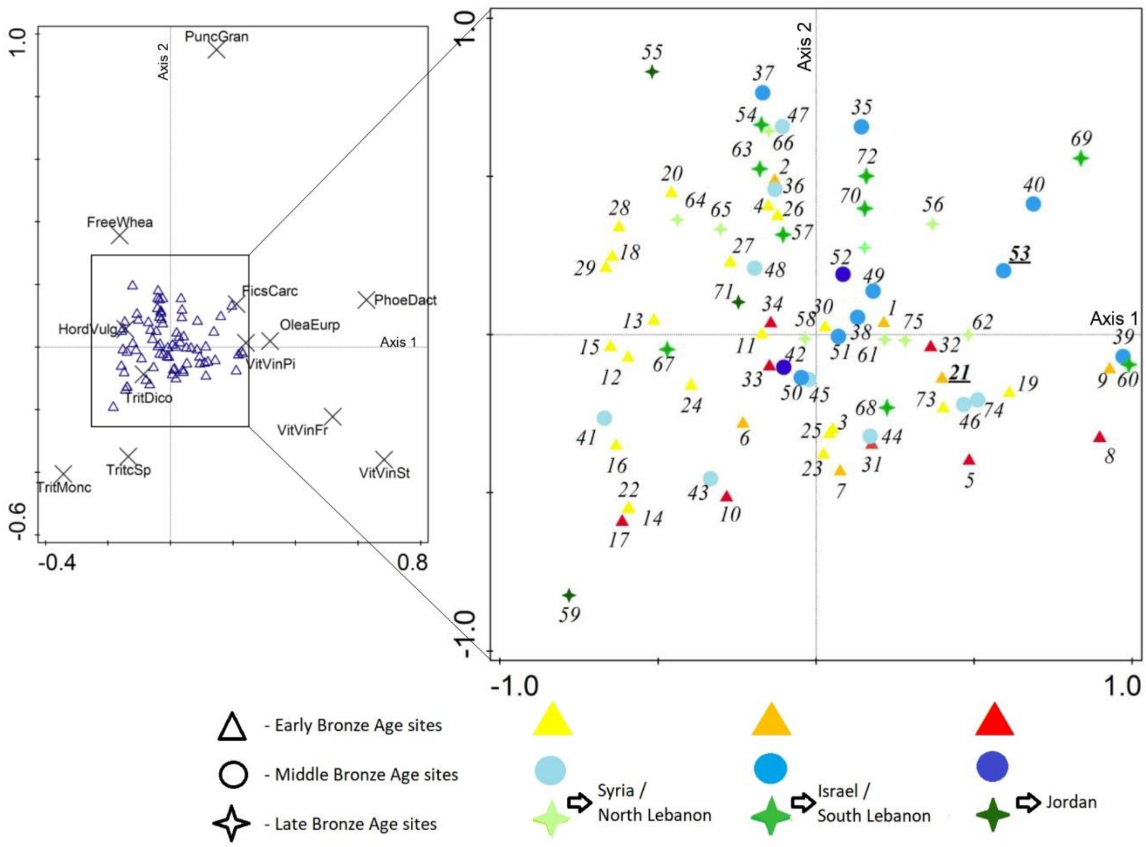

Fig. 10 CA biplot of Levant Bronze Age sites patterns for cereal and fruit crops. Cumulative variance axis 1=23.70, axis 2=40.10; eigenvalues axis 1=0.2012, axis 2=0.1392. For legend please see figure 6, Appendix 2, Nicoli' et al. 2023

Notably in this cluster, Bab' edh Dhra shares an environmental similarity with Tel Kabri in having numerous springs in proximity (McCreery 1979, 2003, 2011). Additionally, Tell Tweini and Tell Fadous-Kfarabida, which are also situated near the coast, exhibit comparable assemblages with a predominance in olive and emmer (Linseele et al. 2019; Riehl and Deckers 2009).

Regarding MBA Tel Kabri botanical assemblage, it is situated within the first quadrant of the CA biplot, where it clusters with most other contemporaneous sites in the southern Levant. Notably, Tel Kabri exhibits strong affinities in its botanical assemblage with a few of other sites. One of these sites is Shiloh, with which it shares similarities in terms of fruit taxa, especially the prominence of olives. Moreover, both Tel Kabri and Shiloh share environmental similarities, as they both have convenient access to various springs and comparable modern mean annual precipitation (Kislev 1993, Cohen 2009). Another site is precisely that of Lachish. Both Tel Kabri and Lachish share not only the same palatial context for the MBA botanical assemblage but also a dominance of fruit taxa, particularly olive remains.

3.3.3 Discussion on the regional context

The distance between the Levantine sites in the CA approximates the dissimilarities in their botanical assemblage, specifically concerning the crop taxa under consideration.

The use of various colors and shapes for the figures in the CANOCO software aids in discerning and tracking distinct patterns formed by the positioning of the sites on the biplot graph.

To gain a more comprehensive understanding of the transition in agricultural resources across the southern Levant during the Bronze Age and to enhance the clarity of the CA, three maps were generated. These maps depict the three Bronze Age periods (EBA, MBA, LBA), with assemblages expressed as percentage data in pie charts.

It is clear how in Figure 10 cereal crops are differentiated from fruit trees along the Axis 2, and this axis also serves to separate sites that are primarily dominated by either cereal or fruit tree remains. This pattern appears to correspond to a chrono-geographical trend, as most of the sites on the left side of the ordinate are situated in the northern Levant (modern Syria and northern Lebanon) having their botanical assemblages primarily dominated by cereal crops.

On the other hand, the majority of sites situated on the right side of the ordinate predominantly belong to the southern Levant (modern southern Lebanon and Israel). In these cases, the botanical assemblages are frequently characterized by intensive cultivation of olive and grape crops.

Starting with the Early Bronze Age it seems that in the CA the sites of the southern Levant are typically more prominent regarding their fruit tree proportions, mostly olive and grape. In contrast, in the northern regions, the botanical assemblages of the sites are primarily characterized by cereals, particularly barley, with significantly higher proportions, especially in the inland sites.

Upon examining the map in Figure 11, it becomes evident that the sites where olive is the predominant plant taxa percentage, including Tel Kabri, are mostly located in the coastal region. This observation aligns with the fact that olive trees are typical of the Mediterranean climate and can also endure arid conditions to some extent (Sofo et al. 2008). However, for optimal fruit production, olive trees require a minimum of 600 mm of rainfall or the use of irrigation (Riehl 2009).

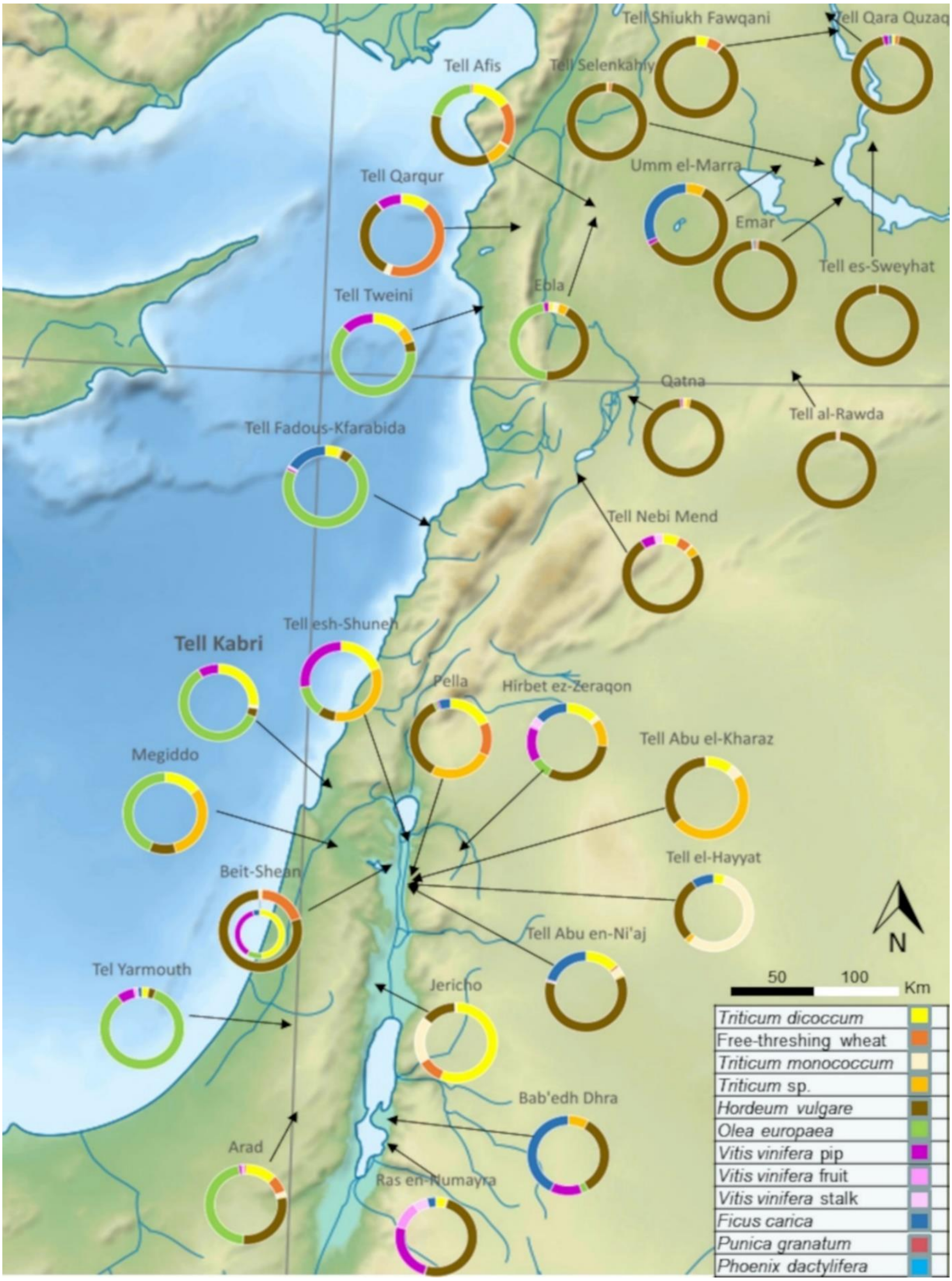

Fig. 11 EBA crop proportions in Levantine sites used in CA. From Appendix 2, Nicoli' et al. 2023

The three major orchards crops of olive, grape and fig are widespread at the start of the Chalcolithic period but they are definitely intensified during the EBA, making their appearance in the botanical assemblages of many sites in the southern Levant (Fall et al. 2002). The presence of both orchards and vineyards in archaeological findings is indicative of long-term agricultural planning. This is because these types of crops typically take 3 to 8 years to start bearing fruits, and it can take 10 to 20 years for them to reach full productivity.

The substantial presence of these fruit taxa, owing to their versatility in terms of their products, which can be stored (oil and wine), dried, or consumed fresh, may also suggest a deliberate effort to expand agricultural production for potential trade resources. Olive oil held significant value as a trade commodity starting in the EBA (Neef 1990). During this period, the increasing number of pressing facilities and vessels for storing oil that have been discovered in archaeological sites signifies the growing significance of olive horticulture and its profound impact on human society. This development may have been influenced by the demands of Old Kingdom Egypt (Kamlah and Riehl 2020). This influence may also have affected the high presence of emmer for some inland sites in the southern Levant. Emmer wheat is predominantly found in coastal regions, often in combination with barley. In contrast, in northern regions, barley takes precedence in the botanical assemblages.

The Jordan sites do not create a specific patter in the CA biplot graph but it is intriguing to observe that some of these sites, such as Bab edh-Dhra (Figure 11), exhibit a high presence of grape and barley but low quantities of other taxa like emmer wheat or olive. Even though discrepancy can be attributed to the water requirements as in the case of barley that can thrive with lower water levels and can withstand periods of drought, grape cultivation demands a more consistent water supply. This underscores how even in arid environments people tend to prioritize specific agricultural resources based on their adaptability to local conditions (Fall et al. 2002)

During the Middle Bronze Age (Figure 12) we have a general reduction of frequencies of botanical remains, at least during the earlier phase. These changes in the quantities of plant remains findings compared to previous period, which can also be observed in Tel Kabri, may be explained by climatically triggered adaptive processes in ancient societies leading to changes in agricultural production (see paragraph 1.2). The MBA botanical assemblages of the sites in the southern Levant are primarily located in the first quadrant of the CA, dragged by the presence of fruit taxa in their botanical assemblage. Throughout the MBA, barley continues to be consistently present in Levantine botanical assemblages. However, during this

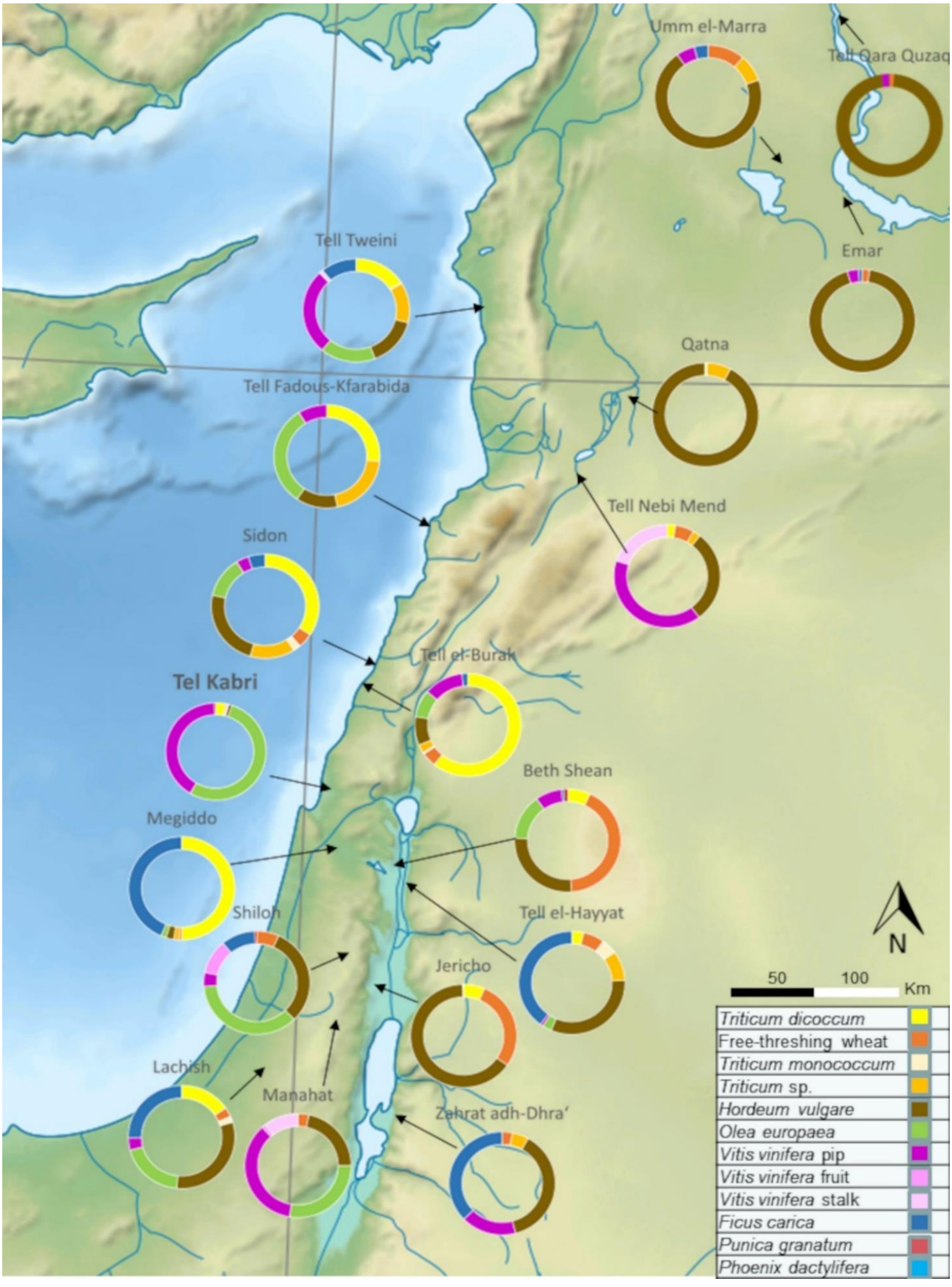

Fig. 12 MBA crop proportions in Levantine sites used in CA. From Appendix 2, Nicoli' et al. 2023

period, the presence and frequency of emmer wheat in the southern Levant are noticeably reduced. The decreased presence of emmer and the significant prevalence of barley and fig in the MBA settlements of the southern Levant, except for sites around the Jordan rift, may be linked to the arid event at the end of the EBA previously discussed. This climatic change could have impacted the considered sites and the production of crops that have higher water requirements. A unique case is observed in Beth Shean, located in the top part of the CA graph, standing apart from the other sites due to its role as a trade hub that involved the importation of crops during the MBA. This is supported by the identification of wild taxa that originated from outside the region of the site.

While the alterations in the botanical assemblages during the MBA may have been a response to climatic fluctuations, the changes in agricultural resources during the Late Bronze Age (Figure 13) appear to have been influenced to a greater extent by economic interests or cultural preferences. In the CA patterns for the LBA, a majority of the southern Levantine sites form a cluster on the positive side of Axis 1. This suggests not only the presence of fruit trees in the assemblages but also more cereal crops, in particular the presence of free-threshing wheat which gradually replace emmer. The shift from a drought-resistant crop like emmer to a more susceptible one such as free-threshing wheat has been suggested to be driven by economic considerations. The time-consuming processing required for emmer, in comparison to the more convenient processing of free-threshing wheat, likely made the latter more attractive for cultivation (Nesbitt and Samuel 1996). In some cases barley and emmer are still present in the botanical assemblages of some sites in the southern Levant, as in the case of Lachish. The preference for emmer wheat has been linked to the influence of Egyptian political power on these sites. In Egypt, emmer remained the primary cereal crop species until the Graeco-Roman period, and both emmer and barley were utilized in the production of bread and beer (Nesbitt and Samuel 1996). Trade relationships are substantiated by both written sources, such as the Amarna letters, and the material culture (Cohen 2014), which provides evidence of trade not only between the southern Levant and Egypt but also with northern sites. In the CA, a majority of the northern region LBA sites are positioned in the first and second quadrants of the graph as an increase in the presence of fruit taxa in the northern region occurred during this period.

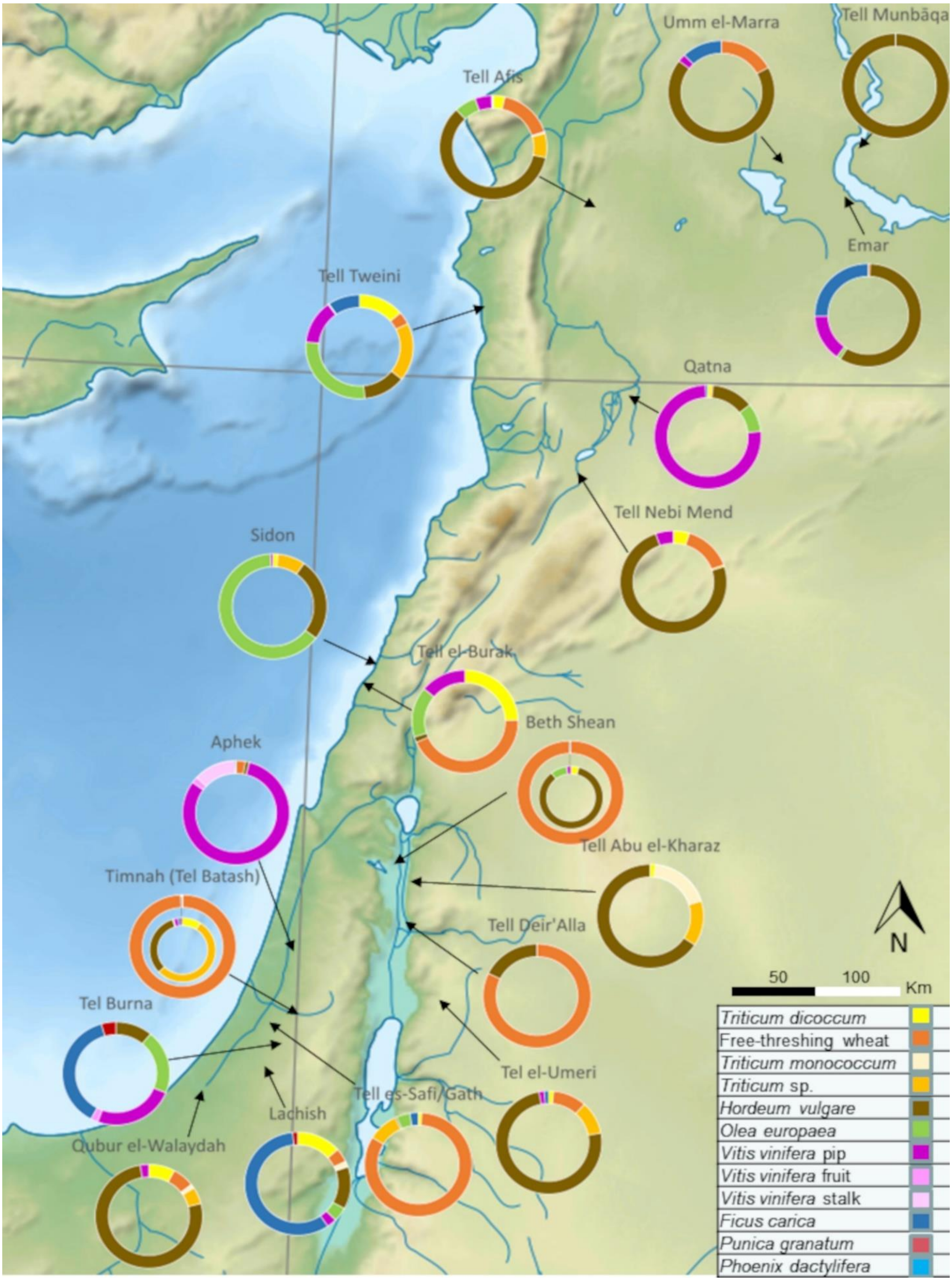

Fig. 13 LBA crop proportions in Levantine sites used in CA. From Appendix 2, Nicoli' et al. 2023

4. Conclusion

The primary aim of this dissertation was to analyze the plant macro-remains from two pivotal Bronze Age sites in the southern Levant, Lachish and Tel Kabri. This objective was accomplished through systematic sampling conducted during this research, which enabled the comprehensive examination of agricultural resource utilization at both sites. Additionally, thanks to the archaeobotanical identifications, the study provided more detailed information on the archaeological context of the sampled areas.
The second objective of this study was to compile and compare these archaeobotanical analyses results to understand the transformations and continuities of agricultural resources in the southern Levant during the Bronze Age.

The domestic contexts of the EBA plant assemblage in Tel Kabri reflect the dominance of fruit plant taxa, consistent with the trend observed in other southern Levant sites during this period, indicating an intensification of horticulture and vineyard cultivation. Pollen records from the nearby Sea of Galilee also reveal that during this period, olive trees reached peak frequency. A clear distinction is evident between the northern Levant sites, which predominantly focused on cereals, particularly barley, and the southern Levant and coastal sites. The EBA plant assemblage from Tel Kabri exhibits a notable emphasis on legumes. Contrary to barley and emmer, which showed signs of drought stress in stable isotope measurements, legumes displayed no stress signals and consistent water availability. This suggests that legumes may have been cultivated in environments with a reliable and constant water supply, conducive to optimal yields. The presence of significantly high drought stress in barley and emmer, despite evidence of wet climate conditions throughout the EBA, raises questions about the agricultural practices of the time. The high values of manuring observed, in the case of emmer, suggest a specific soil fertility strategy or alternatively, it could imply that emmer was obtained through trade, potentially from regions with different soil conditions or agricultural practices.
The plant assemblages from both Lachish and Tel Kabri during the MBA exhibit similar characteristics, likely influenced by their palace contexts. Notably, both sites showed no chaff remains, indicating that the process of cereal cleaning likely occurred outside of the elite palace areas. Additionally, there were minimal findings of wild seed taxa, while the presence of other crops was typically associated with domestic waste. The remains from the wine cellar in Tel Kabri are primarily associated with grape seeds, which were found in a mineralized

state. This preservation is attributed to the presence of unfiltered stored wine in the vessels or to the breakage of the vessels which allowed the seeds to become soaked and preserved due to the acid present in the wine.

The overall decrease in the quantities of botanical remains during the MBA seems to be a widespread phenomenon in the southern Levant (with few exceptions), likely in response to climatic fluctuations and dry events, evidenced by various environmental research findings. These climatic conditions may have led to a decrease in emmer, a more susceptible crop, and an increase in the regional frequencies of barley and figs.

For the LBA plant assemblages at Lachish, there is a notable proliferation of remains in terms of frequencies and newly identified cultivated plant taxa, particularly fruits, indicating their significance in the local diet. In general, during the LBA, changes in plant assemblages for southern Levant sites appear to be more influenced by economic interests or cultural factors. Preferences for the economically advantageous free-threshing wheat resulted in the gradual replacement of emmer in most of the southern Levant sites. This shift was also favored by the predominantly wet climate during the LBA, as proven also by local pollen samples sourced from Lachish. In the case of Lachish, however, it appears that the production of cereal crops was influenced by Egyptian political power as the city came under their sphere of influence. This is likely the reason why emmer remained the main cereal crop in some cities, thereby influencing the composition of their agricultural resources for a requested surplus.

What Lachish and Tel Kabri share with most other southern Levant sites throughout the Bronze Age is their emphasis on fruit plant taxa, particularly the presence of olive in the majority of their samples. Olive is the most abundant taxon found in both sites and undoubtedly held significant economic value for its oil, which can be stored for extended periods and utilized for various purposes beyond daily consumption.

This research underscores the significance of comprehensive archaeobotanical investigations across multiple contexts within multi-period sites. While archaeobotany offers only a partial depiction of actual plant resources, systematic sampling facilitates thorough analysis and examination, enabling in-site diachronic studies as well as comparative analyses within a broader regional framework. It will be crucial for future analyses to continue filling the research gaps that persist in the archaeological field. This can be achieved by incorporating archaeobotany as an essential component of site studies and subsequently by updating and creating diachronic syntheses with new data as it becomes available.

References

Bar-Matthews M, Ayalon A (2004) Speleothems as paleoclimate indicators, a case study from Soreq cave located in the eastern Mediterranean region, Israel. In: Battarbee RW, Gasse F, Stickley CE (eds) Past climate variability through Europe and Africa. Springer, Dordrecht, pp 363–391

Bar-Matthews M, Ayalon A (2011) Mid-Holocene climate variations revealed by high resolution speleothem records from Soreq Cave, Israel and their correlation with cultural changes. The Holocene 21, 163-171

Bourke S. J. (2014) The Southern Levant (Transjordan) during the Middle Bronze Age. In: Steiner M L, Killebrew A E (eds.) The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE., Oxford, pp. 445–458

Caracuta V, Barzilai O, Khalaily H, Milevski I, Paz Y, Vardi J, Regev L, Boaretto E (2015) On the onset of faba bean farming in the southern Levant. Sci Rep 5:14370

Clarke J, Brooks N, Banning E B, Bar-Matthews M et al. (2016) Climatic changes and social transformations in the Near East and North Africa during the "long" 4th millennium BC: A comparative study of environmental and archaeological evidence, Quat Scie Rev 136:96-121

Cohen H (2009) Middle Bronze Age IIB Rural settlements in the eastern valleys and the desert frontier of Samaria hill country. Ostracon Press, Haifa

Cohen S (2014) The Southern Levant (Cisjordan) during the Middle Bronze Age. In: Steiner M L, Killebrew A E (eds) The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE, Oxford, 451-464

Dalman G (1935) Arbeit und Sitte in Palästina. Bertelsmann, Gütersloh. Digitized version 2013. http://nbnresolving.de/urn:nbn:de:bsz:21-opus-69119

de Miroschedji P (2009). Rise and collapse in the Southern Levant in the Early Bronze Age. Scienze dell'Antichita. Storia Archeol. Antropol. 15:101-129

de Miroschedji P (2014) The Southern Levant (Cisjordan) during the Early Bronze Age. In: Steiner, M. L., Killebrew, A. E. (eds.), The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE, Oxford, 308-328

De Moulins D (2015) Plant remains from middle bronze age to iron age: samples of the college site. Sidon Archaeol Hist Lebanon 42(43):32–54

DeNiro M J, Hastorf C A (1985) Alteration of $^{15}N/^{14}N$ and $^{13}C/^{12}C$ ratios of plant matter during the initial stages of diagenesis: studies utilizing archaeological specimens from Peru. Geochim Cosmochim Acta 49:97–115

Drori I, Horowitz A (1989) Tel Lachish: Environment and subsistence during the Middle Bronze, Late Bronze and Iron Ages. J Inst Archaeol Tel Aviv Univ 16:206–211

Fall P L, Falconer SE, Lines L (2002) Agricultural intensification and the secondary products revolution along the Jordan Rift. Hum Ecol 30:445–482

Ferrio J P, Araus J L, Buxó R, Voltas J, Bort J (2005) Water management practices and climate in ancient agriculture: inference from the stable isotope composition of archaeobotanical remains. Veget Hist Archaeobot 14:510–517

Ferrio J P, Alonso N, López B, Araus J L, Voltas J (2006) Carbon isotope composition of fossil charcoal reveals aridity changes in NW Mediterranean Basin. Glob Change Biol 12:1-14

Ferrio J P, Voltas J, Araus JL (2012) A smoothed curve of δ13C of atmospheric CO2 from 16.100 BCE to 2.010 CE http://web.udl.es/usuaris/x3845331/AIRCO2_LOESS.xls. Accessed Dec 2021

Ferrio J P, Aguilera M, Voltas J, Araus JL (2020) Stable carbon isotopes in archaeological plant remains. In: Montenari M (ed) Stratigraphy & timescales. Academic Press, pp 107–145

Fiorentino G, Ferrio J P, Bogaard A, Araus J L, Riehl S (2015) Stable isotopes in archaeobotanical research, Veget Hist Archaeobot 24:215–227

Frumkin A, Carmi I, Gopher A, Ford D C, Schwarcz H P, Tsuk T (1999) A Holocene millennial-scale climatic cycle from a speleothem in Nahal Qanah Cave, Israel. The Holo, 9(6), 677–682. https://doi.org/10.1191/095968399669422210

Frumin S I, Melamed Y, Weiss E (2019) The wheat-people of Canaan. In: Maeir AM, Shai I, McKinny C (eds) The Late Bronze and Early Iron Ages of Southern Canaan. De Gruyter, Berlin/Boston, pp 19–36

Fuks D, Ackermannn O, Ayalon A, Bar-Matthews M, Levi Y, Maeir A, Weiss E, Zilberman T, Safrai Z (2017). Dust clouds, climate change and coins: consiliences of palaeoclimate and economy in the Late Antique southern Levant Dust clouds, climate change and coins: consiliences of palaeoclimate and economy in the Late Antique southern Levant. Levant. 49. 10.1080/00758914.2017.1379181

Fuller D Q, Lucas L (2014) Archaeobotany. In: Smith, C. (eds) Encyclopedia of Global Archaeology, New York, pp. 305-310

Genz H (2010) Thoughts on the Function of 'Public Buildings' in the Early Bronze Age Southern Levant. In Bolger D, Maguire L C (eds) The Development of Pre-State Communities in the Ancient Near East, Oxbow, pp. 46-52

Genz H (2014) The Northern Levant (Lebanon) during the Early Bronze Age. In: Steiner M L, Killebrew A E (eds.) The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE, Oxford, 292-306

Grasso A M, D'Aquino S, Vacca E, Nicolì M, Primavera M, Fiorentino G (2021) Innovation: Turning Something Old into Something New. *Vicia faba* var. *major*. In Grau Sologestoa I, Albarella U (eds.) The Rural World in the Sixteenth Century, Turnhout

Johnston P (2023) Archaeobotany: what can plant macro-remains tell us?, Arch Ire, 37:36-40

Hansson MC, Foley BP (2008) Ancient DNA fragments inside Classical Greek amphoras reveal cargo of 2400-year-old shipwreck. J Arch Sci 35:1169–1176

Helbæk H (1958) Plant economy in ancient Lachish. In: Tufnell O (ed) Lachish (Tell ed-Duweir), vol 4: The Bronze Age. Oxford University Press, London, pp 309–317

Hruby K, Rosenberg D (2023) Urbanizing food: New perspectives on food processing tools in the Early Bronze Age villages and early urban centers of the southern Levant, Jour of Anthro Arch, 72:101549

Kintigh KW, Altschul J H, Beaudry M C et al. (2014) Grand challenges for archaeology, Ameri Antiq 79:5-24

Lancelotti C, Madella M (2023) Archaeobotany. In: Pollard M, Armitage R A, Makarewicz C A (eds) Handbook of Archaeological Sciences, Second Edition. New Jersey, pp. 701 713

Langgut D, Finkelstein I, Litt T (2013) Climate and the Late Bronze Age collapse: new evidence from the southern Levant. J Inst Archaeol Tel Aviv 40:149–175

Langgut D, Finkelstein I, Litt T, Neumann F H, Stein M (2015) Vegetation and Climate Changes during the Bronze and Iron Ages (~3600–600 BCE) in the Southern Levant Based on Palynological Records, Radiocarbon. 57:217–235. 10.2458/azu_rc.57.18555.

Lazar M, Cline EH, Nickelsberg R, Shahack-Gross R, Yasur-Landau A (2020) Earthquake damage as a catalyst to abandonment of a Middle Bronze Age settlement: Tel Kabri, Israel. PLoS One 15(9):e0239079

Leps J, Smilauer P (2014) Multivariate Analysis of Ecological Data using CANOCO, Cambridge

Linseele V, Marinova E, De Cupere B, van der Valk J, Vandorpe P, Van Neer W (2019) Bronze and Iron Age Paleo-Economy in a changing environment. The bioarchaelogy of Tell Tweini, on the Northern Levantine coast. In Bretschneider J, Jans G (eds) About Tell Tweini (Syria): artefacts, ecofacts and landscape. Leuven, pp. 417–617

Liphschitz N (2002) The paleobotanical remains. In: Kempinksi A (2002) Tel Kabri. The 1986–1993 excavation seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv, pp 428–434

Liphschitz N (2004) The archaeobotanical remains. In: Ussishkin D (ed) The renewed archaeological excavations at Lachish 1973–1994. Emery and Claire Yass Publications in Archaeology, Tel Aviv, pp 2230–2247

Lorentzen B (2023) Ancient wood remains. In: Cline EH, Rarzlaf A, Yasur-Landau A (eds) Excavations at Tel Kabri III: The 2023 to 2019 Seasons. Brill, Leiden

Maeir M, Shai I, McKinny C, The Late Bronze and Early Iron Ages of Southern Canaan, Berlin-Boston

McCreery D W (1979) Flotation of the Bab edh-Dhra and Numeira plant remains. Ann Am Schools Orient Res 46:165–169

McCreery D W (2003) The Paleoethnobotany of Bab Edh-Dhra. In Rast W, Schaub R T (eds) Bâb edh-Dhrâ‘: Excavations at the Town Site (1975–1981), Winona Lake, pp. 449 463

McCreery D W (2011) Agriculture and Religion at Bab edh-Dhra and Numeira during the Early Bronze Age. In Chesson MS (ed) Daily life, materiality, and complexity in early urban communities of the southern Levant, State College, pp. 77–87

Milevski I (2013) The Transition from the Chalcolithic to the Early Bronze Age of the Southern Levant in Socio-economic Context. Paléorient 39(1): 193-208

Migowski C, Stein M, Prasad S, Negendank JFW, Agnon A (2006) Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. Quat Res 66:421–431

Neef, R. 1990. Introduction, Development and Environmental Implications of Olive Culture: The Evidence from Jordan. In Bottema S, Entjes-Nieborg G, van Zeist W (eds) Man's Role in the Shaping of the Eastern Mediterranean Landscape, Rotterdam, pp.295-306

Nesbitt M, Samuel D (1996) From staple crop to extinction? The archaeology and history of hulled wheats. In: Paludosi S, Hammer K, Heller J (eds) Hulled wheats. Proceedings of the first International Workshop on Hulled Wheats, 21-22 July 1995, Castelvecchio Pascoli, Tuscany, Italy. (Promoting the conservation and use of underutilized and neglected crops 4) International Plant Genetic Resources Institute, Rome, pp 41-100

Neumann K, Chevalier A, Vrydaghs L (2017) Phytoliths in archaeology: recent advances. Veget Hist Archaeobot 26:1–3

Nicolì M, Riehl S, Webster L, Streit K, Höflmayer F (2022) Agricultural resources in the Bronze Age city of Tel Lachish. Veget Hist Archaeobot 31, 559–577

Nicolì M, Riehl S, Cline E H, Yasur-Landau A (2023) From Early Bronze Age domestic plant production to Middle Bronze Age regional exchange economy: the archaeobotanical assemblages from Tel Kabri. Archaeol Anthropol Sci 15:128

Jones G (1991) Numerical analysis in archaeobotany. In: Wasylikowa K, Behre K-E (eds) Van Zeist W. Progress in old world paleoethnobotany, Rotterdam, pp 63–80

Jones G, Bogaard A, Charles M, Hodgson JG (2000) Distinguishing the effects of agricultural practices relating to fertility and disturbance: a functional ecological approach in archaeobotany. J Arch Sci 27:1073–1084

Jongman R H, ter Braak J F, van Tongeren O F R (1995) Data analysis and community and landscape ecology. Cambridge University Press, Cambridge

Kagan EJ, Langgut D, Boaretto E, Neumann FH, Stein M (2015) Dead sea levels during the bronze and iron ages. Radiocarbon 57:237–252

Kamlah J, Riehl S (2020) Agriculture in the Bronze Age Levant. In Hollander D, Howe T (eds.) A Companion to Ancient Agriculture. John Wiley & Sons, Oxford, pp. 193-209

Kamlah J, Riehl S (in press) Atlas zum Ackerbau im Antiken Palästina, RessourcenKulturen

Kempinski A (2002) Tel Kabri: The 1986–1993 excavations seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv

Kislev ME (1993) Food remains. In: Finkelstein I, Bunimovich S, Lederman Z (eds) Shiloh: the archaeology of a biblical site. Monograph Series of the Institute of Archaeology Tel Aviv University No. 10, Tel Aviv, pp 354–361

Koch I (2019) Southwestern Canaan and Egypt during the Late Bronze Age I–IIA. In: Maeir M, Shai I, McKinny C (eds) The Late Bronze and Early Iron Ages of Southern Canaan, Berlin-Boston, pp. 262-282

Koh AJ, Yasur-Landau A, Cline EH (2014) Characterizing a Middle Bronze palatial wine cellar from Tel Kabri, Israel. PLoS ONE 9:1–15

Oren R (2002) Chapter 4: Area D. In: Kempinski A (ed) Tel Kabri: The 1986 1993 excavations seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv, pp 55–70

Rambeau C (2010) Palaeoenvironmental reconstruction in the Southern Levant: Synthesis, challenges, recent developments and perspectives, Philos trans. Ser Math, phys, and eng scie. 368:5225-48

Riehl S (2008) Climate and agriculture in the ancient Near East: a synthesis of the archaeobotanical and stable carbon isotope evidence, Veget Hist Archaeobot 17:43-51. https://doi.org/10.1007/s00334-008-0156-8

Riehl S (2009) Archaeobotanical evidence for the interrelationship of agricultural decision making and climate change in the ancient Near East. Quat Int 197:93–114

Riehl S, Deckers K (2009) The botanical fnds from the 2007 and 2008 seasons of excavations. In: Genz H (ed) Excavations at Tell Fadous – Kfarabida: Preliminary report on the 2009 seasons of excavations, vol. 13. BAAL, Beirut, pp. 110–116

Panitz-Cohen N (2014) The southern Levant (Cisjordan) during the Late Bronze Age. In: Steiner, M.L., Killebrew, A.E. (eds) The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE., Oxford Handbooks in Archaeology, Oxford, pp. 541–560

Pfoh E (2019) "Prestige and authority in the Southern Levant during the Amarna Age". In Maeir M, Shai I, McKinny C (eds) The Late Bronze and Early Iron Ages of Southern Canaan, Berlin-Boston, pp. 247-261

Philip G (2003) The Early Bronze Age of the Southern Levant: A landscape approach. Jour of Medi Arch. 16:103-132

Prag K (2014) The Southern Levant during the Intermediate Bronze Age. In: Steiner M L, Killebrew A E (eds) The Oxford Handbook of the Archaeology of the Levant c. 8000 332 BCE, Oxford, 388-400

Primavera M, D'Oronzo C, Muntoni I M et al. (2017) Environment, crops and harvesting strategies during the II millennium BC: resilience and adaptation in socio-economic systems of Bronze Age communities in Apulia (SE Italy), Quat Int 436:83–95

Pustovoytov K E, Riehl S, Mittmann S (2004) Radiocarbon age of carbonate in fruits of Lithospermum from the early Bronze Age settlement of Hirbet ez-Zeraqōn (Jordan). Veg Hist Archaeob, 13:207–212

Schiebel V, Litt T (2017) Holocene vegetation history of the southern Levant based on pollen record from Lake Kinneret (Sea of Galilee), Israel, Veg Hist and Arch 27:577-590

Schilman B, Ayalon A, Bar-Matthews M, Kagan EJ, Almogi Labin A (2002) Sea-land paleoclimate correlation in the Eastern Mediterranean region during the Late Holocene. Isr J of Earth Sci 51:181–19

Sharon I (2014) Levantine Chronology. In: Steiner, M. L., Killebrew, A. E. (eds.), The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE (Ox- ford) 44 65

Smith A, Munro ND (2009) A holistic approach to examining ancient agriculture: a case study from the Bronze and Iron Age Near East. Curr Anthrop 50:925–936

Sofo A, Manfreda S, Fiorentino M, Dichio B, Xiloyannis C (2008) The olive tree: a paradigm for drought tolerance in Mediterranean climates. Hydrol Earth Syst Sci 12:293–301

Steiner M L, Killebrew A E (2014) The Oxford Handbook of the Archaeology of the Levant c. 8000-332 BCE, Oxford

Stern B, Heron C, Tellefsen T, Serpico M (2008) New investigations into the Uluburun resin cargo. J Arch Sci 35:2188–2203

Ussishkin D (2004) The renewed archaeological excavations at Lachish (1973–1944), vols 1 5. Emery and Clairs Yass Publications in Archaeology, Tel Aviv

Webster L, Streit K, Dee M, Hajdas I, Höflmayer F (2019a) New radiocarbon-based assessment supports the prominence of Tel Lachish during late Bronze age IB-IIA. Radiocarbon 61:1,711–1,727

Webster L, Streit K, Dee M, Hajdas I, Höflmayer F (2019b) Identifying the Lachish of papyrus Hermitage 1116A verso and the Amarna Letters: implications of new radiocarbon dating. J Anc Egypt Interconnect 21:88–99

Weiss E, Kislev M (2007) Plant remains as a tool for reconstruction of the past environment, economy, and society: Archaeobotany in Israel. Isr Jour of Earth Scie 56:163-173

Wilcox G (1992) Preliminary report on plant remains from Pella. In: McNicoll AW, Edwards PC, Hanbury-Tenison J et al (eds) Pella in Jordan 2. The second interim report of the joint University of Sydney and the College of Wooster excavations at Pella, 1982-1985. Meditarch, Sidney, pp 253–256

Zohary M (1962) Plant life of Palestine. Ronald Press, New York, Israel and Jordan.

Appendix 1

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ORIGINAL ARTICLE

Agricultural resources in the Bronze Age city of Tel Lachish

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Abstract

In this paper, we present the results of the plant macrofossil analyses from the site of Tel Lachish, Israel with focus on the botanical assemblage of the Middle and Late Bronze Age layers collected in two different areas of the tell: Area S, a trench on the western edge of the site, whose samples belong to Late Bronze Age deposits, and Area P, the palace area on the top of the mound with samples ranging from the Middle to Late Bronze Age. Systematic sampling of these areas and analysis of the remains have extended our knowledge of the agricultural resources of one of the most influential Late Bronze Age cities in the southern Levant. Multivariate statistics have been applied to gain insight into regional patterns of crop growing. Fruit crops account for the majority of the identified remains from this site, which also included large quantities of *Hordeum vulgare* (barley) and *Triticum dicoccum* (emmer wheat) grains. The virtual lack of chaff remains is not solely a matter of preservation, since the Late Bronze Age assemblage preserved fragile small seeds. Rather, this finding suggests that cereal processing took place some distance from the area of deposition. Overall high diversity, ubiquity and proportions of fruit crops indicate that these played a fundamental role in their cultivation and probably also in cultural life at Lachish throughout the 15th–12th centuries BCE.

Keywords Southern levant · Shephelah · Cereal crops · Fruit tree cultivation · Ancient agriculture

Introduction

Lachish was an urban centre from the Middle Bronze Age (MBA) until the Iron Age (IA), 2000-586 BCE. The tell is among the largest in the southern Levant and is located in the Shephelah region in Israel, between the Mediterranean coast and the Judaean mountains (Fig. 1). Lachish has been the destination of many archaeological expeditions throughout the years, starting from the 1930s with the Wellcome-Marston expedition (Torczyner et al. 1938; Tufnell et al. 1940, 1953, 1958) and continuing in the second half of the 20th century, with an expedition directed by Yohanan Aharoni between 1966 and 1968 (Aharoni 1975). A third expedition is the 'renewed excavations', the most extensive excavations, which took place between 1973 and 1994, on behalf of Tel Aviv University and directed by David Ussishkin (Ussishkin 2004). A fourth expedition took place between 2013 and 2016, under the co-direction of Garfinkel, Hasel and Klingbeil (Weissbein et al. 2016; Ganor and Kreimermann 2018; Garfinkel et al. 2021). Since 2017, an Austrian expedition has been excavating two areas which were previously opened by Tel Aviv University, Area S, a deep section on the western edge of the tell, and Area P, the palace area on the top of the mound (Fig. 2). The botanical remains discussed in this paper came from these two areas of specific architectural units (Table 1).

The earliest archaeological finds from Lachish date to the Neolithic period. The pottery evidence points to an occupation of the mound during the Early Bronze Age (EBA), but during the Intermediate Bronze Age (EBA IV) the settlement was almost completely abandoned and excavations

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Fig. 1 Map of the southern Levant showing the position of Lachish and some of the other sites mentioned

proved the existence only of small campsites and burials of nomadic tribes on the slope beneath the site (Ussishkin 2004). A renewed settlement and urbanization then occurred during the Middle Bronze Age (MBA), when Canaanite city states began to develop, shown by massive fortifications and a substantial mudbrick building that has been interpreted as a palace. Eventually this MBA city came to a violent end. In the Late Bronze Age (LBA), the city was rebuilt again and it entered the Egyptian sphere of influence. Thanks to the textual evidence of the *Papyrus Hermitage 1116A* and the *Amarna Letters*, we know that Lachish was highly valued by the Egyptian rulers, who acknowledged it as one of the most important kingdoms in the southern Levant during this time, together with Gezer and Gath (Tell es-Safi) which are also in the Shephelah (Golénischeff 1913; Epstein 1963; Rainey 2015). Radiocarbon dating of samples from buildings in layer S-3 and contexts within layer S-2 at Lachish, confirm that the site is contemporary with the textual evidence (Webster et al. 2019a, b).

The project "Tracing Transformation" aims to shed new light on the period between the collapse of MBA urbanism and the consolidation of LBA city states. As part of the CRC 1070 Resource Cultures, these archaeobotanical analyses seek to understand the social and cultural changes from the MBA to the LBA from the agricultural resources. Since agriculture and subsistence are fundamental to the social and political functioning of settlements and states, their investigation is crucial for understanding the historical development and external perception of Lachish and other settlements of the region during these periods.

Systematic archaeobotanical sampling has resulted in a large and representative dataset, which helps understand the different aspects of agriculture, such as fruit cultivation, which may have contributed to the importance of Lachish during the LBA. Moreover, by analysing the results through time, this research aims to detect any changes that may have been influenced by climatic fluctuations.

Previous archaeobotanical research in Lachish was mainly on charcoal remains (Liphschitz 2004), whereas seed remains have only been recorded for their overall proportions and ubiquities (Helbæk 1958), which does not allow for comparative studies through time or in various regions. Furthermore, the tendency in earlier analyses to only collect larger seeds leads to their over-representation in the assemblages at the expense of small seeded and wild taxa. The new results presented here fill these gaps and contribute to a better understanding of the agronomic basis of one of the most influential LBA cities in the southern Levant.

Environmental background

The present-day southern Levant is characterized by a semi-arid Mediterranean climate, with a mean annual precipitation of ca. 350 mm in the Lachish region (Drori and Horowitz 1989). There are no natural springs around the tell, but a seasonal stream runs in the vicinity carrying the name of the city, wadi Lachish. The vegetation of the region is characterized by a Mediterranean carob-lentisk maquis (Zohary 1962) and is heavily affected by human activities like agriculture, viticulture and the introduction of exotic taxa such as *Eucalyptus*, *Cupressus* etc. (Olsvig-Whittaker et al. 2015). While faunal data on more or less dry climate elements of datasets from the wider region show only a little difference between the LBA and IA environments around Tel Lachish, there is a consistent association with relatively dry environments (Olsvig-Whittaker et al. 2015). Geoarchaeological and pollen studies, however, provide a more varied picture of environmental development there.

The Middle Bronze Age, when a new settlement was established at Lachish leading to the formation of a city state, was a time of semi-arid climate that was moister than today, as shown by the stable oxygen data of the Soreq cave mineral deposits (speleothems), located only about 26 km northeast of Lachish (Bar-Matthews and Ayalon 2004). This climatic period occurred after a short regional dry event, indicated by the decrease of Mediterranean tree pollen

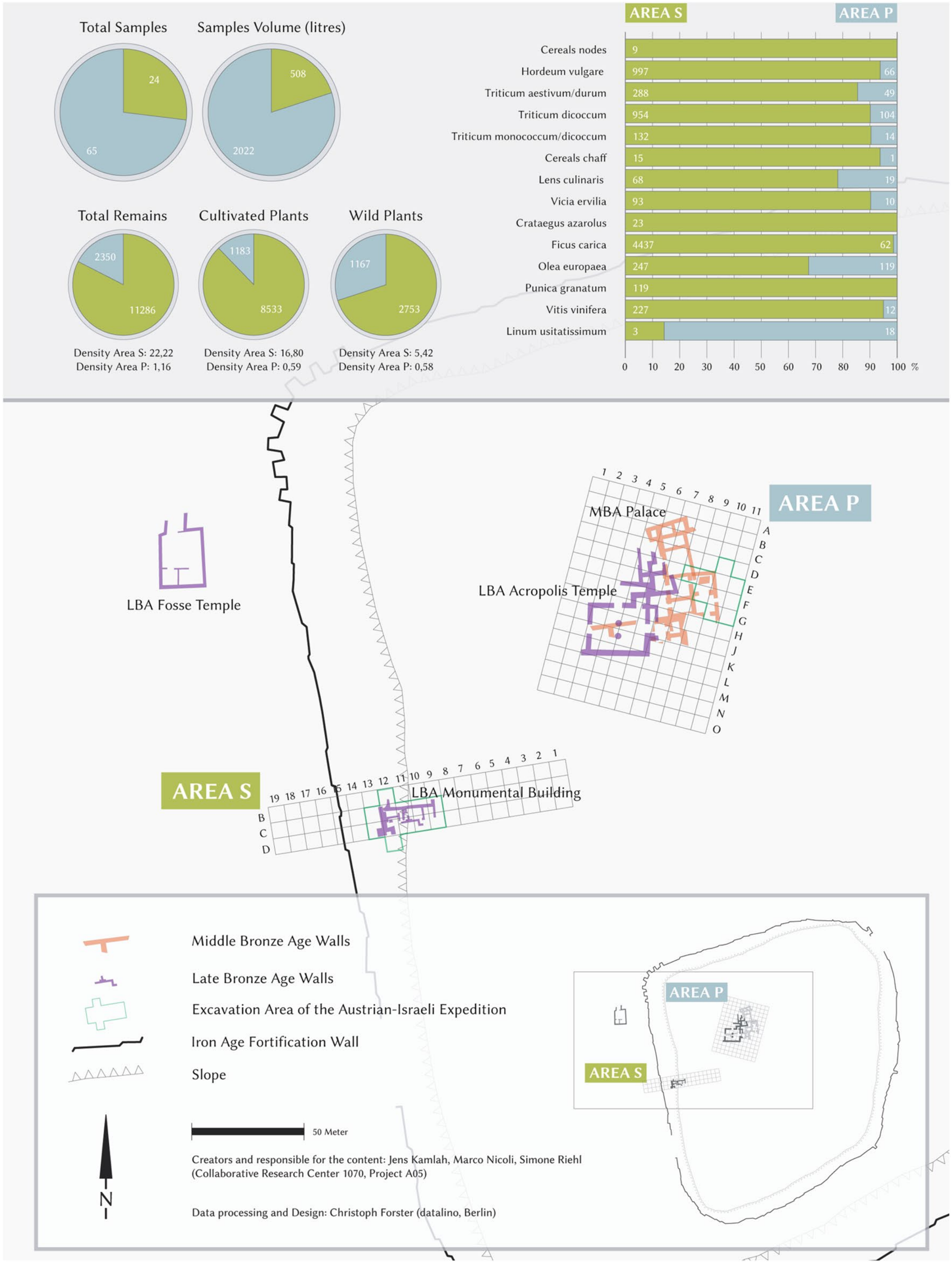

Fig. 2 Lachish, plans of areas S and P. On the top left the sample details (including Iron Age). On the top right the quantities of the main crop remains, the white numbers in the bar chart represent seed counts

values (Langgut et al. 2013). Furthermore, there are signs of rapid fluctuations in rainfall in the Lachish stream sediments at the beginning of MBA I (Rosen 1986). For the LBA, trees and shrubs are recorded in pollen diagrams in which indicate Mediterranean woodlands or maquis scrub with a peak in evergreen *Quercus* and *Pistacia* around 1350 BCE (Langgut

Table 1 Sampling context and phases in Areas S and P (absolute chronology based on Webster 2020)

Layer	Absolute chronology[a]	Description
Area S		
S-3c	1495–1440 BCE, 1σ	Late Bronze Age I: fortification, monumental building and domestic units
S-3b	1460–1430 BCE, 1σ	Re-use of monumental building and new domestic units
S-3a	1445–1420 BCE, 1σ	Re-use of monumental building and new domestic units
S-2	1435–1305 BCE, 1σ	Late Bronze Age II waste context
Area P		
P-4	1618–1573 BCE, 1σ	Middle Bronze Age III, last use of the palace
P-3	1605–1530 BCE, 1σ)	Re-use of the palace building for industrial/domestic purposes
P-2	ca 1200–1300 BCE	Late Bronze Age II structures and pits

[a]Numerical ranges include both the start and end boundaries of each phase; see Webster et al. (2019a,b; 2020)

et al. 2015), coinciding with a time of prosperity in the city state. The rich arboreal vegetation is also shown in LBA pollen samples from Lachish, showing a peak in Mediterranean maquis trees (in particular *Pinus halepensis*) but also higher values of *Olea europaea* compared with the MBA and IA pollen spectra (Drori and Horowitz 1989). At the end of the LBA, another dry climate event occurred in the Levant, as shown not only by a reduction in arboreal pollen but also by a strong increase in $\delta^{18}O$ and $\delta^{13}C$ values in the speleothems of Soreq cave, Jerusalem (Bar-Matthews and Ayalon 2004). Additional signs of increased aridity comes from the isotopic composition of plankton in Mediterranean sea cores on the coastal plain (Schilman et al. 2002). Studies carried out in the Dead Sea area suggest an earlier start of this dry event at around 1500 BCE (Migowski et al. 2006; Kagan et al. 2015), although dating results from different lines of evidence have not been correlated yet. The Iron Age has been associated with a less dry climate (Langgut et al. 2013, 2015). Both modern ecological data and archaeobotanical assemblages from sites located in the Coastal Plains and the Shephelah (Shfela) suggest a shift from mesic to xeric biomes for the LBA/IA transition, except for Lachish which falls into the xeric class throughout the whole sequence investigated (Olsvig-Whittaker et al. 2015). Nevertheless, in Lachish, a rich arboreal pollen record collected from floors, artificial fillings, contents of pottery and mudbricks, has been found from IA layers similar to those of the LBA, showing a Mediterranean environment which is comparable to the present day one, but less arid (Drori and Horowitz 1989).

Since the environmental results appear elusive in terms of fluctuations in aridity and partially contradictory, a consideration of the general environmental pattern as obtained from charcoal studies at Lachish and other sites in the Shephelah may be more conclusive. These data have not shown any major changes in the tree and shrub composition, the three main taxa during the EBA, LBA and IA being *Olea europaea*, *Quercus calliprinos* and *Pistacia palaestina* (Liphschitz 2004).

Material and methods

During the 2018 and 2019 excavation seasons, 89 archaeobotanical samples were collected. Each sample was between 5 and 70 L, based on the archaeological context, but the majority measured 30 L, amounting to a total volume of about 2,530 L of sediment which was collected at the tell. These samples were processed using a flotation machine with a water recycling system built at the site in 2018 (ESM Fig. 1). There are 24 samples from Area S and 65 from Area P (Fig. 2), belonging to four different periods or phases (ESM Table 1). The samples from Iron Age IIA (4 samples) and IIB (1 sample), which belong solely to Area P (phase V and IV), are not included in the overall evaluation due to their small sample size.

The heavy residues from the flotation were collected on a 1 mm mesh inside a large barrel, dried and then sorted into three groups for plant remains, fauna and small archaeological finds (beads, etc.). The light fraction, the flot, was collected on a 0.2 mm sieve, then dried on small pieces of linen cloth.

The plant remains collected from both the heavy and the light fractions were sent to the archaeobotanical laboratory at the University of Tübingen for study. Plant remains were identified using an Euromex stereo microscope with up to 30× magnification using the Senckenberg seed reference collection available there (with roughly 20,000 seed taxa), various identification keys, recently published archaeobotanical research, seed catalogues and floras (for example, Post 1980; Jacomet 2006; Kislev et al. 2006; 2009a; b; Nesbitt 2009; Neef et al. 2012; Danin and Fragman 2016; Rousou et al. 2021). In a few cases, where the light fraction (0.2 mm) was larger than 200 ml, a riffle type sample splitter was used to produce sub-samples of one half or less (for Area S: L.1187, L.1122; Area P: L.2049). Most of the seed remains were charred, but some mineralized seeds were also present among some taxa, such as some specimens of *Vitis vinifera, Ficus carica* and Cyperaceae.

For some seeds, species identification was impossible due to bad preservation and, in some cases, breakage or the lack of surface texture limited identification to genus level. For example, in the case of *Triticum monococcum/dicoccum*, the grains, sometimes badly preserved, showed characteristics of both species. In side view, the biconvex outline morphologically categorizes them as one-grained einkorn. The apexes were however characteristic of slender emmer grains, making it impossible to identify them as either emmer or einkorn.

Some wild plant taxa have not been identified to the species level. Most of these seeds lack important identification features such as the mericarp in *Malva* sp. or surface patterns in small seeded pulses. Most of the Poaceae remains were not preserved in complete form, making it possible only to identify them to genus level, as in the case of *Bromus* spp., *Avena* sp. and *Phalaris* spp.

The samples from Area P were heavily affected by modern contamination, mainly within the light fractions which were packed with roots. A considerable number of remains from Area P were heavily corroded and cereal grains showed the typical expanded "bubble" pattern, except for the remains from pit L. 2049.

Weighing was used to quantify highly fragmented seeds and fruitstones (especially olives), and then converted into equivalent complete seeds from the weight of a complete individual. In cases where only one fragment was present, it was considered as one seed. Additionally, two halves and four quarters of cereal grains have been counted as one. Percentages and ubiquity of the recorded taxa and correspondence analysis (CA) for comparison between sites was done with CANOCO v. 5. Plant remains were photographed using a Zeiss Stereo Discovery V8 digital microscope (Figs. 3, 4).

Results

The botanical assemblage is composed of 58 identified taxa, which includes 20 cultivated plants from a total of 9,714 remains and 38 wild plant taxa from 3,920 remains. The plant remains from the various phases of the LBA (S-3, S-2 and P-2), MBA III (P-4 and P-3) and Iron Age II are given in Tables 2 and 3. IA samples will not be discussed in this paper due to their rarity, nevertheless, the plant remains identified from these samples have been listed in the tables to comply with open data access requirements.

Cereals

A total of 4,203 cereal remains were identified (Table 2). The best represented is *Hordeum vulgare* (barley, Fig. 3a), with a total of 1,063 grains and 13 rachis remains (Fig. 3b) representing 21% of all MBA crop remains and 11% of LBA crop remains. In terms of quantity, *Triticum dicoccum* (emmer wheat, Fig. 3c), is very close to barley in numbers, with a total of 1,058 grains and two glume bases (Fig. 3d), making up 10% of the MBA remains and 11% of the LBA crop assemblage. After barley and emmer, *Triticum aestivum/durum* (free-threshing wheat) follows with 337 grains (2% of MBA and 3.5% of LBA crop assemblages) and a single rachis fragment. Although barley is dominant in Area S, emmer is the main wheat in Area P. Particularly in Area P, cereal fragments were badly preserved and therefore identified only as Cerealia.

Fruit

The majority of the identified crop remains are of fruit. *Ficus carica* (fig) (Fig. 3i) is the crop with the highest number of seeds from LBA Lachish, with 47% of the total, but only 17% of the total MBA crop remains. *Olea europaea* (olive) (Fig. 3k) is the only fruit present in all analysed periods, and it is the most frequently represented taxon from the site, with 20 olive stones for MBA III (13% of the cultivated remains) and 343 for the LBA (3.6%). *Vitis vinifera* (grape) (Fig. 3q) is the next in terms of seed quantity from fruit, with a total of 239 remains representing 2.5% of both the MBA and LBA crop remains.

Punica granatum (pomegranate) is represented by 83 seeds and 36 exocarp fragments in a well-preserved state (Fig. 3n, o) and they are only present in LBA contexts since the remains come from Area S (25% of the LBA samples). The other two taxa from this category include one fruitstone of *Phoenix dactylifera* (date) (Fig. 3l m), and 23 *Crataegus azarolus* remains (azarole or Mediterranean medlar) (Fig. 3g, h), all of which come from LBA contexts in Area S.

Other crops

Vicia ervilia (bitter vetch) is the most abundant pulse in LBA contexts (1% of LBA crop remains). *Lens culinaris* (lentil) is the main legume found in the MBA samples, representing 3% of the MBA crop assemblage. Other legumes are *Cicer arietinum* (chickpea), *Lathyrus sativus* (grass pea), *Pisum sativum* (pea) and *Vicia faba* var. *minor* (faba bean) (Fig. 3e, f), which are present in small numbers. *Linum usitatissimum* (flax) is concentrated in a few LBA contexts, comprising 20 seeds and one capsule (Fig. 3s).

Wild plants

Overall, 38 wild plant taxa were identified from Lachish (Table 3). *Lolium* cf. *temulentum* (Fig. 4d) is the commonest wild plant from the LBA contexts, with a total of 3,206 remains and it is present in more than half of the samples. In

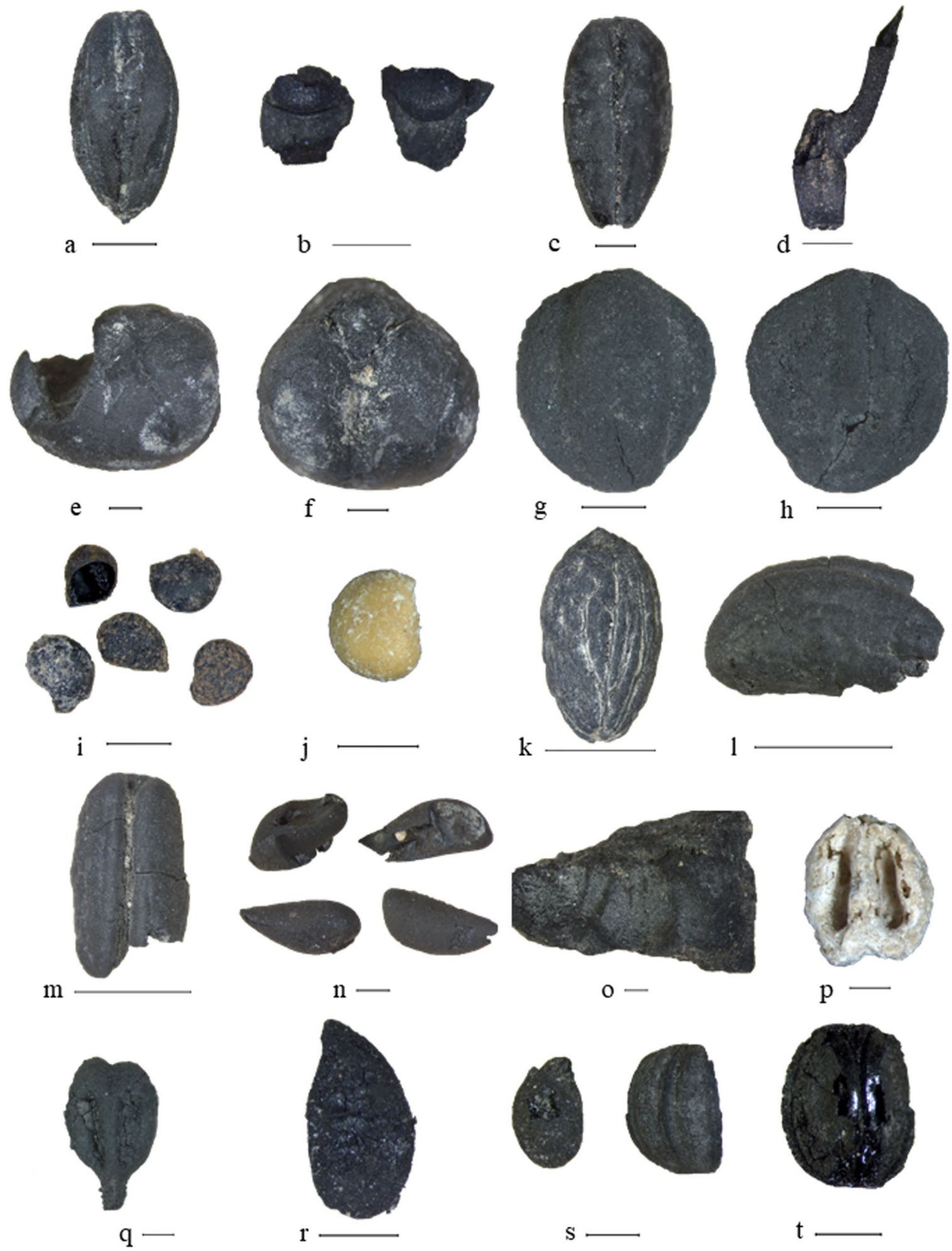

Fig. 3 *Hordeum vulgare* (barley) (L.1122), **a** grain, **b** rachises (L.1122); *Triticum dicoccum* (emmer wheat) (L.1212), **c** grain, **d** glume base; *Vicia faba* var. *minor* (faba bean) (L.1212), **e** lateral view, **f** front view; *Crataegus azarolus* (azarole) (L.1132), **g** top view, **h** bottom view; *Ficus carica* (fig), **i** seeds (L.1122), **j** mineralized seeds (L. 2038); **k** *Olea europaea* (olive) (L.1122); *Phoenix dactylifera* (date) (L.1132), **l** lateral view, **m** top view; *Punica granatum* (pomegranate) (L.1187), **n** seeds, **o** exocarp fragment; *Vitis vinifera* (grape), **p** mineralized pip (L.2049), **q** pip (L.1187); *Linum usitatissimum* (flax), **r** seed (L.2049), **s** seed and capsule (L.1212), **t** capsule detail (L.1212); scale bars = 1 mm except for a, g, h = 2 mm and k, l, m = 5 mm

terms of ubiquity, *Chenopodium* sp. (Fig. 4c) is found from all periods. Few remains of *Pistacia* (lentisc) were identified and one of the seeds showed damage caused by an insect (Fig. 4i).

Other wild plants have been found, such as *Plantago lanceolata*, *Phalaris* sp., *Bromus* sp. and including *Malva* sp. (Fig. 4e), which is the most frequent wild plant in the MBA III samples.

Several small wild leguminous taxa like *Medicago* sp. (48 seeds) and *Scorpiurus* cf. *muricatus* (55 seeds) were found solely in LBA samples from Area S contexts (S-3 and S-2). Furthermore, and only from this period, are 19 *Cephalaria* cf. *syriaca* (Fig. 4b) seeds and 16 Cyperaceae seeds.

Charcoal

Wood charcoal remains constitute a large proportion of the archaeobotanical remains found in Lachish, with a total of 6,706 large and small fragments recovered. Of these, 5,116 came from the MBA contexts in Area P.

The analyses of these by Katleen Deckers are in progress, but the first results for the MBA contexts show a large amount of Pinaceae, mainly *Cedrus* sp. (cedar), *Pinus* sp. and *Olea europaea*. These results partially confirm the previous charcoal analysis carried out for the site by Nili Liphschitz during the excavations directed by David Ussishkin, which and were mainly on wood samples from MBA, LBA

Fig. 4 **a** *Capparis spinosa* (caper) (modern and L.2049), seeds; **b** *Cephalaria* cf. *syriaca* (L.2049); **c** *Chenopodium* (L.1197); **d** *Lolium* cf. *temulentum* (darnel) (L.1122); **e** *Malva* (mallow) (L.2136); *Plantago lanceolata (*ribwort plantain) (L.2049), **f** seed, **g** seed including a modern specimen; **h** Polygonaceae (L.2049); **i** *Pistacia terebinthus* (terebinth) (L.1212); **j** *Thymelaea passerine* (L.1122); *Torilis leptophylla* (L. 2049), **k** front view; **l** back view; **m**, **n** *Tribulus terrestris* (L.1187); scale bars = 1 mm

and IA layers (Liphschitz 2004). Most of the wood remains were of *O. europaea*, followed by *Quercus calliprinos, Pistacia* sp. and *Cedrus libani* (cedar of Lebanon). In the MBA contexts, *O. europaea* and *Cedrus libani* were the two most frequent taxa. *Olea* was also the most represented fruitstone identified by Liphschitz.

Contextual considerations of the plant assemblages

Composition of the plant assemblages through time periods

In comparing plant assemblages through time, it is important to note that much of the new archaeobotanical data is well dated, and many samples are directly radiocarbon dated. In addition to Table 1, summarized plots of ^{14}C dates for the main MBA and LBA levels from which remains were archaeobotanically analysed, are provided in Fig. 5. The full data can be consulted in Webster et al. (2019a, b) and Webster (2020).

Tables 2 and 3 list the cultivated and wild plants for the three periods, MBA III, LBA and IA II. Only five IA II samples were collected from Area P, producing a very small number of remains and taxa, mainly *Hordeum vulgare* and *O. europaea* for cultivated plants and *Chenopodium* for wild plants.

The number of samples and their total volume are similar for the MBA III and LBA, but considerably more remains

Table 2 Cultivated plants identified from Lachish, by period

Area	P			S and P			P		
Period	Middle Bronze III			Late Bronze Age			Iron Age II		
Samples (*n*)	36			48			5		
Volume (L)	~1,150			~1,197			~183		
	n	%	Ubiq. (%)	*n*	%	Ubiq. (%)	*n*	%	Ubiq. (%)
Cereals									
Cerealia (frag.)	31	20	36	1,091	11	83	1	10	20
Cereal culm nodes				9	0.1	8.3			
Hordeum vulgare	32	21	44	1,025	11	77	6	60	40
Triticum aestivum/durum	3	2	8.3	334	3.5	45			
T. dicoccum	16	10	27	1,042	11	62.5			
T. monococcum/dicoccum	2	1	5.5	144	1.5	43.7			
T. sp. (frag.)	8	5	13.8	443	5	45.8			
Cereal chaff[a]	1	0.6	2.7	15	0.15	16			
Legumes									
Cicer arietinum				3	0.03	4.2			
Fabaceae (frag.)	4	2.5	8.3	12	0.13	16			
Lathyrus sativus	1	0.6	2.7	27	0.3	25			
Lens culinaris	5	3	11	82	0.9	41.6			
Pisum sativum				5	0.05	8.3			
Vicia ervilia	2	1	5.5	101	1	43.7			
V. faba var. *minor*				3	0.03	6.2			
Fruit									
Crataegus azarolus				23	0.2	14.5			
Ficus carica	26	17	33	4,471	47	66			
Olea europaea	20	13	55	343	3.6	83	3	30	40
Phoenix dactylifera				1	0.01	2			
Punica granatum [b]				119	1.25	25			
Vitis vinifera	4	2.5	8.3	235	2.5	48			
Others									
Linum usitatissimum				21	0.22	8.3			
Total	155	100		9,549	100		10	100	

[a]Includes: 13 *Hordeum*, 1 *Triticum aestivum/durum* rachises, 2 *Triticum dicoccum* glume bases

[b]Includes: 36 exocarp fragments

were recovered from the LBA samples. MBA III samples are dominated by *H. vulgare,* followed by *Ficus carica, O. europaea* and *Triticum dicoccum*, while in the wild plant assemblage *Malva* sp. and Polygonaceae were mainly found. It is worthwhile noting that 76.3% of the charcoal remains come from this period. From the LBA samples there is a substantial increase of remains compared with the MBA and new taxa appear, mostly *F. carica* followed by *T. dicoccum* and *H. vulgare*, *T. aestivum/durum* and then *O. europaea* and *Vitis vinifera*. Olive remains show a remarkably high ubiquity which is in agreement with earlier investigations of EBA and IA samples (Helbæk 1958).

Some taxa were exclusively found in LBA samples, such as *Punica granatum* and *Crataegus azarolus*. Many different wild plant taxa appear in this period and its assemblage is largely dominated by *Lolium* cf. *temulentum*, which also occurred in higher proportions in the IA samples studied by Helbæk (1958).

Interpretation of the sampling locations by their contexts and functions

The results of the identifications from the two areas show how the proportion of plant remains differs between Areas S and P (Fig. 2). The density of remains from Area S is much higher, even though from Area P more samples and a greater volume of sediment were collected.

Table 3 Wild plants identified from Lachish, by period

Area	P			S and P			P		
Period	Middle Bronze III			Late Bronze			Iron Age II		
Samples (n)	36			48			5		
Volume (L)	~1,150			~1,197			~183		
	n	%	Ubiq. (%)	n	%	Ubiq. (%)	n	%	Ubiq. (%)
Ajuga sp.	1	1.5	2.7						
Apiaceae				5	0.13	6.2			
Asperula sp.	2	2.9	5.5	2	0.05	4.2			
Asphodelus sp.				1	0.03	2			
Avena sp.				3	0.08	4.2			
Brassicaceae				1	0.03	2			
Bromus sp.	6	8.7	8.3	13	0.34	12.5			
Capparis spinosa				2	0.05	4.2			
Carthamus sp.				1	0.03	2			
Cephalaria cf. *syriaca*				19	0.5	8.3			
Chenopodium album	1	1.5	2.7	34	0.9	8.3	16	26.2	60
Ch. cf. *murale*	6	8.7	11.1	35	0.92	14.5	40	65.6	100
Ch. sp.				1	0.03	2			
Coronilla sp.				1	0.03	2			
Cyperaceae				16	0.42	8.3			
Euphorbia sp.	1	1.5	2.7	1	0.03	2	5	8.2	40
Galium cf. *aparine*				6	0.16	10.4			
Muscari sp.	1	1.5	2.7	16	0.42	4.2			
Lithospermum arvense				1	0.03	2			
Lolium cf. *temulentum*	6	8.7	8.3	3,206	84.56	58.3			
Malva sp.	12	17.4	19.4	93	2.45	33			
Medicago sp.				48	1.27	30			
Melilotus sp.				3	0.08	6.2			
Phalaris sp.	3	4.3	8.3	64	1.69	23			
Phleum sp.				8	0.21	4.1			
Pistacia lentiscus				11	0.29	10.4			
P. terebinthus				2	0.05	2			
P. sp.	3	4.3	8.3	21	0.55	12.5			
Plantago lanceolata	7	10.1	11.1	64	1.69	27			
Poaceae				7	0.18	8.3			
Polygonaceae	13	18.8	8.3	1	0.03	2			
Scorpiurus cf. *muricatus*				55	1.45	20			
Silene sp.	1	1.5	2.7	1	0.03	2			
Torilis leptophylla				5	0.13	4.2			
Tribulus terrestris				1	0.03	2			
Trifolium sp.	3	4.3	5.5	25	0.66	23			
Trigonella sp.				8	0.21	10.4			
Thymelaea passerina	1	1.5	2.7	4	0.1	4.2			
Undetermined	2	2.9		6	0.16				
Total	69	100		3,791	100		61	100	

Area S

24 samples totalling about 508 L sediment were collected from Area S (Fig. 6) and from this deep section, 8,533 cultivated and 2,753 wild plant remains were identified. Area S has the highest plant remains density of 22.22 remains/L (Fig. 2).

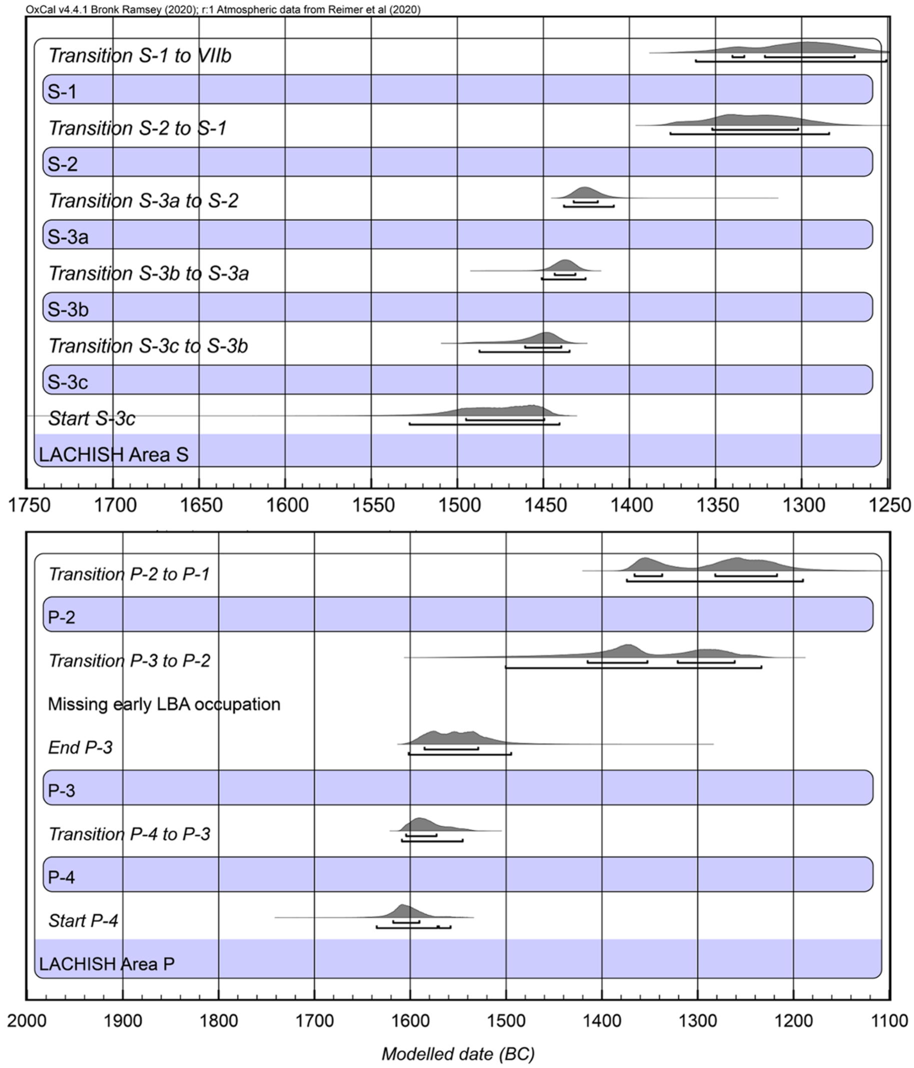

Fig. 5 Radiocarbon chronology for Area S (top) and Area P (bottom) using Bayesian analysis. The summarized plots show estimated transitions between layers that are of interest to the archaeobotanical study. The dates were calibrated with OxCal (Bronk Ramsey 2009) and the latest calibration curve, IntCal20 (Reimer et al. 2020)

The samples derive almost exclusively from LBA layers S-3c-a and S-2. Layer S-3c features a monumental building and a fortification wall, and dates to 1495–1440 BCE. S-3b and S-3a, 1460–1420 BCE, represent a period when the fortification wall went out of use, but the monumental building was reused, with additional smaller structures built to the south. In S-3 a series of deposits began to accumulate in Area S with numerous burnt layers interspersed with fill and surfaces, some plastered. This deposition continued in layer S-2 (1435–1305 BCE), after the monumental building went out of use, with the deposits now extending across almost the whole excavation area.

Square D11 provided most of the plant remains from the 2018 season, from four samples from layer S-3a collected in square D11, specifically from L.1122, a layer which included a plastered floor and associated burnt remains, L.1121, a burnt layer directly overlying L.1122, and L.1132, another burnt layer running immediately below L.1122. Note that the dating of S-3a derives from these and other closely associated contexts. From these three contexts, a large amount of *T. dicoccum* and *H. vulgare* were found together with most of the small number of chaff remains identified from the site, ten *Hordeum* rachises and one of *T. aestivum/durum*. However, the largest number of remains from this square are of *F. carica* with 996 seeds (including three mineralised ones), accounting for the 22% of the total number found in Area S. Furthermore, these three contexts have yielded large quantities of various other fruit taxa, 85% *O. europaea* (209 olive stones), making D11 the square from which the highest quantity of olives were found, and 59% of the *V. vinifera* (134 pips) found in Area S.

The highest number of *Lolium* cf. *temulentum* seeds, nearly 55% of its total remains from Lachish, were found from this square.

Square C12 represented deep fill layers that were deposited directly next to the fortification wall and monumental building and included frequent patches of black burnt remains, rich in charcoal. A single context, L.1187 (S-3b-c),

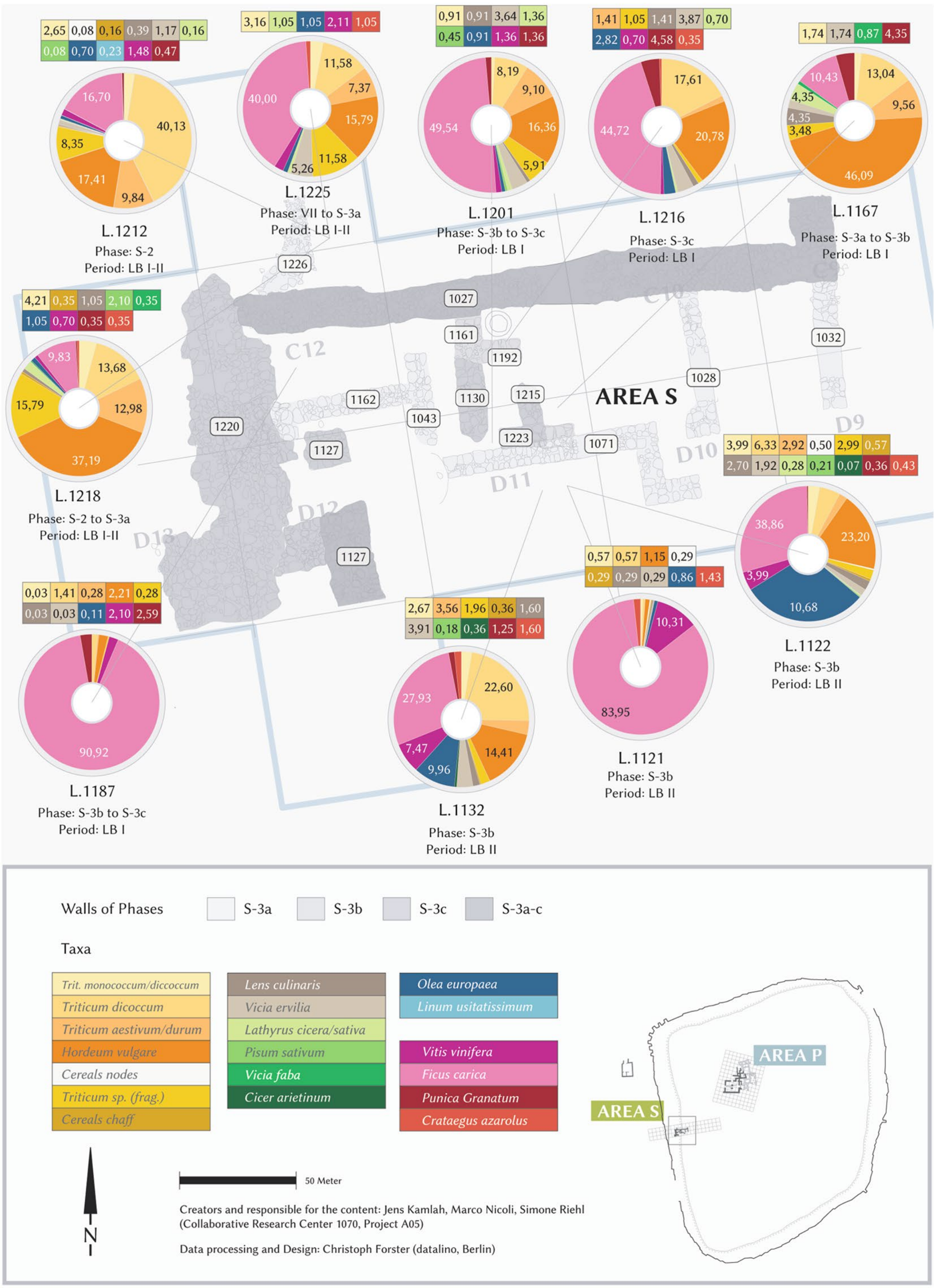

Fig. 6 Lachish, Area S. Pie charts representing the percentages of crop remains from selected samples

was sampled from this square and many seeds were identified from it. *Ficus* amounts to 58.6% of the total fig pips from the whole site; square C12 also provided 68% of the *Punica* remains, together with a large number of *Vitis* (61 seeds), *H. vulgare* (64 grains) and *T. dicoccum* (41 grains).

Most of the remains from this square were found in a different state of preservation compared with the other contexts of Area S, showing what appears to be a compressed state.

In another square, C11, a *tabun* clay oven was discovered in 2018 from which two samples (S-3b) were collected, which provided only a few botanical remains, though sufficient to provide ^{14}C dates for this material. In 2019, a floor was excavated in layer S-3c and samples were collected from the burnt layers above it, also used for dating. From these samples (L.1216) the same pattern of cereals from the previous squares was identified, with barley and emmer being the main taxa in terms of quantity and fig still the most frequent one.

Square B12 was excavated in 2019 to start a new investigation inside the monumental building in Area S. From this, ten samples were collected from S2, resulting in large numbers of barley (365 grains), emmer (606 grains), Fig. (506 seeds, 12% mineralized) and *Lolium* cf. *temulentum* (462 seeds). Moreover, the only *Linum usitatissimum* (flax) remains from Area S were found here, two seeds and part of a seed capsule. It may be noted that the ca. 20–30 cm thick ash layer from which the archaeobotanical samples were taken can be traced with images from the Tel Aviv University expedition southwards across the area, where it ran over the disused wall of the monumental building and equates to the S-2 deposit to the south, in square D11, though here it is represented by a laminated deposit with multiple burnt layers.

Area P, palace area

A total of 65 samples were collected from the palace area, with a sediment volume of about 2,022 L. These samples provided 1,183 remains of cultivated plants and 1,167 of wild plants. This area was heavily affected by modern contamination and the preservation of the remains was mediocre (Fig. 4a). This is shown by the large amount of Cerealia and *Triticum* sp. grain fragments in the archaeobotanical assemblage, in fact, in many cases, complete identification could not be achieved. The samples derive primarily from MB III layers P-4 and P-3, ^{14}C dated to ca 1650–1550 BCE and from LBA layers P-2/1, broadly dated to 1300–1200 BCE. Layer P-4 represents the last use of the MBA palace, which ended in its fiery destruction. Shortly afterwards, the building was rebuilt and used for industrial and domestic purposes before being destroyed for a second time. LB I is poorly represented in Area P, but subsequently a domestic building (P-2/1) replaced the palace.

L.2049

A 1.6 m deep Late Bronze Age pit, L2049, was found in Area P (P-2), square F10, during the 2018 excavation. Interpreted as an offering pit, this included a large deposit of black charred material together with complete vessels in situ, a jug, a Mycenaean straight-sided alabastron (a pottery or glass container for oil or perfume) and a bowl (Fig. 7). Note that the two currently available dates for layer P-2 are from pit L.2049. Eight samples were collected from different levels in this pit, with a total volume of nearly 270 L. A total of 1,946 plant remains were recovered, 82.8% of the total remains from Area P, marking the importance of this pit for the whole assemblage (Tables 2, 3). The quantity of finds decreased near the bottom of the pit where the soil was denser and more organic. The samples taken from the bottom of the pit and slightly above provided all the taxa found in L.2049.

The cultivated plants from this pit were mainly cereals, with a large amount of Cerealia and *Triticum* sp. grain fragments. *Triticum dicoccum* (86 grains), *T. aestivum/durum* (46 grains) and *Olea* (80 stones) were the most numerous remains, but it is worth also noting the large numbers of seeds from wild plants, *Cephalaria* cf. *syriaca* (17), *Chenopodium album* (25), *Phalaris* sp. (50), *Plantago lanceolata* (55) and a large quantity of *Lolium* cf. *temulentum* (821).

The main assemblage of *Linum usitatissimum* came from this LBA pit, with 85.7% of all the flax, emphasizing again its presence in this period.

Areas S and P are structurally, contextually and taphonomically different areas, as reflected in the results from them. Area P, located on the top of the mound, was always an elite area where palaces were located in various periods. While the nearly total absence of chaff remains in Area P can be explained by poor preservation due to disturbance of the soil as suggested by the heavy modern contamination, this interpretation is not applicable to Area S, a deep excavated trench with much better preserved botanical remains located on the edge of the tell. Here the relative absence of chaff must be explained differently, since other fragile seeds, such as flax and fig are preserved there. Most likely, cereal processing took place at some distance from the area of deposition. Based on the archaeological finds, the contexts of squares D11 and C12 can probably be associated with the dumping of waste material, even though C12 has yielded many and various well preserved remains, revealing an extraordinary depositional history. For example, L.1187 (S-3), the lowest layer of a fill outside the monumental building, dominated Area S and was enclosed by small walls. It was rich in pottery, animal bones and charred plant remains. The plant remains consisted mainly of fig, followed by grape and pomegranate (including exocarp fragments), barley, emmer and few wild plant remains. Some of these remains had been highly compressed before charring, but still preserved enough of their diagnostic features to allow a complete identification. Some other seeds were in a semi-mineralized state. These preservation conditions were probably because L.1187 was the lowest layer in a waste context outside the monumental building, based on the archaeological finds and the spatial setting. It will be important to enlarge the excavation in Area S to be able to better understand the context and the function of this structure.

Lachish internal phases

Due to the small number of remains in the individual samples from the Area P layers P-4 (11 samples and 55 remains) and P-3 (20 samples, 45 remains), a detailed comparison between these phases is not possible. However, they both contain the same taxa, matching the pattern for the MBA III samples described previously.

In Area S, samples from buildings and fortification contexts in phase S-3 yielded a larger quantity of remains of crops compared to the waste contexts (middens) in phase S-2 (Table 4). Fruit remains dominate S-3, with *Ficus* found in each S-3 sample, representing 64.35% of the assemblage but *Vitis* (3.7%), *Olea* (3.78%) and *Punica* (1.8%) are also present in large quantities compared to S-2. Cereals were less abundant from the fortification context and the most frequent one, *Hordeum*, represents 10.35% of the assemblage. The remains from phase S-2 are mainly figs and cereals, but while the main cereal from the S-3 samples is *Hordeum*, from S-2 it is *Triticum dicoccum* (27.86%). Some pulses and fruit taxa, *Cicer arietinum* (chickpea), *Pisum sativum* (pea), *Crataegus azarolus* (a hawthorn) and *Phoenix dactylifera* (date), are absent from the S-2 phase of waste deposition. The only taxon present from S-2 but not from S-3 is *Linum usitatissimum*.

The Late Bronze Age plant assemblage from Tel Lachish in its regional context

The Late Bronze Age crop data from several settlement sites in the southern Levant have been compared using correspondance analysis (CA) (Fig. 8). Sites with only presence/absence data were excluded as well as those with less than five crop taxa, since small samples may be unrepresentative of farming and subsistence practices. Similarly, taxa that occur from less than four sites have not been included to avoid any "noise" in the graph that could conceal real patterns (Jones 1991).

It was not possible to remove the omnipresent species such as *O. europaea*, *H. vulgare* and *F. carica* due to the limitation of the data, after the initial exclusions, which would not have reached a minimum threshold needed to plot the graphs, considering that only crop taxa are considered. The results from Beth-Shean (Simchoni et al. 2007), Tell es-Safi (Gath) (Mahler-Slasky and Kislev 2012) and Timnah (Kislev et al. 2006) stand out from other sites by their dominance in free-threshing wheat. Tell es-Safi (Gath) and Timnah are located close to each other in the Shephelah (Fig. 1). The inhabitants of Beth-Shean, which is further away, did not grow wheat locally due to low mean annual precipitation there, and no evidence of irrigation has been found. The presence of exotic weeds at the site suggested trade in crops with distant agricultural lands (Simchoni et al. 2007).

Aphek is isolated from the other groups, located in the positive part of the first axis and negative part of the second axis, and is associated with large numbers of *Vitis* and *Linum*. Located on the central coastal plain of Israel, on the Yarkon river, Aphek has a more moderate, less arid, environment which distinguishes it from the other sites (Kislev 2009a; Olsvig-Whittaker et al. 2015).

Another group of sites, comprising Tell Der ‘Alla (Van Zeist and Heeres 1973) and Kamid el-Loz (Baas 1980; Behre 1970), are concentrated in the upper part of the diagram, characterized by a large amount of barley. Tell Der ‘Alla, located on the east side of the Jordan valley shares the same richness in *Hordeum* as other LBA sites in this region, such as Tall al- ‘Umayri (Ramsay and Mueller 2016) and Tell el-Hayyat (Metzger 1984), as they show a similar trend to sites located in Lebanon, on the coast near Sidon and in the Beqaa valley, such as Kamid el-Loz.

The other sites, including Lachish, cluster in the upper right part of the diagram and are concentrated around a dense area of taxa consisting of *T. dicoccum*, some legumes and most of the fruit, *Olea*, *Punica* and *Ficus*.

Figure 9 shows the occurrence of crop taxa in the sites and their frequency represented by the size of the circles. Barley is the only taxon present in each site, followed by free-threshing wheat and grape.

Discussion

Lachish has the closest affinities with Pella and Sidon, as shown in the correspondance analysis results. Pella is situated in the foothills of the Jordan valley, 5 km east of the river Jordan. The site is located on a large artificial mound, separated from a natural hill by a perennial spring and stream (Bourke et al. 2006). This stream would have offered irrigation possibilities while the modern mean annual rainfall of 300 mm, which is close to that of Lachish, is sufficient for dry farming (Wilcox 1992). The plant assemblage for the Bronze Age is not as well represented as the other periods due to a limited number of samples, but it is clear that Pella, with its abundant finds of *Hordeum*, is similar to the other sites in the northern and eastern Jordan valley. The other cereal found from there is *T. dicoccum*, but the fruit finds are limited to a single *Vitis* (Wilcox 1992). The other site with similarities to Lachish is Sidon, which is on the coast of Lebanon and is bordered by two rivers to the north

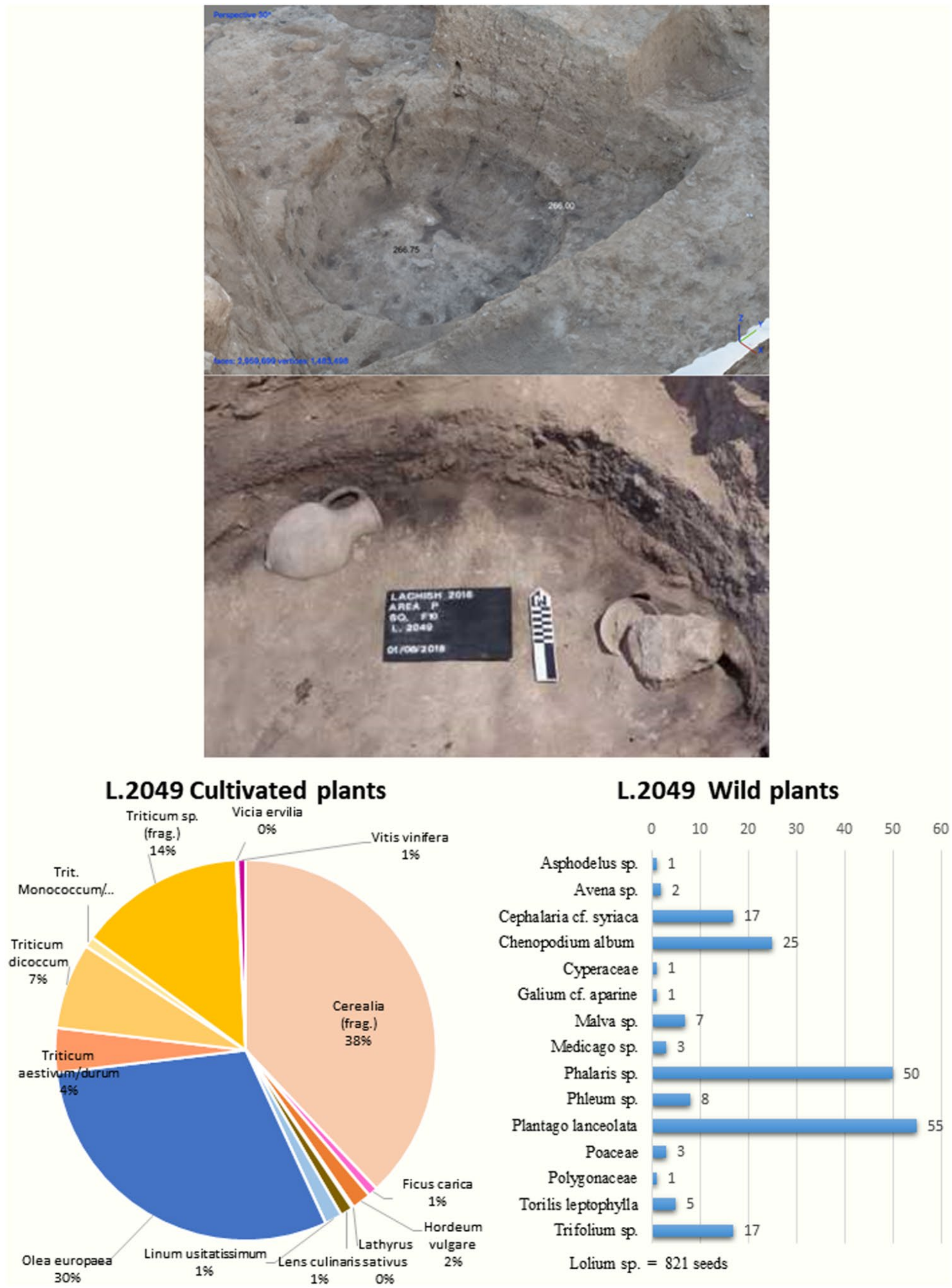

Fig. 7 Lachish, Area P. Photos of L.2049 pit with vessels in situ. On the bottom, two graphs showing the percentages of cultivated and wild plant remains from the pit

and south of the city, and to the east by the escarpment of Mount Lebanon, and has a mean annual precipitation around 650–700 mm. During the Late Bronze Age, Sidon was one of the most active ports on this coast, making it an important centre for trade (Carayon et al. 2011). The LBA botanical assemblage from Sidon is composed mainly of olive stones, the most frequent crop plant, followed by barley. As with Pella, the only other cereal and fruit found in Sidon are emmer and grape (De Moulins 2015).

Barley is the main crop found from both LBA Pella and Sidon and also from phase S-3 at Lachish. Moreover, olive was the most frequent crop remain found at both Sidon and Lachish.

The LBA sites mostly group around free-threshing wheat, emmer and barley as shown by the correspondance analysis, except for Aphek and some other sites.

The position of Lachish compared to the other LBA sites in the Shephelah is relatively close only to Tel Burna (Orendi 2018), creating a different cluster opposed to Tell es-Safi (Gath) and Timnah, where free-threshing wheat was the dominant cereal (Kislev et al. 2006; Mahler-Slasky and Kislev 2012), while at Lachish, emmer was the most abundant cereal along with a great quantity of barley.

Barley, which is present in all LBA sites, was also an important part of the human diet at Lachish as indicated by its high ubiquity in Area S.

Like barley, emmer and free-threshing wheat have yielded almost no chaff remains with just one *T. aestivum/durum* rachis and two *T. dicoccum* glume bases, as in the case in Tell es-Safi (Gath) and Timnah, which may be interpreted as a sign that threshing was not done within the cities.

It is interesting to notice the main changes in cereals between phases S-3 and S-2 at Lachish (Table 4). S-3 yielded a large quantity and variety of crop remains, including cereals, mainly barley. The samples from the later phase S-2 contained mainly cereal grains, but here *T. dicoccum* (emmer) dominates the assemblage. Assuming that these different layers represent successive time periods, the dominance of emmer seems to agree with the crop production strategy in Egypt at the time (Nesbitt and Samuel 1996).

From the Late Bronze Age, *Linum usitatissimum* starts appearing in the assemblages from S-2 and P-2. Flax is a water demanding crop and notably 87.5% of *Plantago lanceolata* seeds were obtained from the same contexts. *P. lanceolata* has oval seeds with broad rims and dorsal ridges, clearly differing from the other *Plantago* species (Figs. 4f, g). It can be associated with relatively moist habitats (Danin and Fragman 2016), suggesting that flax was cultivated in an area with easy access to additional water sources as opposed to the cornfields. Besides *P. lanceolata*, many other local weeds have been identified and, as in the case of *Lolium* cf. *temulentum*, found in large quantities together with cereal grains. In Area S-3, square D11 provided nearly 68% of the chaff remains and 89% of the cereal culm nodes together with most of the *L.* cf. *temulentum* seeds, and we can presume that this was part of a working or storage area on the tell. Even though some *Lolium* species could have been used as fodder (Malleson 2015), *L. temulentum* (darnel) is considered a noxious weed and had an unintentional role in the human diet when mixed with wheat, since it was difficult to separate the weed seeds from the cereal grains (Kislev et al. 2009b).

Lolium cf. *temulentum*, *Phalaris* sp. and *Cephalaria syriaca* are weeds, commonly associated with crops using winter rain, a common practice in Late Bronze Age Shephelah (Zohary 1950; Frumin et al. 2019), so that irrigation may have not been extensively used. This applies especially for

Table 4 Cultivated plants identified from Lachish Area S, by layer

Area S phases	S-3		S-2	
Samples (Vol., L)	14 (330)		6 (136)	
	n	%	*n*	%
Cerealia (frag.)	187	3.06	375	18.79
Cereal culm nodes	8	0.13	1	0.05
Cicer arietinum	3	0.05		
Crataegus azarolus	21	0.34		
Fabaceae (frag.)	9	0.15	1	0.05
Ficus carica	3,931	64.35	440	22.04
Hordeum vulgare	632	10.35	242	12.12
Lathyrus sativus	15	0.25	2	0.1
Lens culinaris	60	0.98	5	0.25
Linum usitatissimum			3	0.15
Olea europaea	231	3.78	11	0.55
Phoenix dactylifera	1	0.02		
Pisum sativum	5	0.08		
Punica granatum	110	1.8	8	0.4
Triticum aestivum/durum	104	1.7	140	7.01
T. dicoccum	348	5.70	556	27.86
T. monococcum/dicoccum	79	1.29	38	1.9
T. sp. (frag.)	81	1.33	131	6.56
Cereal chaff	11	0.18	3	0.15
Vicia ervilia	72	1.18	16	0.80
V. faba minor	1	0.02	1	0.05
Vitis vinifera	200	3.27	23	1.15
Total	6,109	100	1,996	100

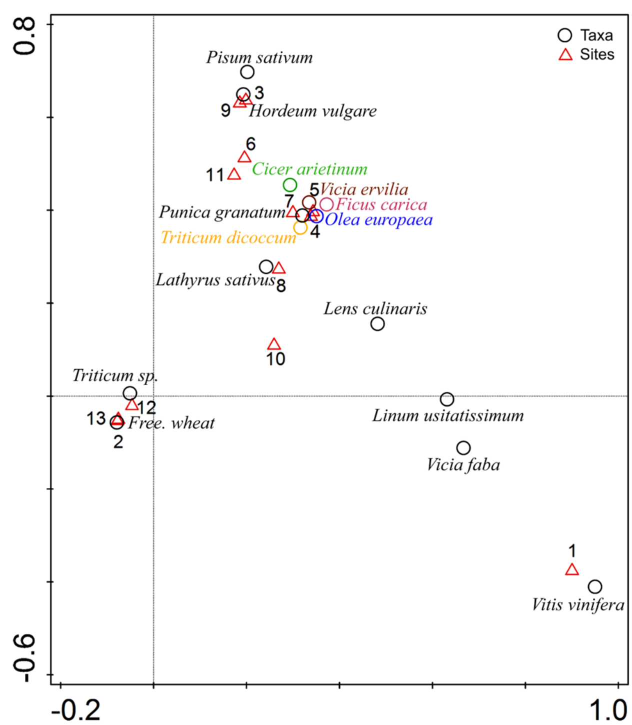

Fig. 8 Correspondence analysis biplot of Southern Levant LBA sites and crop taxa. FreeWheat = free threshing wheat (cumulative variance, Axis 1 = 27.35, Axis 2 = 53.30; Eigenvalues Axis 1 = 0.9370, Axis 2 = 0.8889). 1, Aphek; 2, Beth-Shean; 3, Kamid el-Loz; 4, Lachish; 5, Pella; 6, Qubur el-Waleyide; 7, Sidon; 8, Tel Burna; 9, Tell Der ʻAlla; 10, Tell el-Burak; 11, Tell el- ʻUmeri; 12, Tell es-Safi (Gath); 13, Timnah

Lachish phase S-3 from where more than the 85% of the *L.* cf. *temulentum* seeds from Area S have been found.

Fruit growing

The first archaeobotanical work on Lachish was published in 1958 by Hans Helbæk, and in the Early Bronze Age and Iron Age samples, the presence of cereals and fruit stands out. The main cereals in the EBA samples are emmer wheat and barley, whereas in the IA samples they are mainly free-threshing wheat, which providing a distinct sequence of cereal cultivation over time, from emmer and barley during the EBA to the LBA, then changing to free-threshing wheat in the Iron Age. The small number of samples in these early studies must be noted, five EBA and 7 LBA. The fruit that Helbæk mainly found were olive, but also grape and *Crataegus azarolus*, a hawthorn which grows around the whole Mediterranean basin, but is no longer much eaten. It still has frequent use in traditional Arab medicine in Israel, where it is considered an important resource of antioxidants and a remedy for treating cardiovascular diseases (Ljubuncic et al. 2005) and its foliage is still used as fodder for sheep and goats. *C. azarolus* is scattered in the present natural scrub of the Shephelah as part of the widespread carob lentisk maquis that dominates the natural landscape of the region (Hepper 1992; Olsvig-Whittaker et al. 2015).

The presence of fruit orchards, vineyards and olive groves around Lachish is based on several lines of evidence. The most ubiquitous taxon on the site is *O. europaea*, present in 69.7% of the samples, which shows an emphasis on olive growing around the city. Fig, grape, pomegranate, date and *C. azarolus* are also present. This pattern of olive, fig and pomegranate remains is shared by all the other LBA sites in the Shephelah, giving another clue to the past local diet (Frumin et al. 2019). It is interesting to notice also that the presence of a *Phoenix dactylifera* fruitstone represents a rare find for the Shephelah region. The date stone, characterized by its oblong shape with a deeply grooved furrow, was found in Area S L.1132 in association with all the other fruit remains (Fig. 3l, m). Although isolated date stones have been found from as early as Late Chalcolithic Tuleilat Ghassul (Zohary and Spiegel-Roy 1975) or Nahal Mishmar (Zaitschek 1961), they remain rare in the archaeobotanical record of the southern Levant and dates were probably never part of everyday diet. The presence of a date stone at Lachish and the relative absence of *Phoenix* records from other sites in the region raises the question whether the dates might have been cultivated locally. It is usually assumed that dates were traded between regions through trade networks and as recent finds of date phytoliths in EBA Tell Fadous-Kfarabida, Lebanon (Damick 2019) and in MBA to LBA Megiddo, Israel (Scott et al. 2021) suggest, there must have been a long tradition of date trade, which may also explain the date record from LBA Lachish.

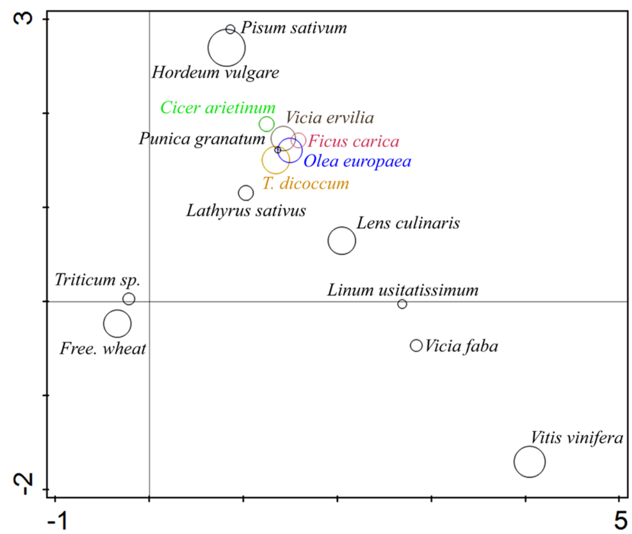

Fig. 9 Correspondence analysis biplot (following Fig. 8). Recurrence of crop taxa within the sites. *FreeWheat* free threshing wheat

The famous Lachish relief, carved by the Assyrians and depicting their siege and conquest of the city in 701 BCE, shows the most common fruits which are also represented in the archaeobotanical record, olive, fig and grape which represent the main fruits in the whole Mediterranean basin (Zohary et al. 2012).

Even though the relief was created in a period later than the contexts analyzed in this paper, it indicates that fruits were highly esteemed, and that fruit growing was well established in Lachish, since the Assyrians associated this with the identity of the city (ESM Fig. 2, Ussishkin 1982).

We found a large number of cultivated plants such as pomegranate from the LBA compared to the MBA and a drastic increase of cereals and fruit, in particular olive, grape and fig. These results match the pollen analyses which show a peak in the tree and shrub vegetation around the same period as the Egyptian texts which mention Lachish (Langgut et al. 2013). This is before the climatic drying at the end of LBA in the southern Levant, and also the increased importance of olive in the economy of Lachish that is possibly indicated by the appearance of new oil presses at various sites during this period (Onozuka 2012). Olive was one of the most important fruits of the eastern Mediterranean, since olive oil can be stored for long periods and, apart from daily diet, it was used for many other purposes (Zohary 1982). Thanks to their high tolerance to drought, olive trees are the optimal fruit crop for the Mediterranean ecosystem (Sofo et al. 2008).

Figs seeds represent 52% of the archaeobotanical assemblage in Lachish Area S, with more than 88% of them in the S-3 samples. This seeming dominance of fig is biased by the fact that one fruit contains up to several hundred seeds. Figs played an important role in ancient diet and they could have been dried and stored for a long time, as with a Neolithic example from Gezer (Zohary 1982). Furthermore, they may represent animal feed as interpreted for EBA Tell Abu en-Ni ‘aj where dung remains were found (Fall et al. 2015).

Possible use of dung in Lachish?

Dung has been identified from a number of sites in this area, although no dung remains have been found at Lachish up to now. It has been demonstrated that not all seed types survive animal digestion and would therefore be expected in dung (Miller and Smart 1984; Valamoti and Charles 2005). Apart from Tell Abu en-Ni ‘aj, other sites in the southern Levant have yielded large amounts of *Ficus carica* and dung remains, such as MBA Tell el-Hayyat and Zahrat adh-Dhra (Fall et al. 2019) and IA Khirbat al-Mudayna al-Aliya (Farahani et al. 2016) (Fig. 1). However, each of these sites had a different setting, context and sources of fuel. Tell Abu en-Ni’ai and Tell el-Hayyat were two productive farming settlements, located in the northern Jordan valley. Here, the use of dung was identified from its remains, mostly material deriving from shrubs, fruit trees and riverside vegetation, mixed with charcoal. Khirbat al-Mudayna al-Aliya, located in west-central Jordan, depended strongly on dung, remains of which were found with small quantities of charcoal (Farahani et al. 2016). Zahrat adh-Dhra was an isolated farming settlement east of the Dead Sea, which relied more on desert trees than on dung for fuel. In the first three sites, the dung remains indicate that the livestock was feeding mainly on cereals and also grazing. At Khirbat al-Mudayna al-Aliya, the animals were probably kept inside the settlement, making the collection of dung easier. The botanical assemblage in Lachish is similar to these sites, even though it is hard to suggest that dung was used without a direct find. Once the results of the charcoal analysis are complete, it will be possible to understand more about the sources of fuel used at Lachish, considering the large quantity of charcoal and the differences in the results between areas P and S.

Nonetheless, it is worth noting the presence of a *tabun* oven in Area S. As described by Dalman in his work *Leben und Sitte in Palästina*, on the customs and working traditions of the people living in the region during the first decades of the 20th century, dung cakes were still being used then to heat ovens for baking bread (Dalman 1935).

Conclusions

The results from Lachish confirm that the Shephelah area was good for the agriculture and subsistence of the communities that lived there. The high diversity, ubiquity and quantities of fruit remains in the archaeobotanical assemblage support the importance of fruit in the local diet. This is still true nowadays, since even though human activities have caused drastic changes to the landscape of the region throughout the centuries, there are still many vineyards spread across the fields below the tell.

The finding of a large number of fig seeds from Area S, combined with plant remains connected with animal feed, allow us to suggest the possible use of animal dung at the site. However, without actual evidence of dung, it is hard to determine whether the fig remains are related to fodder. However, remains of dung found at other sites in the southern Levant have yielded large numbers of fig seeds and a similar range of plant remains to the Lachish plant assemblage.

There is a significant change over time, since there are more cultivated plant taxa and an overall increase of remains in the LBA samples, compared to the ones from the MBA. The LBA remains from Area S are much better preserved than from the MBA, even though the amounts of sediment collected for the two periods are rather similar. The two investigated areas differ completely in the preservation of their remains and probably also in their functions, considering their differing locations on the tell. It would be important for further analyses to expand the excavation and sampling of Area S to further understand the purpose of the monumental building and also of Area P to shed more light on the function of the palace rooms.

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Data availability All data provided in the manuscript and supplementary material.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Aharoni Y (1975) Investigations at Lachish: The sanctuary and the residency (Lachish 5). Gateway Publishers, Tel Aviv

Bar-Matthews M, Ayalon A (2004) Speleothems as paleoclimate indicators, a case study from Soreq cave located in the eastern Mediterranean region, Israel. In: Battarbee RW, Gasse F, Stickley CE (eds) Past climate variability through Europe and Africa. Springer, Dordrecht, pp 363–391

Baas J (1980) Ein bedeutsamer botanischer Fund der Gattung Echium Linné aus Kamid el-Loz. In: Hachmann R (ed) Bericht über die Ergebnisse in Kamid el-Loz in den Jahren 1968 bis 1970. (Saarbrücker Beiträge zur Altertumskunde 22) Habelt, Bonn, pp 111–115

Behre K-E (1970) Kulturpflanzenreste aus Kamid el-Loz. In: Hachmann R (ed) Bericht über die Ergebnisseder Ausgrabungen in Kamid el-Loz (Libanon) in den Jahren 1966 und 1967. (Saarbrücker Beiträge zur Altertumskunde 4) Habelt, Bonn, pp 59–69

Bourke S, Sparks R, Schroder M (2006) Pella in the Middle Bronze Age. In: Fischer PM (ed) Thechronology of the Jordan Valley during the Middle and Late Bronze Ages: Pella, Tell Abu AL-Kharaz and Tell Deir 'Alla. Verlag der Österreichischen Akademie der Wissenschaften, Wien, pp 9–58

Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. Radiocarbon 51:337–360

Carayon N, Morhange C, Marriner N (2011) Sidon's ancient harbour: natural characteristics and hazards. Archaeol Hist Lebanon 34(35):433–459

Dalman G (1935) Arbeit und Sitte in Palästina. Bertelsmann, Gütersloh. Digitized version 2013. http://nbnresolving.de/urn:nbn:de:bsz:21-opus-69119

Damick A (2019) The first identification of *Phoenix dactylifera* (date palm) from Early Bronze Age Lebanon. Veget Hist Archaeobot 28:583–589

Danin A, Fragman O (2016) Flora of Israel. https://flora.org.il/en/plants/. Accessed 30 June 2021

De Moulins D (2015) Plant remains from middle bronze age to iron age: samples of the college site. Sidon Archaeol Hist Lebanon 42(43):32–54

Drori I, Horowitz A (1989) Tel Lachish: Environment and subsistence during the Middle Bronze, Late Bronze and Iron Ages. J Inst Archaeol Tel Aviv Univ 16:206–211

Epstein C (1963) A new appraisal of some lines from a long-known papyrus. J Egypt Archaeol 49:49–56

Fall PL, Falconer SE, Klinge J (2015) Bronze age fuel use and its implications for agrarian landscapes in the eastern Mediterranean. J Archeol Sci 4:182–191

Fall PL, Falconer SE, Porson S (2019) Archaeological inference of intermittent settlement and agriculture at Middle Bronze Age Zahrat adh-Dhra'1. Jordan. J Archeol Sci 26:101884

Farahani A, Porter BW, Huynh H, Routledge B (2016) Crop storage and animal husbandry at Early Iron Age Khirbat al-Mudayna al-'Aliya (Jordan): A paleoethnobotnical approach. In: McGeough KM (ed) The archaeology of agro-pastoralist economies in Jordan. (Annual of the American Schools of Oriental Research 69) American Schools of Oriental Research, Boston, pp 27-89

Frumin SI, Melamed Y, Weiss E (2019) The wheat-people of Canaan. In: Maeir AM, Shai I, McKinny C (eds) The Late Bronze and Early Iron Ages of Southern Canaan. De Gruyter, Berlin/Boston, pp 19–36

Ganor S, Kreimerman I (2018) Tel Lakhish (Tel Lachish): preliminary report. Hadashot Arkheologiyot: (Excavations and Surveys in Israel 130) http://www.hadashot-esi.org.il/Report_Detail_Eng.aspx?id=25415

Garfinkel Y, Hasel MG, Klingbeil MG et al (2021) The Canaanite and Judean cities of Lachish, Israel: Preliminary Report of the Fourth Expedition, 2013–2017. Am J Archaeol 125:419–459

Golénischeff WS (1913) Les Papyrus Hiératiques Nos. 1115, 1116A et 1116B de l'Ermitage Impériale à St.- Pétersbourg. Manufacture des papiers de l'État, Saint Pétersbourg

Helbæk H (1958) Plant economy in ancient Lachish. In: Tufnell O (ed) Lachish (Tell ed-Duweir), vol 4: The Bronze Age. Oxford University Press, London, pp 309–317

Hepper FN (1992) Baker encyclopedia of bible plants: flowers and trees, fruits and vegetables, ecology. Three's Company, London

Jacomet S (2006) Identification of cereal remains from archaeological sites, 2nd edn. Basel University, Basel, IPAS

Jones G (1991) Numerical analysis in archaeobotany. In: van Zeist W, Wasylikowa K, Behre K-E (eds) Progress in Old World palaeoethnobotany. Balkema, Rotterdam, pp 63–80

Kagan EJ, Langgut D, Boaretto E, Neumann FH, Stein M (2015) Dead sea levels during the bronze and iron ages. Radiocarbon 57:237–252

Kislev ME, Mahler-Slasky Y (2009) Food remains. In: Gadot Y, Yadin E (eds) Aphek-Antipatris II: The remains in the Acropolis. Emery and Claire Yass Publications in Archaeology, Tel Aviv, pp 499–525

Kislev ME, Melamed Y, Langsam Y (2006) Plant Remains from Tel Batash. In. Panitz-Cohen N, Mazar A (eds) Timnah (Tel Batash) III: The Finds from the Second Millennium BCE. Qedem 45. Hebrew University of Jerusalem, Jerusalem, pp 295–310

Kislev ME, Simchoni O, Melamed Y, Maroz L (2009) Botanical remains: food and industrial crops. In: Panitz-Cohen N, Mazar A (eds) Excavation at Tell Beth-Shean 1989–1996, Vvl 3: The 13th-11th Century BCE strata in Areas N and S. Israel Exploration Society, Hebrew University, Jerusalem, pp 764–771

Langgut D, Finkelstein I, Litt T (2013) Climate and the Late Bronze Age collapse: new evidence from the southern Levant. J Inst Archaeol Tel Aviv 40:149–175

Langgut D, Finkelstein I, Litt T, Neumann FH, Stein M (2015) Vegetation and climate changes during the Bronze and Iron ages (~3600–600 BCE) in the Southern Levant based on palynological records. Radiocarbon 57:217–235

Liphschitz N (2004) The archaeobotanical remains. In: Ussishkin D (ed) The renewed archaeological excavations at Lachish 1973–1994. Emery and Claire Yass Publications in Archaeology, Tel Aviv, pp 2230–2247

Ljubuncic P, Portnaya I, Cogan U, Azaizeh H, Bomzon A (2005) Antioxidant activity of *Crataegus aronia* aqueous extract used in traditional Arab medicine in Israel. J Ethnopharmacol 101:153–161

Mahler-Slasky Y, Kislev ME (2012) Preliminary archaeobo-tanical Research at Tell es-Safi/Gath - the 1997-2002 Seasons. In: Maeir AM (ed) Tell es-Safi/Gath I: The 1996-2005 Sea-sons, part 1: Text. (Ägypten und Altes Testament 69) Har-rassowitz, Wiesbaden, pp 579-587

Malleson C (2015) Archaeobotanical investigations at Tell El-Retaba. Egypt and the Levant 25:175–199

Metzger MC (1984) Preliminary report of the first season of the Tell el-Hayyat Project. (Faunal and floral remains at Tell el-Hayyat. Preliminary results.). Bull Am Sch Orient Res 255:68–70

Migowski C, Stein M, Prasad S, Negendank JFW, Agnon A (2006) Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. Quat Res 66:421–431

Miller NF, Smart TL (1984) Intentional burning of dung as fuel: a mechanism for the incorporstion of charred seeds into the archaeological record. J Ethnobiol 4:15–28

Neef R, Cappers RTJ, Bekker RM (2012) Digital atlas of economic plants in archaeology. (Groningen Archaeological Studies 17) Barkhuis, Groningen

Nesbitt M (2009) Identification guide for Near Eastern grass seeds. Routledge, London

Nesbitt M, Samuel D (1996) From staple crop to extinction? The archaeology and history of hulled wheats. In: Paludosi S, Hammer K, Heller J (eds) Hulled wheats. Proceedings of the first International Workshop on Hulled Wheats, 21-22 July 1995, Castelvecchio Pascoli, Tuscany, Italy. (Promoting the conservation and use of underutilized and neglected crops 4) International Plant Genetic Resources Institute, Rome, pp 41-100

Olsvig-Whittaker L, Maeir AM, Weiss E, Frumin S, Ackermann O, Horwitz LK (2015) Ecology of the past - Late Bronze and Iron Age landscapes, people and climate change in Philistia (the southern Coastal Plain and Shephelah), Israel. J Mediterr Ecol 13:57–75

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 47:67–90

Orendi A, Smejda L, Mckinny C, Cassuto D, Sharp C, Shai I (2018) The agricultural landscape of Tel Burna: Ecology and economy of a Bronze Age/Iron Age settlement in the southern Levant. J of Land Eco 10:165–188

Post GE (1980) Flora of Syria, Palestine and Sinai: From the Taurus to Ras Muhammad and from the Mediterranean Sea to the Syrian Desert. Periodical Experts Book Agency, Delhi

Rainey AF (2015) The El-Amarna correspondence: A new edition of the cuneiform letters from the site of El-Amarna based on collations of all extant tablets. (Handbook of Oriental Studies. Section 1, The Near and Middle East 110) Brill, Leiden

Ramsay J, Mueller N (2016) Telling seeds: archaeobotanical investigations at Tall al-‘Umayri, Jordan. In: McGeough KM (ed) The archaeology of agro-pastoralist economies in Jordan. (The Annual of the American Schools of Oriental Research 69) American Schools of Oriental Research, Boston, pp 1-25

Reimer PJ, Austin WEN, Bard E et al (2020) The Intcal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62:725–757

Rosen AM (1986) Environmental change and settlement at Tel Lachish, Israel. Bull Am Sch Orient Res 263:55–60

Rousou M, Parés A, Douché C, Ergun M, Tengberg M (2021) Identification of archaeobotanical *Pistacia* L. fruit remains: implications for our knowledge on past distribution and use in prehistoric Cyprus. Veget Hist Archaeobot 30:623–639. https://doi.org/10.1007/s00334-020-00812-z

Schilman B, Ayalon A, Bar-Matthews M, Kagan EJ, Almogi Labin A (2002) Sea-land paleoclimate correlation in the Eastern Mediterranean region during the Late Holocene. Isr J of Earth Sci 51:181–190

Scott A, Power RC, Altmann-Wendling V et al (2021) Exotic foods reveal contact between South Asia and the Near East during the second millennium BCE. Proc Natl Acad Sci USA 118:e2014956117. https://doi.org/10.1073/pnas.2014956117

Simchoni O, Kislev ME, Melamed Y (2007) Botanica remains: Beth-Shean as a trade center for crops in the Bronze Age, botanical and entomological evidence. In: Mazar A, Mullins RA (eds) Excavation at Tell Beth-Shean 1989–1996, vol 2. The Middle and Late Bronze Age strata in area R. The Israel Exploration Society, Jerusalem, pp 702–715

Sofo A, Manfreda S, Fiorentino M, Dichio B, Xiloyannis C (2008) The olive tree: a paradigm for drought tolerance in Mediterranean climates. Hydrol Earth Syst Sci 12:293–301

Torczyner H, Harding GL, Lewis A, Starkey JL (1938) Lachish I (Tell ed Duweir): The Lachish letters. (The Wellcome-Marston archaeological research expedition to the Near East 1) Oxford University Press, London

Tufnell O (1953) Lachish III (Tell ed-Duweir): The Iron Age. (The Wellcome-Marston archaeological research expedition to the Near East 3) Oxford University Press, London

Tufnell O (1958) Lachish IV (Tell Ed Duweir): The Bronze Age. (The Wellcome-Marston archaeological research expedition to the Near East 4) Oxford University Press, London

Tufnell O, Inge CH, Harding GL (1940) Lachish II (Tell ed Duweir): The Fosse temple. (The Wellcome-Marston archaeological research expedition to the Near East 2) Oxford University Press, London

Ussishkin D (1982) The conquest of Lachish by Sennacherib. Tel Aviv University, Institute of Archaeology, Tel Aviv

Ussishkin D (2004) The renewed archaeological excavations at Lachish (1973–1944), vols 1–5. Emery and Clairs Yass Publications in Archaeology, Tel Aviv

Valamoti SM, Charles M (2005) Distinguishing food from fodder through the study of charred plant remains: an experimental approach to dung-derived chaff. Veget Hist Archaeobot 14:528–533

Van Zeist W, Heeres JAH (1973) Paleobotanical studies of Deir ‘Alla, Jordan. Paléorient 1:21–37

Webster L (2020) Synchronising the chronologies of the Late Bronze Age southern Levant and Egypt: a radiocarbon dating perspective. Doctoral dissertation, University of Vienna and Macquarie University, Marquarie Park

Webster L, Streit K, Dee M, Hajdas I, Höflmayer F (2019a) New radiocarbon-based assessment supports the prominence of Tel Lachish during late Bronze age IB-IIA. Radiocarbon 61:1,711–1,727

Webster L, Streit K, Dee M, Hajdas I, Höflmayer F (2019b) Identifying the Lachish of papyrus Hermitage 1116A verso and the Amarna Letters: implications of new radiocarbon dating. J Anc Egypt Interconnect 21:88–99

Weissbein I, Garfinkel Y, Hasel MG, Klingbeil MG (2016) Goddesses from Canaanite Lachish Strata. Bull Ango-Israel Archaeol Soc 34:41–55

Wilcox G (1992) Preliminary report on plant remains from Pella. In: McNicoll AW, Edwards PC, Hanbury-Tenison J et al (eds) Pella in Jordan 2. The second interim report of the joint University of Sydney and the College of Wooster excavations at Pella, 1982–1985. Meditarch, Sidney, pp 253–256

Zaitschek DV (1961) Remains of cultivated plants from the caves of Nahal Mishmar: preliminary note. Isr Explor J 11:70–72

Zohary D, Spiegel-Roy P (1975) Beginnings of fruit growing in the old world. Science 187:319–327

Zohary M (1950) The segetal plant communities of Palestine. Vegetatio 2:387–411

Zohary M (1962) Plant life of Palestine. Ronald Press, New York, Israel and Jordan

Zohary M (1982) Plants of the Bible. Cambridge University Press, Cambridge

Zohary M, Hopf M, 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, 4th edn. Oxford University Press, Oxford

Appendix 2

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RESEARCH

From Early Bronze Age domestic plant production to Middle Bronze Age regional exchange economy: the archaeobotanical assemblages from Tel Kabri

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Abstract

Recent excavations at the site of Tel Kabri have brought some extraordinary findings, including the earliest wine cellar in the ancient Near East discovered in 2013. During these excavations, archaeobotanical samples were collected continuously and then processed in 2019. The archaeobotanical studies focus on the Middle Bronze Age palace in Area DW and the Early Bronze Age domestic deposits in Area L. The results confirm the different nature of the two contexts. Legumes form a large portion of the crop remains in the Early Bronze Age Area L: *Lathyrus sativus* (grass pea), *Vicia faba* var. minor (faba bean), and *Lens culinaris* (lentil), all showing no drought stress and similar growing conditions in terms of moisture availability, as indicated by stable carbon isotope measurements. For Area L, several wild seeds have been identified to represent weeds of cereal crops, whereas Area DW is strongly affected by small wild seeds that entered the sediments as modern contaminants. Fruit crops are present in both assemblages with *Olea europapea* (olive), representing the most ubiquitous taxon, and *Vitis vinifera* (grape), with most of its pips found mineralized. The identified remains also include cereal crops, primarily *Triticum dicoccum* (emmer), which appears cultivated under exceptionally dry conditions. The stable nitrogen values for emmer also raised some questions regarding the growing location and cultivation strategy. Correspondence analysis has been applied, comparing the archaeobotanical assemblages of Tel Kabri within the wider geographical and chronological Levantine context and determining their placement in sub-regional patterns.

Keywords Levant · Olive production · Correspondence analysis · Stable isotopes · Bronze Age

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Introduction

Tel Kabri is an archaeological tell in the Western Galilee region of northwest Israel, located approximately 5 km from the Mediterranean Sea (Fig. 1). It is a multi-period site that reached the height of its power during the Middle Bronze Age, when one of the largest palaces in the Levant was built on the mound (Lazar et al. 2020). Since its discovery in the 1950s (Stekelis 1958), when Late Neolithic stone implements were found, the site has been the subject of different archaeological studies starting with a salvage excavation in 1957 and 1958 (Prausnitz 1959, 1969) in Area A. Salvage excavations continued after 1961 when a 500-m trench was cut to include two of the springs present around the tell into the national water system (Prausnitz and Kempinski 1977), which led to the discovery of Bronze Age settlement structures on the tell.

In 1969, another excavation carried out by the Department of Antiquities and Museums took place when Middle

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Fig. 1 The position of Tel Kabri in the Southern Levant

Bronze Age vessels were discovered in the surroundings of Area B (Prausnitz and Kempinski 1977). One more short rescue excavation was conducted in Area B by the Israel Department of Antiquities and Tel Aviv University in 1975, to investigate and date the rampart present in the Area (Prausnitz and Kempinski 1977).

Starting in 1986, a large excavation by the Tel Aviv University and directed by Aharon Kempinski (Kempinski 2002) investigated four main areas around the site: Area B, Area C, Area D (where the first remains of the Middle Bronze Age palace were found), and Area E (in which the Iron Age settlement was discovered). This excavation, which ended in 1993, aimed to expose architecture in the different areas and included different types of analyses on the various finds, including the first study of botanical remains (Liphschitz 2002). After this major campaign, two minor salvage excavations took place prior to the current excavations: the first one in 1999 focused on Area D (Shalem 2009) and the second in 2004 involved work in Area E (Smithline 2007).

The second major set of excavations started in 2005, with the current Tel Kabri Archaeological Project, and is still ongoing. The project, co-directed by Professor Assaf Yasur-Landau of the University of Haifa and Professor Eric H. Cline of the George Washington University, is providing more information regarding the development and extension of the palace in Area D (Figs. 2 and 3), where the oldest and largest wine cellar in the ancient Near East to date was found, as well as additional evidence for settlements outside the palace area (Yasur-Landau et al. 2018). Originally, trenches were opened in Area L to find residential Middle Bronze Age architecture west of the palace; instead, Early Bronze Age deposits were found.

Archaeobotanical research during the 2019 excavation season of the Tel Kabri Archaeological Project

Fig. 2 Tel Kabri plan of Area DW (Yasur-Landau and Cline 2020)

systematically sampled and investigated plant resources for the first time, including studying contexts. Furthermore, stable isotope measurements on archaeobotanical seeds were analyzed, which add to our understanding of agricultural management and environmental parameters. Through correspondence analysis, the botanical assemblages from Tel Kabri have been defined and compared within the coeval regional framework in order to find any association with other sites and so as to help define chrono-geographical patterns regarding the regional agricultural resources.

Environmental background

The modern Galilee region is characterized by a Mediterranean climate with an average annual precipitation of more than 500 mm and Mediterranean macchia vegetation (Danin and Plitmann 1987; Danin 1992; Zohary 1962). The climate of the Galilee, and in the southern Levant broader region in general, has not always been the same. In addition, the vegetation has also been heavily affected by human activities.

Paleoclimatic indicators show that the first phases of the Early Bronze Age (hereafter EBA) were the most humid during the Bronze and Iron Ages (IA); pollen records indicate that olive trees, and in general all the Mediterranean vegetation, reached their peak at this time (Schiebel and Litt 2017; Langgut et al. 2015). At the end of the EBA, drier episodes are recorded in the pollen diagrams and have been associated with a declining level of the Dead Sea (Kagan et al. 2015; Migowski et al. 2006) and decreasing precipitation (Bar-Matthews and Ayalon 2011).

During the Intermediate Bronze Age period, no major changes in vegetation were recorded for the Galilee region; it is characterized by pollen from well-represented olive trees (Langgut et al. 2013). Throughout the Middle Bronze Age (MBA), when the palaces in Tel Kabri were built and its political influence in the region increased, the climate underwent variations, ranging from drier conditions in the earliest phases to more humid conditions afterwards (Langgut et al. 2015).

For the Late Bronze Age (LBA), rich arboreal vegetation is registered regarding Mediterranean macchia (Langgut et al. 2015) but with drier events occurring especially toward the end of the period (Schilman et al. 2002; Litt et al. 2012; Bar-Matthews and Ayalon 2004). Thanks to the availability of natural resources around the tell, which includes streams and perennial springs (Tsuk 2002), the

Fig. 3 Aerial view of the northwestern part of the palace area at the end of the 2019 season (photo by Griffin Aerial Imaging). Blue: orthostat; red and yellow: L.3264 and L.3269 as part of the Northern Storage Complex. Below these two loci, the Southern Storage Complex (wine cellar)

oscillation in the regional climate conditions likely had little effect on the people living around Tel Kabri, which was almost continuously inhabited since the Neolithic period (Horowitz 2002).

Stability in vegetation patterns is also suggested by past anthracological studies in Tel Kabri, which record mostly the same arboreal species, *Quercus calliprinos*, *Olea europaea*, and *Pistacia palaestina*, throughout all the periods analyzed (Late Neolithic, EBA, MBA, IA) and they can still be found in the present-day environment (Liphschitz 2002).

Material and methods

Tel Kabri samples were collected during three different excavation seasons: 2015, 2017, and 2019. Sediment volumes range between 100 and 5 L, depending on the archaeological context. The majority of the 2015 samples measured 10 L, whereas the 2017 and 2019 samples had an average volume of 30 L.

There was a total volume of about 3961 L of sediment collected during these seasons that belong to two different areas:

- Area DW: 185 samples (MBA), in all 3840 L
- Area L: 6 samples (EBA), in all 121 L

All the samples collected during the three seasons were processed with a flotation machine using a water recycling system, built on-site in 2019 (Fig. 4). The heavy residues, gathered using a 1-mm mesh, were dried and sorted on-site, separating small archaeological finds, like fauna (Marom et al. 2015) and plant remains. A 0.2-mm sieve was used to collect the light fractions which were dried in small cloths.

The plant remains retrieved from the heavy residues and the light fractions were subsequently shipped to the archaeobotanical laboratory at the University of Tübingen. Using a Euromex binocular with up to 30 × magnification, the plant remains collected were identified. For identification purposes, the Senckenberg seed reference collection (SeSam), with more than 15,000 specimens of primarily Mediterranean and Near Eastern floras, located in the archaeobotanical lab of Tübingen University was used. Seed catalogues and floras, together with already published archaeobotanical research, were also used (e.g., Jacomet 2006; Nesbitt 2008; Kislev et al. 2006, 2009; Neef et al. 2012; Post 1980; Danin and Fragman 2016). In all, a total of 29 taxa have been identified in Tel Kabri.

Fig. 4 Built on site flotation machine with water recycling system used at Tel Kabri

The majority of the botanical finds from Tel Kabri are carbonized, except for some seeds that are mineralized. It was difficult to determine if the latter are contemporary with the context analyzed (Area DW storage complexes) or if they are modern contaminants.

Some of the small-seeded wild taxa in the assemblage lack distinguishing features, which made it impossible to identify them to the species level. In addition, many cereal grains were highly fragmented, while others were heavily corroded, maybe through high charring temperatures. In general, however, most of the other crop remains were found in a good state of preservation.

To quantify the olive pit fragments recovered, they were weighed and converted into complete pits, using a whole preserved individual weight as the conversion factor. It should be noted that all seeds may present quantifying problem counts, such as grape (usually having 2 pips in a single fruit) listed in Table 1 as each individual specimen and therefore ubiquity is used. The ubiquity values in Tables 1 and 2 indicate the percentage of samples in which each taxon is present.

Two halves and four quarters of cereal grains were considered one seed; if only one fragment was found in a sample, it was counted as one seed. In the same way, each two glume bases were counted as a single spikelet fork.

To define the assemblages from Tel Kabri within the regional framework, a correspondence analysis (CA) approach was chosen to examine the large data sets of botanical remains collected from archaeological sites in the Levant (Table 3). CA is an ordination technique which permits the analysis of large data and arranges sites along axes based, in this case, on plant species. It has been used successfully in previous research to examine large data and define patterns (e.g., Riehl 1999a, b; Jones et al. 2000; Smith and Munro 2009; Vermeersch et al. 2021). Data selection and cleaning was conducted following Jones (1991) prior to analysis. Due to the lack of representativeness of small samples, sites with less than four crop taxa and only presence/absence data were excluded from the analysis. Furthermore, taxa that occur from less than four sites have not been included to avoid any "noise" in the graph that could conceal real patterns.

CANOCO 5 software was used to carry out the CA and design the graphs (Leps and Smilauer 2014). Although this method can experience some problems when the so-called arch effect appears (a distortion that may lead to wrong interpretation of the first and second axes (Jongman et al. 1995)), the results that we obtained for the data set could be safely interpreted, as the arch effect distortion is not present in the graph. The data were acquired from published reports

Table 1 Cultivated plants identified from Tel Kabri

Area	Area DW		Area L	
Period	Middle Bronze		Early Bronze II	
Numbers of samples	185		6	
Volume of sediment (L)	~3840		~121	
Total no. of specimens	255		240	
	Items	Ubiquity	Items	Ubiquity
Cereals				
Cerealia (frag.)	24	10%	22	50%
Hordeum vulgare	2	1%	3	33%
Triticum aestivum/durum	1	1%	–	–
Triticum dicoccum	6	3%	21	67%
Triticum dicoccum glume base	–	–	3	33%
Triticum monococcum/dicoccum	1	1%	–	–
Triticum sp. (frag.)	8	2%	26	67%
Legumes				
Fabaceae (frag.)	6	3%	57	67%
Lathyrus sativus	5	3%	22	50%
Lens culinaris	10	5%	11	50%
Vicia ervilia	9	4%	–	–
Vicia faba var. *minor*	–	–	16	33%
Fruits				
Olea europaea	103	45%	48	83%
Punica granatum	1	1%	–	–
Vitis vinifera	79	16%	7	50%
Ziziphus cf. *spina-christi*	–	–	4	17%

Table 2 Wild plants identified from Tel Kabri

Area	Area DW		Area L	
Period	Middle Bronze		Early Bronze II	
Numbers of samples	185		6	
Volume of sediment (L)	~3840		~121	
Total no. of specimens	265		29	
	Items	Ubiquity	Items	Ubiquity
Avena sp.	–	–	1	17%
Chenopodium sp.	73	16%	–	–
Euphorbia sp.	1	1%	–	–
Galium cf. *aparine*	1	1%	3	33%
Lolium cf. *rigidum*	–	–	17	67%
Lolium sp.	9	5%	–	–
Phalaris sp.	2	1%	5	17%
Pistacia sp.	1	1%	1	17%
Polygonaceae	71	9%	–	–
Reseda sp.	104	17%	2	17%
Scorpiurus cf. *muricatus*	1	1%	–	–
Trifolium sp.	1	1%	–	–
Undetermined	46	–	4	–

and articles extracted from the ADEMNES database (https://www.ademnes.de/). Even though the contexts from these sites might be various (e.g., not being exclusively palatial contexts for MBA sites), we think this type of analysis might be beneficial in comparing and understanding the development of plant resources in the Levant. The methodology for collecting botanical samples may also differ (machine or manual flotation) but no sites with stated exclusive hand-picking collecting methods are present in the analysis, avoiding biased results. To simplify the process of using large data, chronological phases (e.g., EBA II, EBA IV, LBA II, etc.) were organized into broad EBA, MBA, and LBA groups.

Stable carbon and nitrogen analyses on 37 well-preserved crop seeds from Early and Middle Bronze Age levels at Tel Kabri were conducted at the Institute of Geosciences of the University of Tübingen, Germany, on a FinniganMAT252 gas source mass spectrometer with a ThermoFinnigan Gas-Bench II/CTC Combi-Pal autosampler (Tables 4).

Possible alteration of $\delta^{15}N$ in plant remains through charring has been investigated experimentally by a number of authors (Bogaard et al. 2007; Aguilera et al. 2008; Fraser et al. 2013). They all found no or only insignificant change in $\delta^{15}N$ values after charring at different temperatures, thus preserving the original environmental signal during the lifetime of the plants. Archaeological sediments, however, carry carbonate precipitates and humic/fulvic acids that may accumulate in archaeobiological material and distort stable carbon and nitrogen isotope measurements. Therefore, pretreatment of the material is required. The standard pretreatment method for removing carbonate crusts and humic/fulvic acids is described by DeNiro and Hastorf (1985) and, since that, systematically refined (Fraser et al. 2013; Styring et al. 2013; Vaiglova et al. 2014). For this reason, prior to mass-spectrometric measurements, the carbonized seeds were reacted with 5% HCl to eliminate sedimentary carbonate. Changes in atmospheric CO_2 concentration ($\delta^{13}C_{air}$) over time were transferred into $\Delta^{13}C$ values by using the approximation AIRCO2_LOESS (Ferrio et al. 2012). In-depth discussion of methodological aspects of stable isotope measurements on archaeobotanical remains can be found in Fiorentino et al. (2014), Ferrio et al. (2020), and Riehl (2020).

Some of the seeds, e.g., *Lathyrus sativus*, *Lolium* sp., and *Lens culinaris*, contained insufficient amounts of measurable nitrogen. Despite an uneven representation of measurable seeds from the different chronological units, comparison with existing stable isotope measurements from other Levant sites was conducted (e.g., with the data published in Riehl et al. 2014) to increase the possibility of interpreting the values so far achieved from Tel Kabri.

Results

Sixteen of the 29 taxa identified at Tel Kabri belong to cultivated plants, totaling 495 remains (Table 1). The rest are wild plant taxa, accounting for 294 seeds (Table 2).

Plant remains pictured in Fig. 5 were taken using a Zeiss digital microscope Stereo Discovery V8, keeping a 1-mm scale bar for each picture.

Table 3 Levantine sites analyzed by CA. Number of plant remains based on the CA plant taxa

Site	Reference	Modern reg./site elev. (m)	Chron./no. of remains
Aphek	Kislev and Mahler-Slasky (2009)	S. Levant, Israel/58	LBA/23926
Arad	Hopf (1978)	S. Levant, Israel/500	EBA/168
Bab'edh Dhra	McCreery (1979, 2003, 2011)	S. Levant, Jordan/ – 351	EBA/867
Beth-Shean	Kislev et al. (2009), Simchoni et al. (2007), Liphschitz (1989)	S. Levant, Israel/ – 114	EBA/7248-MBA/260 LBA/175510
Ebla	Wachter-Sarkady (2013)	N. Levant, Syria/389	EBA/628
Emar	Riehl (1999, 2001)	N. Levant, Syria/343	EBA/850-MBA/176 LBA/170
Hirbet ez-Zeraqon	Riehl (2004)	S. Levant, Jordan/489	EBA/3397
Jericho	Hopf (1983), Bar-Yosef (1986)	S. Levant, Palestine/ – 277	EBA/110029–MBA/77987
Lachish	Helbaek (1958), Nicoli' et al. (2022)	S. Levant, Israel/252	MBA/103-LBA/7714
Manahat	Kislev (1998)	S. Levant, Israel/762	MBA/272
Megiddo	Borojevic (2006)	S. Levant, Israel/80	EBA/48-MBA/126
Pella	Wilcox (1992)	S. Levant, Jordan/-80	EBA/370
Qatna	Riehl (2007)	N. Levant, Syria/492	EBA/8215– MBA/4192-LBA/305
Qubur el-Walaydah	Riehl (2010), Orendi (unpublished data)	S. Levant, Israel/66	LBA/76
Ras en-Numayra	White et al. (2014)	S. Levant, Jordan/ – 385	EBA/600
Shiloh	Kislev (1993), Liphschitz (1993)	S. Levant, Israel/690	MBA/298
Sidon	De Moulins (2015)	S. Levant, S. Lebanon/85	MBA/791-LBA/133
Tel Burna	Orendi et al. (2017), and unpublished data	S. Levant, Israel/203	LBA/45
Tel Yarmouth	Salavert (2008)	S. Levant, Israel/291	EBA/1382
Tell Abu el-Kharaz	Holden (1994)	S. Levant, Jordan/275	EBA/10635– LBA/23287
Tell Abu en-Ni'aj	Falconer and Fall (2019)	S. Levant, Jordan/ – 257	EBA/3151
Tell Afis	Wachter-Sarkady (1998)	N. Levant, Syria/330	EBA/158-LBA 199
Tell al-Rawda	Herveux (2004)	N. Levant, Syria/710	EBA/2958
Tell Atij	McCorriston (1995)	N. Levant, Syria/296	EBA/414
Tell Bderi	van Zeist (1999/2000)	N. Levant, Syria/291	EBA/5719-LBA/77
Tell Brak	Charles and Bogaard (2001), Colledge (2003)	N. Levant, Syria/346	EBA/26193– MBA/11443
Tell Deir'Alla	van Zeist and Heeres (1973)	S. Levant, Jordan/ – 256	LBA/193561
Tell el-Burak	Orendi (2020), Orendi and Deckers (2018)	S. Levant, S. Lebanon/ ~ 15	MBA/223-LBA/57
Tell el-Hayyat	Metzger (1984)	S. Levant, Jordan/ – 249	EBA/43-MBA 3214
Tell el-Raqa'I	van Zeist (1999/2000)	N. Levant, Syria/296	EBA/1169
Tell el-Umeri	Ramsay and Mueller (2016)	S. Levant, Jordan/861	LBA/743
Tell esh-Shuneh	Holden (1999)	S. Levant, Jordan/212	EBA/500
Tell es-Safi/Gath	Mahler-Slasky and Kislev (2012)	S. Levant, Israel/169	LBA/196
Tell es-Sweyhat	van Zeist and Bakker-Heeres (1985), Miller (1997)	N. Levant, Syria/338	EBA/9125
Tell Fadous-Kfarabida	Riehl and Deckers (2009), Genz et al. (2009)	N. Levant, N. Lebanon/ ~ 5	EBA/1085-MBA 79
Tell Hammam et-Turkman	van Zeist et al. (1988)	N. Levant, Syria/320	EBA/96
Tell Kerma	McCorriston (1995)	N. Levant, Syria/315	EBA/1060
Tell Mozan	Riehl (2000)	N. Levant, Syria/452	EBA/2536-MBA 669
Tell Munbāqa	Küster (1989)	N. Levant, Syria/311	LBA/8848
Tell Nebi Mend	Moffett (1989)	N. Levant, Syria/503	EBA/2601-MBA 594 LBA/184
Tell Qara Quzaq	Matilla Séiquer and Rivera Núñez (1994)	N. Levant, Syria/332	EBA/348-MBA 1019
Tell Qarqur	Smith (2005)	N. Levant, Syria/169	EBA/250
Tell Selenkahiye	van Zeist and Bakker-Heeres (1985)	N. Levant, Syria/371	EBA/20023
Tell Shiukh Fawqani	Pessin (2004)	N. Levant, Syria/328	EBA/1226
Tell Tweini	Linseele et al. (2019)	N. Levant, Syria/ ~ 21	EBA/92–MBA/1369 LBA/1667
Timnah (Tel Batash)	Kislev et al. (2006)	S. Levant, Israel/158	LBA/192002

Table 3 (continued)

Site	Reference	Modern reg./site elev. (m)	Chron./no. of remains
Umm el-Marra	Miller et al. (2000)	N. Levant, Syria/339	EBA/54-MBA/71-LBA/41
Zahrat adh-Dhra'	Fall et al. (2019)	S. Levant, Jordan/ – 169	MBA/1947

The number of remains for Area DW is low compared to the number of samples and liters of sediment floated. Area L samples, despite the limited number, turned out to be denser in seed remains, with more than two plant remains per liter sediment.

Cereal crops

Twenty-four percent of the cultivated plant assemblage in Tel Kabri is composed of cereal remains (117). *Triticum dicoccum* (emmer) is the best represented taxon, especially

Table 4 Raw data of stable isotope measurements on crop seeds from different archaeological strata at Tel Kabri

Taxon	Locus/description	Period/Phase	$\Delta^{13}C$	$\delta^{15}N$
Hordeum vulgare	L8010/organic sediment around stone installations	EB II	17.8058166	2.9198678
Hordeum vulgare	"	EB II	15.9951142	0.4087795
Lathyrus sativus	"	EB II	18.1062113	–
Lathyrus sativus	"	EB II	18.4542053	–
Lathyrus sativus	"	EB II	17.4904921	–
Lathyrus sativus	"	EB II	17.6828873	– 0.6349926
Lathyrus sativus	"	EB II	17.8350418	0.3669825
Lathyrus sativus	"	EB II	16.8463471	0.1697967
Lolium sp.	"	EB II	18.8367686	– 0.9896014
Lolium sp.	"	EB II	17.2901159	1.113893
Lolium sp.	"	EB II	18.2030205	–
Lolium sp.	"	EB II	16.00616	–
Lolium sp.	"	EB II	16.078466	–
Lolium sp.	"	EB II	17.750394	–
Triticum dicoccum	"	EB II	14.8927439	6.7563221
Triticum dicoccum	"	EB II	15.2696277	6.3810122
Triticum dicoccum	"	EB II	14.5822257	7.2272394
Triticum dicoccum	"	EB II	15.2977047	4.8573964
Triticum dicoccum	"	EB II	14.0777885	4.1505119
Triticum dicoccum	"	EB II	15.1322733	3.820492
Vicia faba var. minor	"	EB II	19.6482687	1.8281247
Vicia faba var. minor	"	EB II	18.0316001	0.65554
Vicia faba var. minor	"	EB II	16.802092	0.9608016
Lens culinaris	L8006/organic soil, part of a colluvial fill	MB	16.5375121	– 3.0825902
Lens culinaris	"	MB	18.7368351	– 0.676
Lens culinaris	"	MB	18.7964083	–
Olea europaea	"	MB	15.954771	3.6524787
Olea europaea	"	MB	16.8774179	1.5624698
Olea europaea	"	MB	15.1270221	2.4851111
Olea europaea	"	MB	16.5797365	1.5916066
Olea europaea	"	MB	17.0766399	– 0.6204543
Olea europaea	"	MB	16.9055859	4.6431698
Vitis vinifera	"	MB	19.4471189	– 0.0658583
Vitis vinifera	L8010/organic sediment around stone installations	MB	20.4936338	– 0.2264285
Olea europaea	DW3253/raised pottery layer	MBI-MBII	17.2417112	5.0740387
Olea europaea	"	MBI-MBII	16.6360412	3.429388
Olea europaea	"	MBI-MBII	17.4148923	12.8416314

Fig. 5 **a** Emmer wheat, *Triticum dicoccum* (Area L, L.8010); **b** emmer wheat, *Triticum dicoccum* (Area DW, L.2765); **c** emmer wheat glume base, *Triticum dicoccum* (Area L, L.8006); **d** emmer wheat, *Triticum dicoccum* (Area L, L.8010); **e** emmer wheat lateral view, *Triticum dicoccum* (Area L, L.8010); **f** emmer wheat dorsal view, *Triticum dicoccum* (Area L, L.8010); **g** faba bean lateral view, *Vicia faba* var. *minor* (Area L, L.8010); **h** faba bean frontal view, *Vicia faba* var. *minor* (Area L, L.8010); **i** lentil, *Lens culinaris* (Area DW, L.2875); **j** bitter vetch, *Vicia ervilia* (Area DW, L.3311) **k** olive, *Olea europaea* (Area DW, L. 2533); **l** grape, *Vitis vinifera* (Area DW, L.2533); **m** mineralized grape, *Vitis vinifera* (Area L, L.8006); **n** mineralized grape (Area DW, L.3269); **o** jujube dorsal view, *Ziziphus* cf. *spina-christi* (Area L, L.8006); **p** jujube frontal view, *Ziziphus* cf. *spina-christi* (Area L, L.8006); **q** mineralized pomegranate (Area DW, L.3269); **r** ryegrass, *Lolium* (Area L, L.8010); **s** canarygrass, *Phalaris* (Area DW, L.2765); **t** weld, *Reseda* (Area DW, L.3264). Scale bars = 1 mm

in the EBA samples of Area L, where *Triticum dicoccum* glume remains have also been found. In general, the MBA samples of Area DW have yielded very few cereal grain remains apart from tiny fragments, i.e., a single *Triticum aestivum/durum* (free-threshing wheat) seed and two *Hordeum vulgare* (barley grain).

Legumes

Legumes represent 27% of the cultivated plants (136 remains). The presence of *Lathyrus sativus* (grass pea) and *Lens culinaris* (lentil) is attested in both areas, the former being the predominant legume in the EBA samples while the latter being the most represented in the MBA assemblage. We also have *Vicia ervilia* (bitter vetch), which starts appearing in the MBA samples of Area DW, and *Vicia faba* var. *minor* (faba bean) seeds that have been found solely in EBA samples of Area L.

Fruits

Nearly half (49%) of the whole cultivated plants assemblage is composed of fruit remains (242).

Olea europaea (olive) is the most frequent taxon in Tel Kabri and the best represented in both areas. After olive, the presence of *Vitis vinifera* (grape) is remarkable in the MBA samples of Area DW, where most of the grape pips have been found in a mineralized state but is also present in minor quantities in Area L. Noteworthy is the finding of a single mineralized seed of *Punica granatum* (pomegranate) in Area DW and four *Ziziphus* cf. *spina-christi* (jujube) seeds in Area L.

Wild plant taxa

In total, 12 wild plant taxa have been identified at Tel Kabri. For Area DW, most of the wild plant seeds belong to *Cheponodium* sp., Polygonaceae, and *Reseda* sp. For most of these seeds, morphological differentiation into modern or ancient is impossible without destruction, but some considerations regarding their contextual relationship within the site may surely help. The orthostat trench, for example, due to the proximity of the topsoil, yielded wild plant seeds which are exclusively modern and that inevitably contaminated the samples (outlined in blue in Fig. 3).

A few more wild taxa, contributing only singular seeds, have been identified, including *Pistacia* sp., *Scorpiurus* cf. *muricatus*, *Galium* cf. *aparine*, *Phalaris* sp., and *Lolium* sp. which are part of the wild botanical assemblage. Regarding Area L, *Lolium* cf. *rigidum* is the main wild taxon.

Correspondence analysis of Bronze Age sites

Correspondence analysis of crops data extracted from the ademnes.de database was applied to examine agricultural patterns at Tel Kabri within the wider regional framework.

The biplot (Fig. 6) is based on a total of 12 plant taxa and 72 Bronze Age botanical assemblages (34 EBA, 19 MBA, 19 LBA) coming from 47 Levant sites (Table 3).

The biplot graph that we produced (Fig. 6) provides patterns of how the different sites and their assemblages are interrelated on the basis of the counts of the plant taxa (variables), being more similar to each other the closer they are to the origin of the axes. The horizontal axis (first axis) delineates the highest variance within the data. The cumulative variation expressed in the graph legend informs about how much variation is explained by the two axes.

The CANOCO plot has been graphically modified to provide a better view of the assemblages and therefore of patterns: labels' size changes and spacing but also using different symbols, to improve the readability of the chronological differentiation, and different colors to highlight the geographical division.

The distance between the sites in Fig. 6 approximates the dissimilarities in their botanical assemblage with regard to the crop taxa considered. If some sites have a high similar frequency of a certain taxon, they generally cluster together in proximity of that taxon. For interpreting the patterns, it is important to also consider the raw data and the context of the sites as provided in the original articles (Table 3). To assist the interpretation of the CA plot, three distribution maps (Figs. 7, 8, and 9) have been created, showing the sites location and their assemblages expressed as percentage data in pie charts.

Cereal crops are separated from fruit trees along the first axis and at the same time separate sites which are dominated by either cereal or fruit tree remains (Fig. 6). A chrono-geographic trend seems also to be associated to this. Most of the sites on the left side of the first axis are located in the northern Levant (modern Syria and N-Lebanon), with assemblages dominated by cereal crops, especially barley. On the right side of the first axis, a majority of sites of the southern Levant (modern S-Lebanon and Israel) are accumulating, in this case instead commonly associated by intense olive and grape cultivation (Riehl 2009; Langgut et al. 2016). The EBA assemblages of the northern Levant appear to be mostly associated with the cereals (notably barley), while those of the southern Levant are in closer association with the fruit trees (mostly olive and grape). This pattern is also supported with the percentage proportions plotted to the geographical maps (Fig. 7). The MBA assemblages of the sites of the southern Levant are located mostly in the first quadrant in association with the fruit trees which is also visualized in Fig. 8, while those of the northern Levant find their place in the second, third, and fourth quadrants, i.e., being strongly associated to high grape and wheat abundance in the crop assemblages. The LBA assemblages appear to accumulate mostly in quadrants 1 and 4, probably associated with decreased emmer cultivation during this period. This can be further specified in Fig. 9 showing comparatively higher proportions of the other cereals than before.

The Jordanian sites appear more diverse in their association with the crop species, while a distinction between the EBA and MBA samples may be linked to comparatively higher amounts of emmer during the EBA (Fig. 6).

Stable isotope measurements

The $\delta^{13}C$ and $\delta^{15}N$ measurements on 37 crop seeds are provided in Table 4. $\Delta^{13}C$ values are converted and corrected for changes in atmospheric CO_2 concentrations throughout time. Barley and emmer wheat show the lowest $\Delta^{13}C$ values (Fig. 10), indicating a considerable drought signal, whereas all other crop taxa indicate sufficient water availability. Most of the $\delta^{15}N$ values fall into a range of no to medium manuring on a scale adapted to mean annual precipitation provided in Styring et al. (2017), with emmer wheat as the most likely candidate for manuring (Fig. 10).

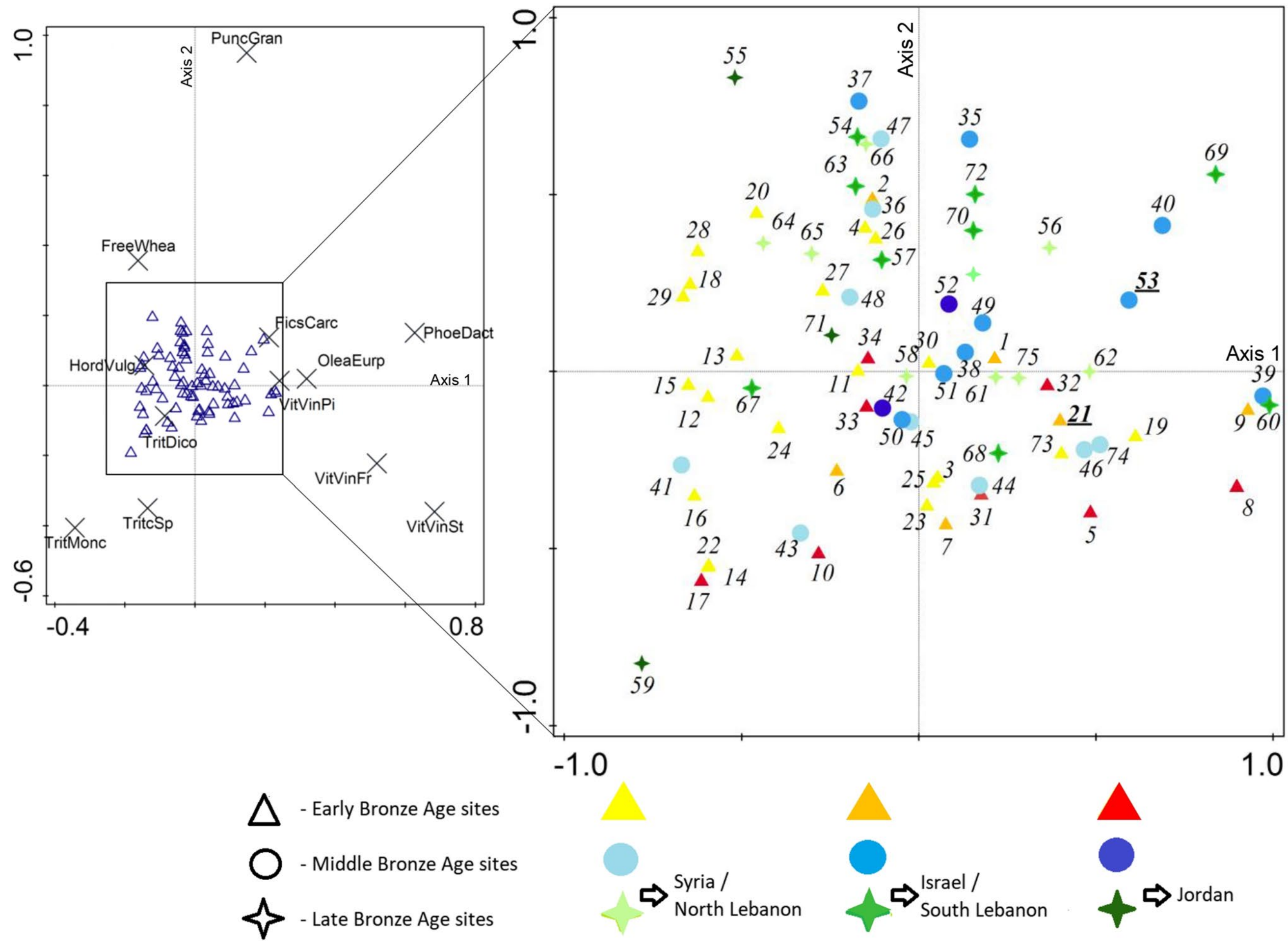

Fig. 6 CA biplot of Levant Bronze Age sites patterns for cereal and fruit crops. Cumulative variance axis 1 = 23.70, axis 2 = 40.10; eigenvalues axis 1 = 0.2012, axis 2 = 0.1392. Legend: (1) Arad_EBA; (2) Beit-Shean_EBA; (3) Ebla_EBA; (4) Emar_EBA; (5) Hirbet ez-Zeraqon_EBA; (6) Jericho_EBA; (7) Megiddo_EBA; (8) Ras en-Numayra_EBA; (9) Tel Yarmouth_EBA; (10) Tell Abu el-Kharaz_EBA; (11) Tell Afis_EBA; (12) Tell el-Raqa'i_EBA; (13) Tell al-Rawda_EBA; (14) Tell Atij_EBA; (15) Tell Bderi_EBA; (16) Tell Brak_EBA; (17) Tell el-Hayyat_EBA; (18) Tell es-Sweyhat_EBA; (19) Tell Fadous-Kfarabida_EBA; (20) Tell Hammam et-Turkman_EBA; (**21**) **Tel Kabri_EBA**; (22) Tell Kerma_EBA; (23) Qatna_EBA; (24) Tell Mozan_EBA; (25) Tell Nebi Mend_EBA; (26) Tell Qara Quzaq_EBA; (27) Tell Qarqur_EBA; (28) Tell Selenkahiye_EBA; (29) Tell Shiukh Fawqani_EBA; (30) Umm el-Marra_EBA; (31) Tell esh-Shuneh_EBA; (32) Bab'edh Dhra_EBA; (33) Tell Abu en-Ni'aj_EBA; (34) Pella_EBA; (35) Beth Shean_MBA; (36) Emar_MBA; (37) Jericho_MBA; (38) Megiddo_MBA; (39) Manahat_MBA; (40) Shiloh_MBA; (41) Tell Brak_MBA; (42) Tell el-Hayyat_MBA; (43) Qatna_MBA; (44) Tell Fadous-Kfarabida_MBA; (45) Tell Mozan_MBA; (46) Tell Nebi Mend_MBA; (47) Tell Qara Quzaq_MBA; (48) Umm el-Marra_MBA; (49) Tel Lachish_MBA; (50) Sidon_MBA; (51) Tell el-Burak_MBA; (52) Zahrat adh-Dhra'_MBA; (**53**) **Tel Kabri_MBA**; (54) Beth Shean_LBA; (55) Tell Deir'Alla_LBA; (56) Emar_LBA; (57) Tell es-Safi/Gath_LBA; (58) Tell Afis_LBA; (59) Tell Abu el-Kharaz_LBA; (60) Aphek_LBA; (61) Tell Bderi_LBA; (62) Qatna_LBA; (63) Timnah (Tel Batash) III_LBA; (64) Tell Munbāqa_LBA; (65) Tell Nebi Mend_LBA; (66) Umm el-Marra_LBA; (67) Qubur el-Walaydah_LBA; (68) Sidon_LBA; (69) Tel Burna_LBA; (70) Tell el-Burak_LBA; (71) Tell el-Umeri_LBA; (72) Tel Lachish_LBA; (73) Tel Tweini_EBA; (74) Tell Tweini_MBA; (75) Tell Tweini_LBA

Discussion

Spatial and contextual patterns in crop distribution at Tel Kabri

Area DW includes the wine cellar (southern storage complex, Yasur-Landau et al. 2018; Koh et al. 2014) and was investigated to better understand the extension of the west part of the palace and its storerooms.

Within Area DW, only few cereal grains were found including a single free-threshing wheat grain. The few cereal seeds of emmer wheat (Fig. 5), barley, and some cereal crop weeds like *Phalaris* (Fig. 5s) and *Lolium* (Fig. 5r) have been found in connection with a good number of charcoal fragments. Weed species, such as *Lolium* spp., have rarely been analyzed for their stable isotope data, but in doing so, we may be able to identify the crop species with which they were associated. Although the

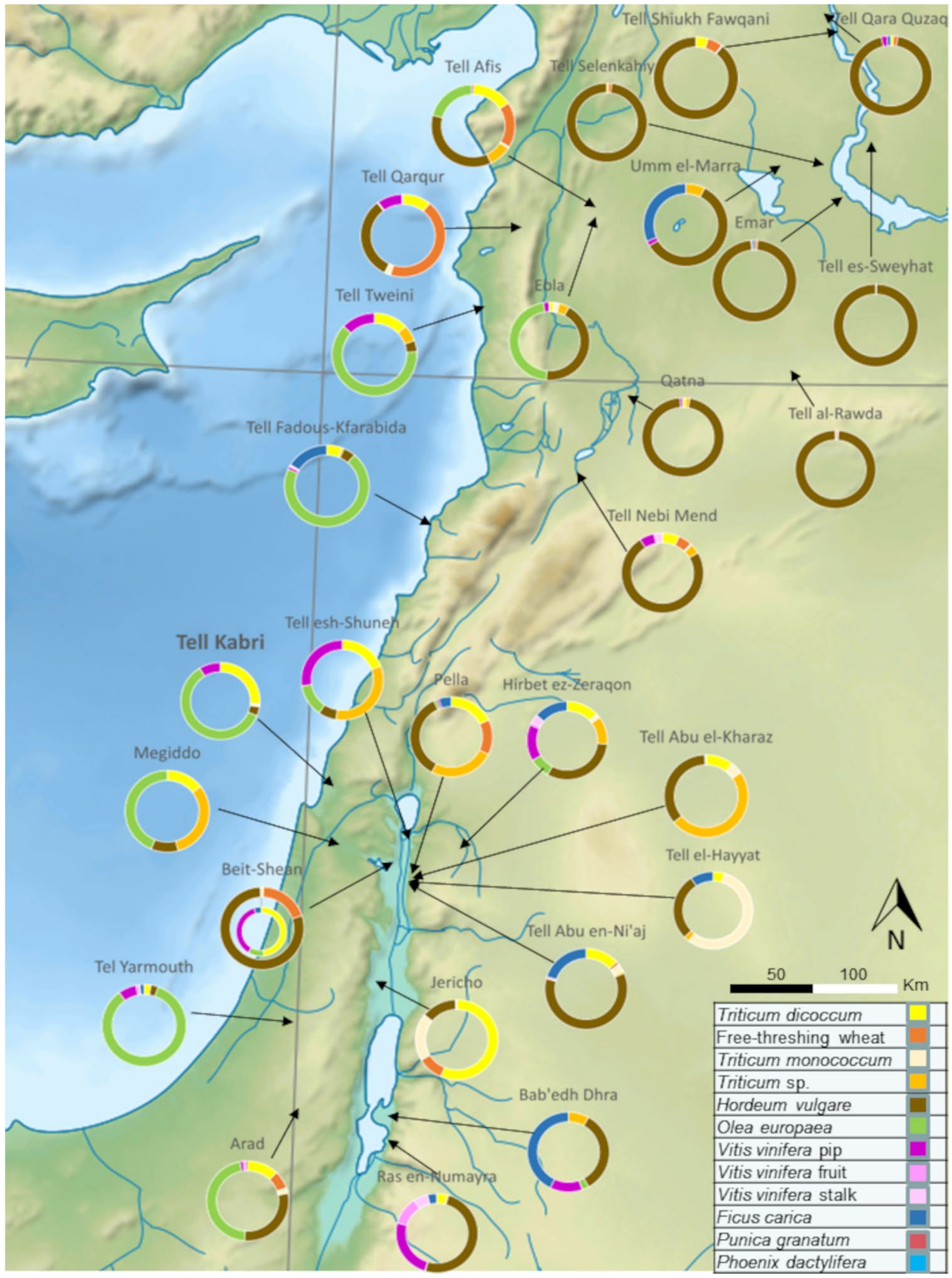

Fig. 7 EBA crop proportions in Levantine sites

individual range of $\Delta^{13}C$ values is so far unknown for *Lolium* sp., the similarity of the values measured to those of barley at Tel Kabri is striking, and since it is more likely that this grass was harvested together with a cereal species, rather than with legumes, it may be interpreted as a weed of barley cultivation.

Most of the legumes in Area DW were found within a single locus, L.3264, with ca. 22 vessels discovered in situ (outlined in red in Fig. 3). Olive and grape are the main findings of the Northern Storage Complex in terms of counts and ubiquities. Most of the grape pips identified in this area (ca. 70%) are mineralized (Fig. 5n), the majority of which come from two loci which are part of the same floor where the previously mentioned vessels were located (Fig. 11).

This mineralization is an indication that the botanical remains went through a transformation process, which allowed them to be preserved, by exchanging organic molecules with inorganic ones (Green 1979; McCobb and Briggs 2001) and testifying to the causes depending on the nature of the context. Many mineralized seeds in Area DW were found in a layer that was probably the result of dumping due to the high quantities of bone remains and pottery sherds (L.3269 which location is outlined in yellow in Fig. 3). This is confirmed also by the botanical remains

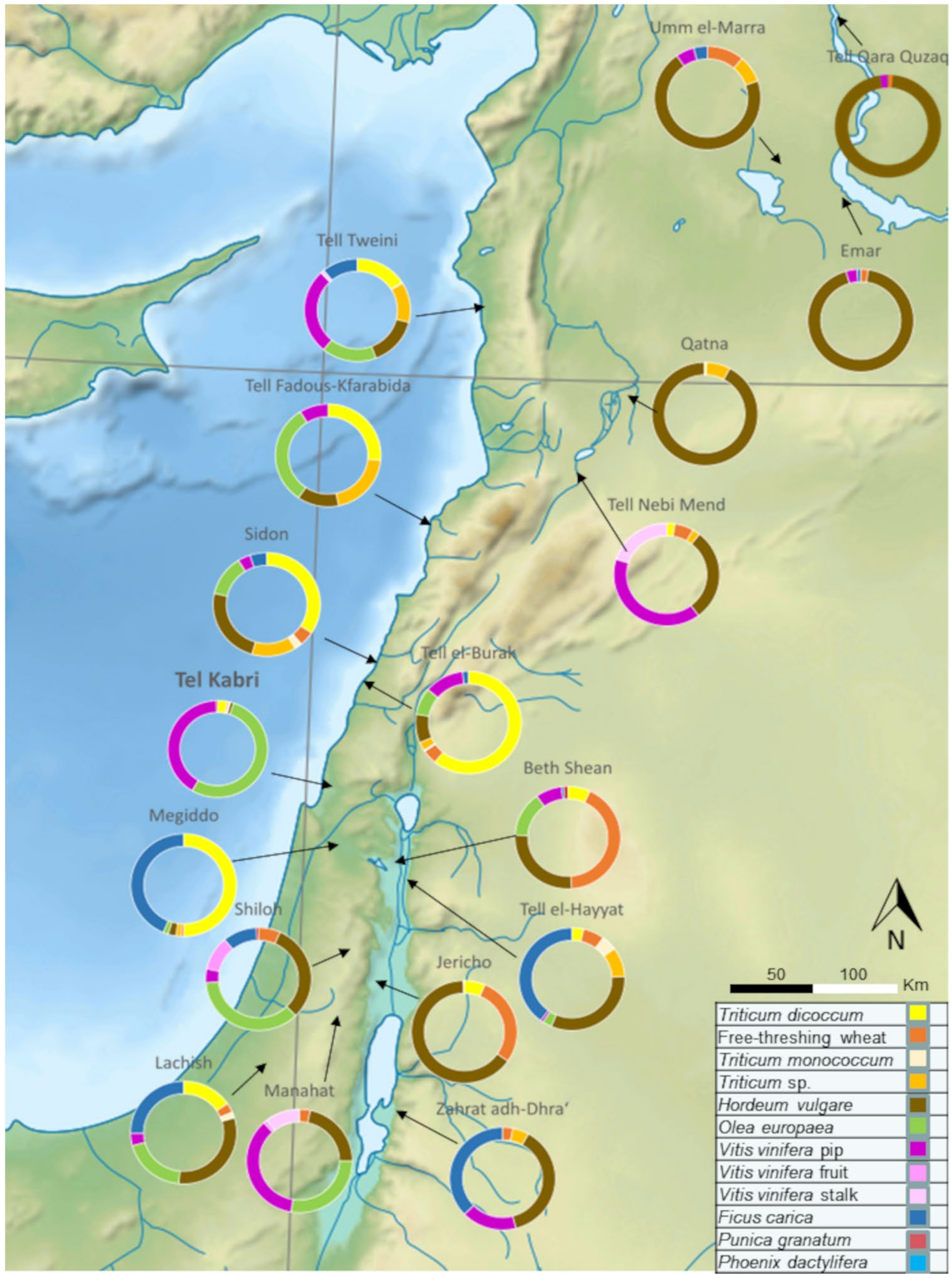

Fig. 8 MBA botanical assemblages of Levant sites used in the CA

within the locus: there are many fruit remains, including charred olive (Fig. 5k), grape (all mineralized), and a mineralized pomegranate seed (Fig. 5q), charred legumes, and very few cereal, charcoal, and wild plants seeds, all indicating domestic waste. The presence of whole mineralized grape pips in the dumping context may usually indicate that the domestic waste also included part of latrine waste (Baeten et al. 2012; Matthews 2010) but no latrine installations or contexts have been found in Tel Kabri so far.

The nature of the sampled areas, their original functionality, preservation conditions, and modern intrusions all affected the outcome of the botanical assemblage. Considering the elite setting in which the palace is located, it is not surprising that no results of cereal cleaning or cereal storage have been found in Area DW.

The plant remains suggest that the whole area was primarily used to store wine. The high presence of mineralized grape seeds might be evidence of unfiltered stored wine. Thanks to the tannin present in the grape seed, they could have acted as preservatives during the transportation and storage of wine vessels (White and Miller 2018). After the filtration, the residues would have probably been discarded in domestic wastes, hence the high presence of mineralized seeds in the archaeobotanical record.

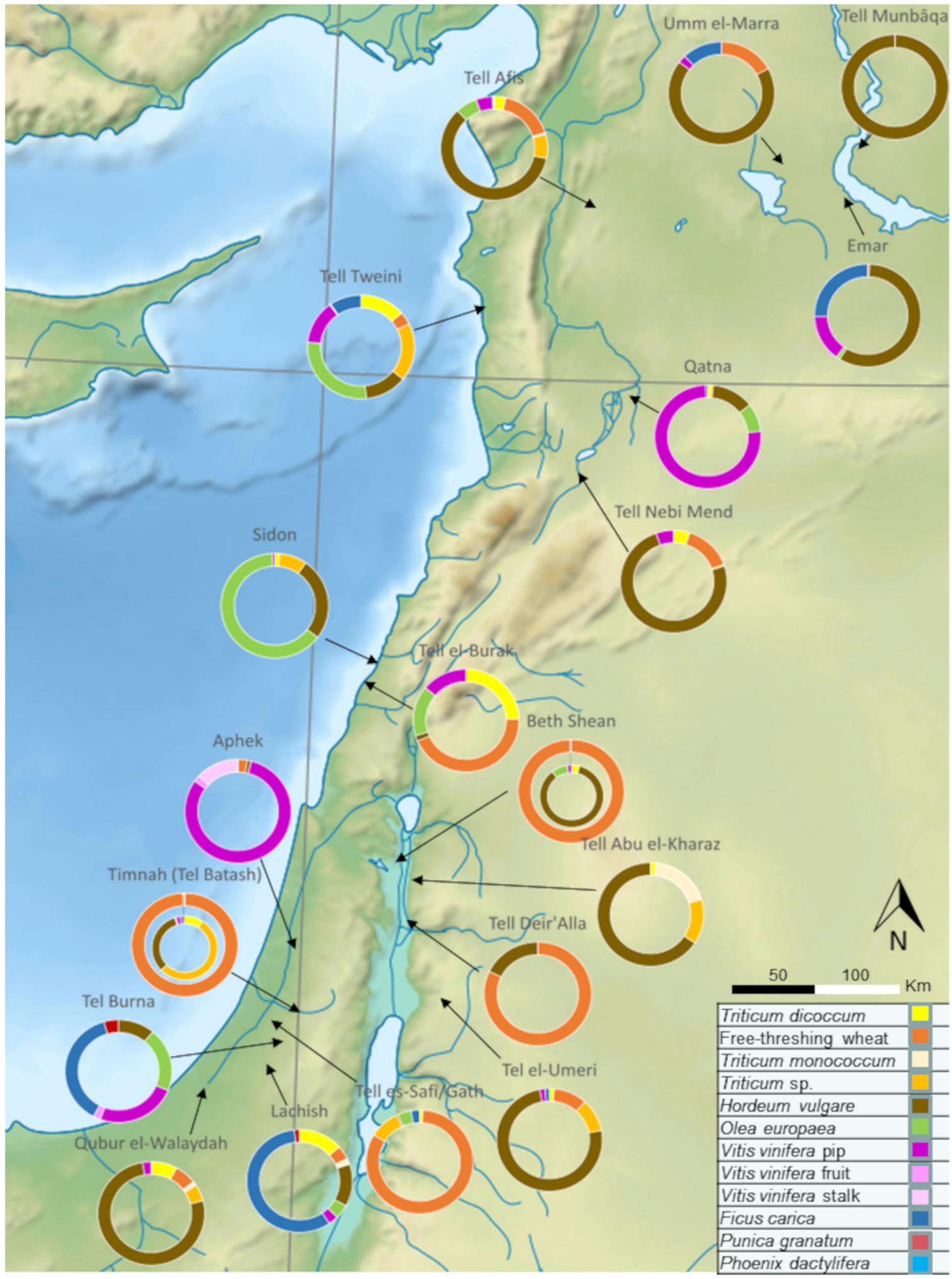

Fig. 9 LBA botanical assemblages of Levant sites used in the CA

The presence of mineralized grape seeds concentrated in locus 3269 where vessels and evidence of mudbrick collapse have been found could be the result of a different type of preservation. The plant material in the sediment, after the shattering of the vessels during the time of the palace collapse, could have been soaked with syringic acid present in the stored wine (Koh et al. 2014). That leaking could have enabled the survival of uncharred seeds, considering that syringic acid intervenes in the plant-soil microorganism interaction (Cheemanapalli et al. 2018).

Similar remarks may be made for the few wild seed taxa that have been found, apart those related to modern intrusions (Fig. 5t), but the finding of *Pistacia* seed in the same locus (L.3269) is significant. Different studies have demonstrated that *Pistacia* fruit, leaves, or mastic could have been used to preserve or add flavor to wine contained in vessels (Hansson and Foley 2008; Stern et al. 2008). There is no guarantee that single findings of *Pistacia* seeds could validate the use of this plant as an additive to stored wine but can support the residue analysis already completed for the site, in which terebinth resin traces, among others, have been found within the jars retrieved in the MBA palace (Koh et al. 2014).

Only few olive pits have been found whole while the vast majority were fragmentary. We can speculate that olives

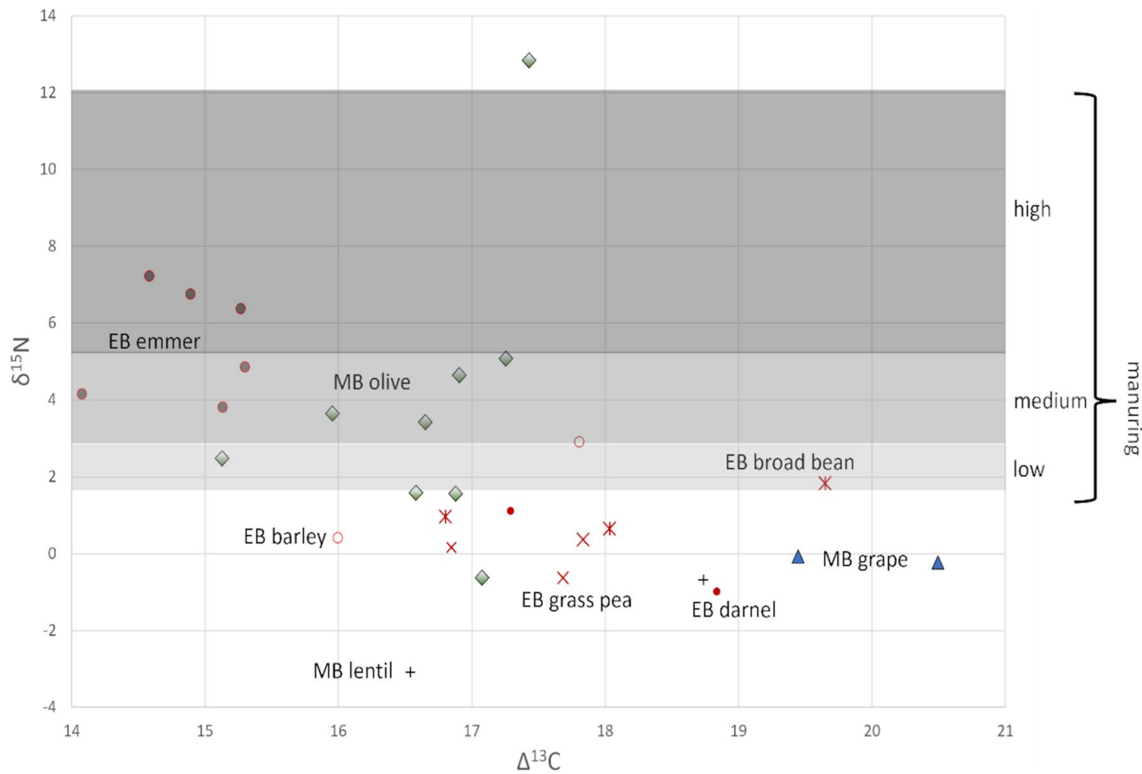

Fig. 10 $\Delta^{13}C/\delta^{15}N$ plot of the different taxa analyzed from Tel Kabri contexts. Manuring levels from Styring et al. (2017) applied to an assumed mean annual precipitation of 500 mm

Fig. 11 In situ jars in L.3264 (Area DW)

were used for oil extraction, if we also consider the great amount of remains retrieved, but without a direct evidence of an oil press we cannot be certain. Nevertheless, it is very likely that these olive pit fragments were used as fuel sources and then discarded together with the other domestic waste found in the area. A great amount of olive charcoal has been identified in Tel Kabri, one of the most abundant taxa in the charcoal assemblage, probably used as fuel sources and partly as building timber (Lorentzen 2023).

Regarding Area L, together with a relatively high quantity of emmer wheat, emmer glume bases were also retrieved, representing the only cereal chaff found in Tel Kabri. Significant in this area is the finding of several legume remains, lentil, grass pea, and faba bean, which could be determined by the different type of context, but it also emphasizes the difference of the EBA botanical assemblage compared to the MBA which will be discussed below. Nevertheless, identical to the other two areas, the most frequent taxon of Area L is olive, although it proportionally plays a limited role compared with the Middle Bronze Age assemblage. Grape pips were also found in this area. The densest soil sample among all the areas in terms of plant remains was recovered in Area L, in a locus composed of dark organic sediment that intercepted a stone installation identified as a storage container or an apsidal house. The plant remains retrieved from this locus might be associated with kitchen waste, confirming the identification of the context. These include large quantities of charred legumes (faba bean, lentils, grass pea), charred cereal seeds (emmer wheat and some barley), and very few fruit remains and wild plant seeds. It is interesting to note the discovery of whole faba bean seeds (Fig. 5g, h), a legume that has been intensively cultivated in the Galilee region since the Neolithic (Caracuta et al. 2015) and that, thanks to the easy access to the springs (it is required a constant amount of water) around the tell, could have been farmed in Tel Kabri during the EBA.

Noteworthy is also the presence of chaff remains in Area L, in comparison to their total absence in the palace area. Area L, a domestic context, has provided the finding of three emmer wheat glume base (Fig. 5c). They have been mostly found in a locus which is part of a colluvial deposit, together with a great number of olive stones and four seeds of jujube (Fig. 5o, p).

The Christ's Thorn Jujube grows nowadays in all valleys and lowlands of Israel, to an elevation of below a.s.l. 500 m. It is still very common in the coastal regions including Galilee and inland Lower Galilee (Danin and Fragman 2016). The tree is still particularly valued by the local population as the fruits are edible and can be dried or used as fodder; furthermore, the trunk is considered for its high-quality charcoal (Dafni et al. 2005). The utilization of jujube has been testified in the region since Palaeolithic as the finding of this plant remains in the archaeological sites of Ohalo II at the Sea of Galilee demonstrates (Weiss 2017).

A diachronic consideration of crop plant distribution and proportions

EBA

Pattern searching using correspondence analysis shows that the botanical assemblages of Tel Kabri, during both the EBA and MBA, are closely associated with the cultivation of olive and grape, but with a stronger association to olive in the MBA contexts (Fig. 6) which is well reflected in the ubiquities of the different crop taxa (Table 1). In these contexts, in addition to olive charcoal mentioned before, grape vine has also been identified (Lorentzen 2023), proving the importance of these crops for Tel Kabri.

Fruit tree proportions are generally more prominent in the EBA sites of the southern Levant, whereas in the North barley proportions are remarkably higher in the inland sites, in particular (Fig. 7). Olive is typical of the Mediterranean climate, characterized by dry summers and cool, but frost-free, winters, corresponding to the Mediterranean Sea coasts up to ca. 200 m. It can also tolerate arid conditions (Sofo et al. 2008). However, for increasing fruit production, mean annual precipitation of at least 600 mm or irrigation is required (Riehl 2009).

The presence of grape is also remarkable, a manifestation of the intensive horticulture that is prominent in this period. Both vineyards and olive orchards testify long-term agricultural planning as they require 3–8 years before bearing fruits and they would need 10–20 years for being fully productive (Fall et al. 2002). Regarding vineyards, a certain degree of soil moisture is recommended for a good harvest, and, unlike olive, it does not tolerate drought conditions for prolonged periods. In the EBA, it was cultivated mainly in areas with modern mean annual precipitation of above 400 mm (Riehl 2008).

In both the northern and the southern Levantine assemblages, barley is often dominating the EBA cereal assemblages, in the south particularly in those along the Jordan valley. Emmer is also present in most assemblages, but with higher proportions concentrating in the coastal region. The proportions of emmer wheat in the Levant assemblages start decreasing in later periods in favor of free threshing wheat. It is still present in MBA and LBA sites especially in the Southern Levant, in some cases even in high proportions (e.g., Tel Lachish, Nicoli' et al. 2022). This crop preference has been associated with the influence of the Egyptian political power on these sites, since in Egypt emmer remained the main cereal crop species until the Graeco-Roman period and was used in bread and beer production together with barley (Nesbitt and Samuel 1996).

In the CA biplot, the EBA botanical assemblage from Tel Kabri seems to be closely associated with other EBA sites. The first one is Bab'edh Dhra. The site is located near the Dead Sea in modern-day Jordan. The assemblage of Bab'edh Dhra is heavily dominated by fruit taxa, fig, and grape as well as a few olive remains (Figs. 6 and 7; McCreery 1979, 2003). Even though the arid environmental background of the area around the Dead Sea with a low average of rainfall per year, Bab'edh Dhra had easy access to springs that allowed continuous irrigation of crops permitting a whole year yield. Moreover, thanks to its location in a low valley, it was made a virtual greenhouse which offered mild winter periods (McCreery 2011).

The ecological setting of this area, offering mitigated winters similar to the coastal regions and with the presence of many springs, similarly to Tel Kabri, differs from territories east and west of Bab'edh Dhra, making it a unique agricultural landscape.

Tell Tweini located in modern Syria is another site closely associated with Tel Kabri in the CA graph (Fig. 6). It presents similar botanical assemblages and environmental characteristics as Tel Kabri. The settlement is in fact situated at a short distance from the Mediterranean Sea (1.5 km) with different freshwater sources around the mound and a mean annual precipitation that can reach 600–1000 mm (Linseele et al. 2019). Olive is the main crop at the site during the EBA (Fig. 7) followed by emmer, which is constantly present in

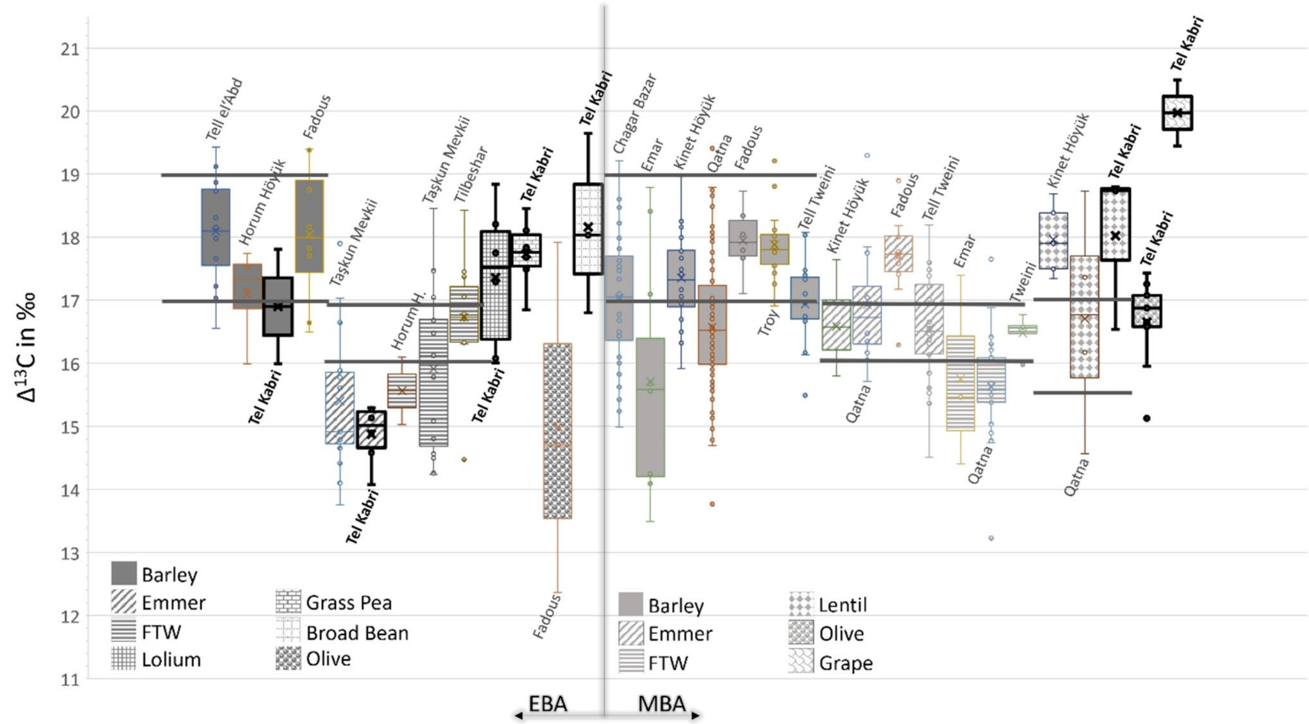

Fig. 12 $\Delta^{13}C$ values of different crop species from a number of Near Eastern archaeological sites of the Early and Middle Bronze Ages. The gray lines indicate the species individual ranges between no stress signal (values above the upper lines), moderate stress (values between both lines), and increased drought stress (values below lower lines). Note that these ranges are only available for the cereals and lentil

later periods. Grape remains are also present but in smaller quantities.

Another site closely associated with EBA Tel Kabri in the CA plot is Tell Fadous-Kfarabida. The site, located on the coast in modern day Lebanon, is approximately 143 km north of Tel Kabri. Similar to the EBA assemblage in Tel Kabri, the seed records of Tell Fadous-Kfarabida are dominated by olive remains with an ubiquity in the samples close to 100% (Figs. 6 and 7, Riehl and Deckers 2009). Emmer is also very abundant in the botanical assemblage, which also include other crops in small numbers: barley, lentil, fig, free-threshing wheat, and grape. No moisture indicators were found in the wild plant assemblage, demonstrating that irrigation in Tell Fadous-Kfarabida was probably not practiced, nor were crops cultivated near freshwater sources. Comparing the available stable isotope data for barley from Tel Kabri and Tell Fadous-Kfarabida (Figs. 12 and 13), the barley from Tel Kabri seems to have experienced some drought stress, whereas at Tell Fadous-Kfarabida no stress is indicated. The nitrogen levels for barley are, in contrast to the $\Delta^{13}C$ values, similarly low at both sites.

In terms of water availability at Tel Kabri and the role of the nearby springs for agricultural production, $\Delta^{13}C$ values suggest that water availability for crop species was variable, indicating particular drought stress for emmer wheat, which was probably also unirrigated (Fig. 12). Intersite comparison of the $\Delta^{13}C$ values in various crop species indicates considerably higher drought stress for barley and emmer wheat at Tel Kabri than can be noted for other sites. Drought stress signals are even stronger at Tel Kabri than at Tell el'Abd, today flooded in Lake Assad, and where barley despite low precipitation (ca. 200 mm) did not suffer any drought stress probably due to irrigation or cultivation near the fluvial catchment area (Riehl 2019). The legume remains at Tel Kabri, in contrast, do not show any stress signals. Even though there are only few comparative data for legumes (e.g., Styring et al. 2017), grass pea, broad bean, and lentil show similar ranges in $\Delta^{13}C$.

Interestingly, emmer appears to have been a manured crop at Tel Kabri, given its relatively high $\delta^{15}N$ compared to the other crops retrieved from the site (Figs. 10 and 13).

The interpretation of $\delta^{15}N$ values as indicators for manuring requires a deeper consideration, taking into account the fact that foliar $\delta^{15}N$ increases with decreasing mean annual precipitation (Craine et al. 2009; Wang et al. 2014). A possible interpretation of the high $\delta^{15}N$ values for emmer in Tel Kabri might be drought-released, which may be supported by the $\Delta^{13}C$ values. These indeed indicate drought-stress, but since the ancient precipitation ranges are unknown, it is difficult to assess to which degree nitrogen levels in emmer

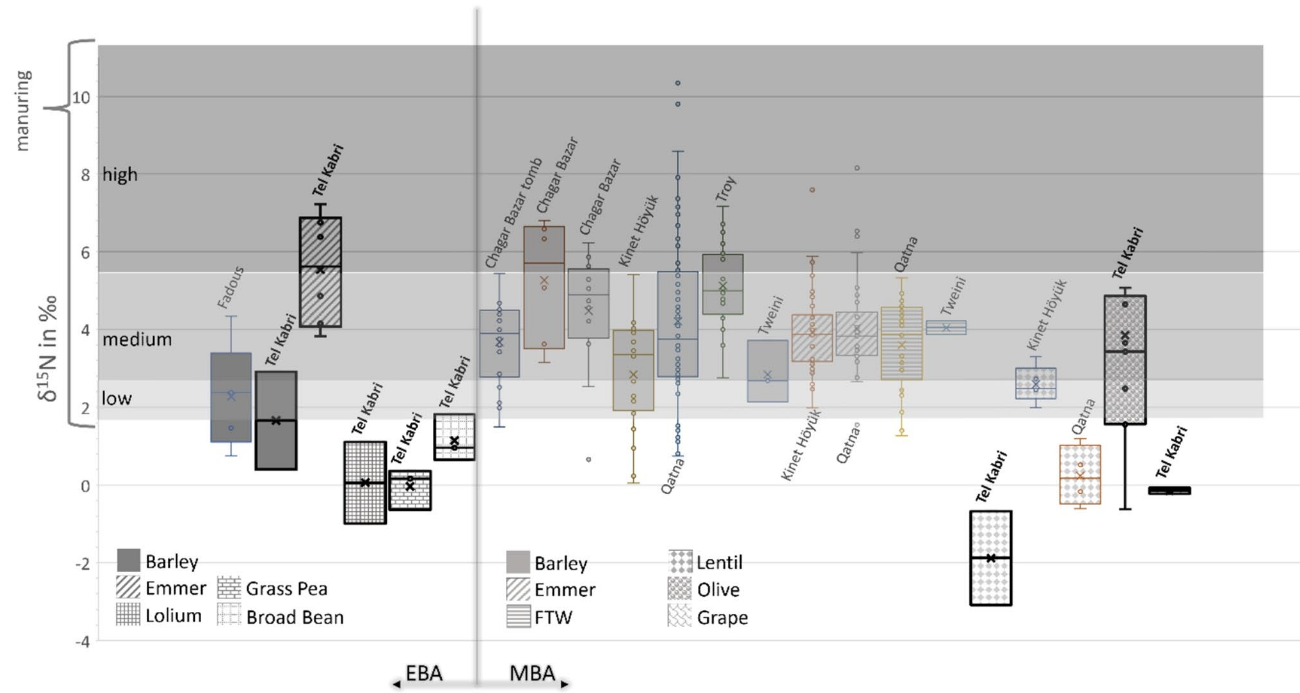

Fig. 13 $\delta^{15}N$ values of different crop species from several Near Eastern archaeological sites of the Early and Middle Bronze Ages

from Tel Kabri might have been elevated through aridity. Styring et al. (2017) propose a model for the relationship between cereal grain $\delta^{15}N$ values from different manuring levels and mean annual precipitation ranges. Modern mean annual precipitation at Nahariya is 511 mm (weather-stats.com, 11.11.2021) and applying this value to the model by Styring et al. (2017), it produces the ranges for manuring indicated as gray-shaded bands in Figs. 10 and 13, still placing the emmer from Tel Kabri into a field of medium to high manure input. This raises the question why emmer might have been manured and simultaneously relinquished under high impact of aridity. Multiple scenarios are possible. If we assume that all crop species in Tel Kabri were cultivated in the closer region around the tell, it is also possible that emmer was growing unirrigated away from natural resources and indirectly manured by browsing ruminants. An alternative interpretation is that emmer was cultivated further away from the site and brought to the city or simply grew during a drier year and is the result of that single harvest.

Other crops, legumes, grape, and probably also barley were not manured as indicated by $\delta^{15}N$ values below 2‰, whereas $\delta^{15}N$ values for olive are highly variable (Fig. 13). High variability of $\delta^{15}N$ values in olive pits has been interpreted to indicate manuring, in contrast to low variability in unmanured crops (Vignola et al. 2017), but this might alternatively be due to the longer period in which olive fruits develop compared to the other crops or because they may have arrived from a variety of different cultivation plots and thereby reflect different soil conditions. The economic role of different agricultural land use zones in past agricultural systems has been discussed for Iron Age Ashkelon (Faust and Weiss 2005) but may have also been practiced in earlier times.

Considering the $\delta^{15}N$ crop record from Tel Kabri in the wider regional comparison, apart the mentioned Tell Fadous-Kfarabida, the lack of stable nitrogen measurements from other Levantine sites limits an extensive direct comparison of the same crop species.

A striking pattern of the crop assemblages from Tel Kabri are the high number as well as high ubiquities of legumes in EBA contexts which are in strong contrast to the low numbers and ubiquities in the MBA. As previously mentioned, it is noteworthy that faba beans have been found solely in the EBA contexts; meanwhile, bitter vetch starts appearing only in the MBA samples. Overall, starting from the MBA, the ubiquity of bitter vetch increases in all the Near Eastern sites, as a drought-resistant species adapting better to the new climatic condition (Riehl 2009). As generally considered a fodder food, the increase in bitter vetch could also indicate an increased need of animal feed for this period. However, since it has been regularly found in households' contexts and storages, we cannot be certain of its solely purpose as fodder crop until later periods.

MBA

The MBA Tel Kabri assemblage in the CA biplot is located in the first quadrant, creating a cluster with most of the other MBA sites of the southern Levant. During the MBA, barley keeps being a regular presence in the Levantine assemblages; meanwhile, the presence and frequency of emmer in the southern Levant are reduced (Fig. 8).

As the CA graph shows, Shiloh, approximately 105 km SSE of Tel Kabri in an area of around 500-mm mean annual rainfall, is a site with close affinities in terms of taxa composition and abundances (Fig. 6). Tel Kabri and Shiloh share a prominence of olive with a focus on other fruits, including grape, but are different in their dominant cereal species (Kislev 1993). The western section of the Samarian hills, where Shiloh is located (Fig. 8), is, likewise Tel Kabri, rich in springs (Cohen 2009) that may have supported fruit tree cultivation.

Beth Shean, located 65 km SSE of Tel Kabri, is thought to have been a center of trade comprising the import of crops during the Middle Bronze Age. This was proved by the presence in the botanical assemblage of wild plants species originating from other regions, including the adjacent Jezreel Valley and the fertile fields of Gilead, such as *Pistacia atlantica* and *Valerianella muricata* (Simchoni et al. 2007). Taking also into consideration that the valley around the site is poor in ground water supply, the lack of evidence of plants distinctive of irrigated field provides further support to their argument (Maeir 2016; Simchoni et al. 2007). Cereals are the main crops at Beth-Shean, free-threshing wheat followed by barley, but a small number of fruits, olive, and grapes, were also found in the MBA assemblage.

The MBA assemblage of Tel Lachish, 162 km south of Tel Kabri, also belongs to a palatial area (Nicoli' et al. 2022). No natural springs are present around Tel Lachish, except for a seasonal stream. Similar to Tel Kabri, olive has been identified as the most ubiquitous crop, but here it is followed by barley. It is during the LBA that we have an increase of species at Tel Lachish, but fruit cultivation was already present during the MBA (Nicoli' et al. 2022; Helbaek 1958). The presence of fig seeds is considerable in the MBA assemblage of Tel Lachish and in general in all the sites in the southern region (Fig. 8), which seems a phenomenon characterizing this area.

There are few published comparative $\Delta^{13}C$ data available for MBA fruit crop taxa, but those for olive from Tell Tweini (unpublished data) indicate a $\Delta^{13}C$ range between 15.3 and 18‰ with a mean of ca. 16.8‰ which is quite similar to the values for olives at Tel Kabri (Table 4). The MBA assemblage in Tell Tweini is dominated by grape and followed by olive but during this period barley remains have nearly the same proportion as emmer, which was the main cereal crop during the EBA (Linseele et al. 2019, Fig. 8).

Given the strong presence of barley and fig in the southern Levantine settlements of the MBA (Figs. 6 and 8), there may be a relation to the arid event at the end of the EBA (Kagan et al. 2015; Migowski et al. 2006; Langgut et al. 2015), which might have affected the sites considered here and the yield of crops with higher water requirements. Isotope analysis conducted on different crops from northern Levant, in fact, confirms an increased aridity during this time (Riehl 2007; Riehl et al. 2014).

Due to the small stable isotopic assemblage from Tel Kabri, it is problematic to draw any diachronic conclusions. However, integrating the results into the supra-regional diachronic pattern, barley appears indeed to have experienced considerable drought stress in the Middle Bronze Age compared to the Early Bronze Age. In contrast, the opposite can be noted for the wheat species, which has been previously interpreted to represent selective irrigation, possibly to counteract increasingly drier climatic conditions over time (Riehl 2017).

LBA

Regarding the CA patterns for the LBA assemblages, the majority of the southern Levantine sites cluster in the positive part of the second axis, indicating intense fruit tree cultivation through plotting at the outer positive ends of the axes. The patterns are also supported by high percentage proportions of this crop category (Fig. 9).

The southern Levantine LBA settlements are generally distinctive to the previous MBA by high proportions in free-threshing wheat, which partially seems to replace emmer (Nesbitt and Samuel 1996; Riehl et al. 2007). Barley still plays a major role, and in some sites fig is also well-represented. One of the sites, Aphek, drops out from the general pattern through a strong dominance in grape. The site has been characterized by laying in a mesic biome (Olsvig-Whittaker et al. 2015) in a particular fertile plain, providing different remains in the botanical assemblage even though not all the sampled context reflected this grape predominance. A singular locus in Aphek provided an incredible number of grape seeds (pedicels and bunch fragments were recovered as well) that formed pomace, as a result of pressed seeds from wine production. The other remains in the LBA assemblage of Aphek reflect the general south Levantine pattern with a high number of free-threshing wheat, and the presence of barley and fruit tree remains including fig (Kislev and Mahler-Slasky 2009).

Conclusions

As supported by correspondence analysis, the archaeobotanical assemblages from Tel Kabri reflect a regional pattern. A considerable number of olives in large ubiquity is remarkable, reflecting the intensity of its horticulture in the southern Levant already during the EBA. Starting from this period, the cultivation of olive was crucial for the region economy since its oil was easy to store and traded or used as food and lighting resource.

The presence of emmer is notable, being the most ubiquitous cereal in both, the EBA and the MBA periods. The stable isotope measurements indicate that barley and emmer underwent considerably high drought stress in Tel Kabri, particularly critical in the case of emmer. In contrast to other crop species, emmer was likely manured, which raises questions as whether this is due to a strategy of soil fertility maintenance or a result of cultivating the crop on naturally fertile ground, which could also be further away from the site. The latter suggests that the emmer might have been a traded product.

The outcome of the MBA samples of Area DW reflects the palatial context to which they belong: fruit remains and few other crops that have been found in association with dumping and domestic waste context, hardly any wild plants seeds (excluding modern contaminations), and no chaff remains. The storage complexes yielded few botanical remains and most of the grape seeds have been found in a mineralized condition, raising speculations about the presence of unfiltered stored wine in the vessels and seeds that got soaked and preserved thanks to the acid present in the wine.

A different situation is found in Area L and the EBA layers. The rich archaeobotanical material recovered, despite the limited number of samples, reveals a range of horticulture and crops cultivation, with a focus on legumes. In the case of legumes, stable isotope measurements showed no stress signals and the same water availability for all of them. In Area L, various wild taxa have been identified, representing cereal crops weeds such as *Lolium* that may be associated with barley cultivation, as the stable isotope measurements suggest.

Continuous sampling of the EBA and MBA contexts at the site will be crucial for gathering new data concerning the agriculture and crop management of the inhabitants. Once recovered, the new types of contexts, such as residential areas, will provide a broader view of the crop husbandry management at Tel Kabri.

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References

Aguilera M, Araus J L, Voltas J, Rodrıguez-Ariza M O, Molina F, Rovina N, Buxo´ R, Ferrio J P (2008) Stable carbon and nitrogenisotopes and quality traits of fossil cereal grains provide clues on sustainability at the beginnings of Mediterranean agriculture. Rapid Commun Mass Spectrom 22:1,653–1,663

Baeten J, Marinova E, De Laet V, Degryse P, De Vos D, Waelkens M (2012) Faecal biomarker and archaebootanical analyses of sediments from a public latrine shed new light on ruralisation in Sagalassos, Turkey. J Archaeol Sci 39(4):1143–1159

Bar-Matthews M, Ayalon A (2004) Speleothems as paleoclimate indicators, a case study from Soreq cave located in the eastern Mediterranean region, Israel. In: Battarbee RW, Gasse F, Stickley CE (eds) Past Climate Variability through Europe and Africa. Kluwer, Dordrecht, pp 363–391

Bar-Matthews M, Ayalon A (2011) Mid-Holocene climate variations revealed by high-resolution speleothem records from Soreq Cave, Israel and their correlation with cultural changes. Holoc 21:163–171

Bar-Yosef O (1986) The walls of Jericho: an alternative interpretation. Curr Anthr 27:157–162
Bogaard A, Heaton THE, Poulton P, Merbach I (2007) The impact of manuring on nitrogen isotope ratios in cereals: archaeological implications for reconstruction of diet and crop management practices. J Archaeol Sci 34(3):335–343
Borojevic K (2006) The Archaeobotanical Finds. Chapter 27. In: Finkelstein I, Ussishkin D, Halpern B (eds) Megiddo IV. The 1998–2002 Seasons, Monograph Series of the Institute of Archaeology University of Tel-Aviv No. 24, Tel Aviv, pp 519–541
Caracuta V, Barzilai O, Khalaily H, Milevski I, Paz Y, Vardi J, Regev L, Boaretto E (2015) On the onset of faba bean farming in the southern Levant. Sci Rep 5:14370
Charles M, Bogaard A (2001) Third-millennium BC charred plant remains from Tell Brak. In: Oates D, Oates J, McDonald h (eds) Excavations at Tell Brak. Nagar in the third millennium BC, Brit Sch of Arch in Iraq, 2:301–326
Cheemanapalli S, Mopuri R, Golla R, Anuradha CM, Chitta KS (2018) Syringic acid (SA) – a review of its occurrence, biosynthesis, pharmacological and industrial importance. Bio Phar 108:547–557
Colledge S (2003) Plants and people. In: Matthews R (ed) Excavations at Tell Brak. Exploring an upper Mesopotamian regional centre, 1994-1996, McDonald Institute Monographs, vol. 4. Oxbow, Cambridge, pp 389–416.
Craine JM, Elmore AJ, Aidar MPM, Bustamante M, Dawson TE, Hobbie EA, Kahmen A, Mack MC, McLauchlan KK, Michelsen A, Nardoto GB, Pardo LH, Peñuelas J, Reich PB, Schuur EAG, Stock WD, Templer PH, Virginia RA, Welker JM, Wright IJ (2009) Global patterns of foliar nitrogen isotopes and their relationships with climate, mycorrhizal fungi, foliar nutrient concentrations, and nitrogen availability. New Phytol 183:980–992
Cohen H (2009) Middle Bronze Age IIB Rural settlements in the eastern valleys and the desert frontier of Samaria hill country. Ostracon Press, Haifa
Dafni A, Levy S, Ley E (2005) The ethnobotany of Christ's Thorn Jujube (Ziziphus spina-christi) in Israel. J Ethnobio Ethnomed. https://doi.org/10.1186/1746-4269-1-8
Danin A (1992) Flora and vegetation of Israel and adjacent areas. Bocconea 3:18–42
Danin A, Plitmann (1987) Revision of plant geographical territories of Israel and Sinai. Plant Syst Evol 159:43–53
Danin A, Fragman O (2016) Flora of Israel Online. https://flora.org.il/en/plants/. Accessed 30 Jun 2021
De Moulins D (2015) Plant remains from Middle Bronze Age to Iron Age: samples of the College site, Sidon. Archaeol Hist Lebanon 42(43):32–54
DeNiro MJ, Hastorf CA (1985) Alteration of $^{15}N/^{14}N$ and $^{13}C/^{12}C$ ratios of plant matter during the initial stages of diagenesis:studies utilizing archaeological specimens from Peru. Geochim Cosmochim Acta 49:97–115
Falconer E S, Fall L P (2019) Early bronze IV village life in the Jordan Valley: excavations at Tell Abu en-Ni'aj and Dhahret Umm el-Marar, Jordan. Archaeopress, Oxford
Fall PL, Falconer SE, Lines L (2002) agricultural intensification and the secondary products revolution along the Jordan Rift. Hum Ecol 30:445–482
Fall PL, Falconer SE, Porson S (2019) Archaeological inference of intermittent settlement and agriculture at Middle Bronze Age Zahrat adh-Dhra'1, Jordan. J Archeol Sci 26:101884
Faust A, Weiss E (2005) Judah, Philistia, and the Mediterranean World: reconstructing the economic system of the 7th century BC. Bull Am Sch Orient Res 338:71–92
Ferrio JP, Voltas J, Araus JL (2012) A smoothed curve of δ13C of atmospheric CO2 from 16.100 BCE to 2.010 CE. http://web.udl.es/usuaris/x3845331/AIRCO2_LOESS.xls. Accessed Dec 2021
Ferrio JP, Aguilera M, Voltas J, Araus JL (2020) Stable carbon isotopes in archaeological plant remains. In: Montenari M (ed) Stratigraphy & timescales. Academic Press, pp 107–145
Fiorentino G, Ferrio JP, Bogaard A, Araus JA, Riehl S (2014) Stable isotopes in archaeobotanical research. Veget Hist Arch 24:1–13
Fraser R, Bogaard A, Charles M, Styring A K, Wallace M, Jones G, Ditchfield P, Heaton THEH (2013) Assessing natural variation and the effects of charring, burial and pre-treatment on the stable carbon and nitrogen isotope values of archaeobotanical cereal and pulse remains. J Archaeol Sci 40:4,754–4,766
Genz H, Çakirlar C, Damick A, Jastrzebska E, Riehl S, Deckers K, Donkin A (2009) Excavations at Tell Fadous –Kfarabdia: Preliminary report on the 2009 seasons of excavations. Baal 13:71–23
Green F (1979) Phosphatic mineralization of seeds from archaeological sites. J Arch Sci 6(279):284
Hansson MC, Foley BP (2008) Ancient DNA fragments inside Classical Greek amphoras reveal cargo of 2400-year-old shipwreck. J Arch Sci 35:1169–1176
Herveux L (2004) Étude archéobotanique préliminaire de tell al-Rawda, site de la fin du Bronze ancien en Syrie intériere. Akkadica 125:79–91
Holden TG (1994) The charred plant remains from Tell Abu Kharaz In The Jordan Valley (AOC 1010, unpubl., Edinburgh)
Holden T (1999) The plant remains from Tell Esh-Shuna North, Jordan Valley
Hopf M (1978) Plant remains, strata V-I. In: Amiran R (ed), Early Arad I, the Chalcolithic settlement and early Bronze city. First-Fifth Season of Excavations, 1962–1966. Israel Exploration Society, Jerusalem, pp 64–82
Hopf M (1983) Jericho plant remains. In: Kenyon KM, Holland TA (eds) Excavations at Jericho, vol The. pottery phases of the Tell and other finds. British school of Archeology in Jerusalem, London, pp 576–621
Horowitz A (2002) Chapter 2: the natural environment. In: Kempinski A (ed) Tel Kabri: The 1986 1993 excavations seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv, pp 7–14
Helbaek H (1958) Plant economy in ancient Lachish in Tufnell O, Lachish, vol 4. The Wellcome Archaeological Research Expedition to the Near East, London, pp 309–317
Jacomet S (2006) Identification of cereal remains from archaeological sites. 2nd edition. IPNA, Basel
Jones G (1991) Numerical analysis in archaeobotany. In: Wasylikowa K, Behre K-E (eds) Van Zeist W. Progress in old world palaeoethnobotany, Rotterdam, pp 63–80
Jones G, Bogaard A, Charles M, Hodgson JG (2000) Distinguishing the effects of agricultural practices relating to fertility and disturbance: a functional ecological approach in archaeobotany. J Arch Sci 27:1073–1084
Jongman RH, ter Braak JF, van Tongeren OFR (1995) Data analysis and community and landscape ecology. Cambridge University Press, Cambridge
Kagan EJ, Langgut D, Boaretto E, Neumann F (2015) Dead Sea levels during the Bronze and Iron Ages. Radiocarbon 57:237–252
Kempinski A (2002) Tel Kabri: The 1986–1993 excavations seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv
Kislev ME (1993) Food remains. In: Finkelstein I, Bunimovich S, Lederman Z (eds) Shiloh: the archaeology of a biblical site. Monograph Series of the Institute of Archaeology Tel Aviv University No. 10, Tel Aviv, pp 354–361
Kislev ME (1998) The relative impact of pig husbandry versus goat browsing on ancient oak forests in Israel. In: Edelstein G, Milevski I, Aurant S (eds) The Rephaim Valley Project. Villages, terraces, and stone mounds. Excavations at Manahat, Jerusalem, 1987–1989. Israel Antiquities Authority Reports, vol. 3, Jerusalem, pp 113–118

Kislev ME, Mahler-Slasky Y (2009) Food remains. In: Gadot Y, Yadin E (eds) Aphek-Antipatris II The remains in the Acropolis. Tel Aviv University, Tel Aviv, pp 499–525

Kislev ME, Melamed Y, Langsam Y (2006) Plant remains from Tel Batash. In: Panitz-Cohen N, Mazar A (eds) Timnah (Tel Batash) III: The finds from the second Millennium BCE. Qedem 45, Hebrew University of Jerusalem, Jerusalem, pp 295–310

Kislev ME, Simchoni O, Melamed Y, Maroz L (2009) Botanical remains: food and industrial crops. In: Panitz-Cohen N, Mazar A (eds) Excavation at Tell Beth-Shean 1989–1996, vol 3. The Israel Exploration Society and the Institute of Archaeology. The Hebrew University, Jerusalem, pp 764–771

Koh AJ, Yasur-Landau A, Cline EH (2014) Characterizing a Middle Bronze palatial wine cellar from Tel Kabri, Israel. PLoS ONE 9:1–15

Küster H (1989) Bronzezeitliche Pflanzenreste aus Tall Munbaqa. Mitt Dtsch Orient-Gesellschaft Zu Berlin 121:85–91

Langgut D, Finkelstein I, Litt T (2013) Climate and the late bronze collapse: new evidence from the Southern Levant. J Inst Archaeol Tel Aviv 40:149–175

Langgut D, Finkelstein I, Neumann F, Stein M (2015) Vegetation and climate changes during the Bronze and Iron ages (~3600-600 BCE) in the Southern Levant based on palynological records. Radocarb 57:217–235

Langgut D, Adams MJ, Finkelstein I (2016) Climate, settlement patterns and olive horticulture in the southern Levant during the Early Bronze and Intermediate Bronze Ages (ca. 3600–1950 BCE). Lev 48:117–134

Lazar M, Cline EH, Nickelsberg R, Shahack-Gross R, Yasur-Landau A (2020) Earthquake damage as a catalyst to abandonment of a Middle Bronze Age settlement: Tel Kabri, Israel. PLoS One 15(9):e0239079 https://doi.org/10.1371/journal.pone.0239079

Leps J, Smilauer P (2014) Multivariate Analysis of Ecological Data using CANOCO, Cambridge

Linseele V, Marinova E, De Cupere B, van der Valk J, Vandorpe P, Van Neer W (2019) Bronze and Iron Age Paleo-Economy in a changing environment. The bioarchaelogy of Tell Tweini, on the Northern Levantine coast. In Bretschneider J, Jans G (eds) About Tell Tweini (Syria): artefacts, ecofacts and landscape. Leuven, pp. 417–617

Liphschitz N (1989) Plant economy and diet in the Early Bronze Age in Israel: a summary of present research. L'urbanisation de la Palestine a l'age du Bronze ancien. Bilan et perspectives des recherches actuelles. P. d. Miroschedji, Oxford, 527:269–277

Liphschitz N (1993) Chapter 16. Palaeobotanical remains. In: Finkelstein I, Bunimovitz S, Lederman Z (eds.) Shiloh. The archaeology of a biblical site, Tel Aviv, pp. 351-353

Liphschitz N (2002) The paleobotanical remains. In: Kempinksi A (2002) Tel Kabri. The 1986–1993 excavation seasons. Emery and Clare Yass publications in Archaeology, Tel Aviv, pp 428–434

Litt T, Ohlwein C, Neumann FH, Hense A, Stein M (2012) Holocene climate variability in the Levant from the Dead Sea pollen record. Quat Sci Rev 49:95–105

Lorentzen B (2023) Ancient wood remains. In: Cline EH, Rarzlaff A, Yasur-Landau A (eds) Excavations at Tel Kabri III: The 2023 to 2019 Seasons. Brill, Leiden

Maeir, A M (2016) Preprint of: Chapter 1: the Beth-Shean Valley: geographical and environmental background. In Mazar A, Panitz-Cohen N (eds) Excavations at Tel Rehov, 1997–2012. Vol. 1, Jerusalem, pp. 1–11

Mahler-Slasky Y, Kislev M (2012) Preliminary archaeobotanical research at Tell es-Safi/Gath: The 1997–2002 Seasons. In: Maeir A (ed) Tell es-Safi/Gath I: Report on the 1996–2005 Seasons, Ägypten und Alten Testament 69, Wiesbaden, pp. 579–588

Marom N, Yasur-Landau A, Cline EH (2015) The silent coast: zooarchaeological evidence to the development trajectory of a second millennium palace at Tel Kabri. J Anthropol Archaeol 39(181):192

Matilla Séiquer G, Rivera Núñez D (1994) Estudio paleoetnobotánico de Tell Qara Quzaq-I. In: Del Olmo Lete G (ed) Tell Qara Quzaq-I. Campañas I-III (1989–1991), Editorial Ausa: Barcelona, 4:151–182

Matthews W (2010) Geoarchaeology and taphonomy of plant remains and microarchaeological residues in early urban environments in the Ancient Near East. Quat Int 214(1–2):98–113

McCreery DW (1979) Flotation of the Bab edh-Dhra and Numeira plant remains. Ann Am Schools Orient Res 46:165–169

McCreery DW (2003) The Paleoethnobotany of Bab Edh-Dhra. In Rast W, Schaub RT (eds) Bâb edh-Dhrâ': Excavations at the Town Site (1975–1981), Winona Lake, pp. 449–463

McCreery DW (2011) Agriculture and Religion at Bab edh-Dhra and Numeira during the Early Bronze Age. In Chesson MS (ed) Daily life, materiality and complexity in early urban communities of the southern Levant, State College, pp. 77–87

McCobb LME, Briggs DEG (2001) Preservation of Fossil Seeds From a 10th Century AD Cess Pit at Coppergate, York. J Archaeol Sci 28:929–940

McCorriston J (1995) Preliminary archaeobotanical analysis in the Middle Habur valley, Syria and studies of socioeconomic change in the early third millennium BC. Bull Can Soc Meso Stud 29:33–46

Metzger MC (1984) Preliminary report of the first season of the Tell el-Hayyat Project. (Faunal and floral remains at Tell el-Hayyat. Preliminary results.). Bull Am Sch Orient Res 255:68–70

Migowski C, Stein M, Prasad S, Negendank JFW (2006) Holocene climate variability and cultural evolution in the near east from the Dead Sea sedimentary record. Quat Res 66:421–431

Miller N F (1997) Sweyhat and Hajji Ibrahim: some archaeobotanical samples from the 1991 and 1993 seasons. In: Zettler RL (ed) Subsistence and settlement in a marginal environment: Tell es-Sweyhat, 1989 – 1995, Masca 14:95–122

Miller NF, Schwartz GM et al (2000) Plant remains. Am J Arch 104:438–447

Moffett L (1989) Appendix. Early Bronze Age plant remains from Tell Nebi Mend. A preliminary report. Lev 21:29–32

Neef R, Cappers RTJ, Bekker RM (2012) Digital atlas of economic plants in archaeology. Barkhuis, Groningen

Nesbitt M (2008) Identification guide for Near Eastern grass seeds. Routledge, London

Nesbitt M, Samuel D (1996) From staple crop to extinction? The archaeology and history of hulled wheats. In: Paludosi S, Hammer K, Heller J (eds) Hulled wheats. Proceedings of the first International Workshop on Hulled Wheats, 21-22 July 1995, Castelvecchio Pascoli, Tuscany, Italy. (Promoting the conservation and use of underutilized and neglected crops 4) International Plant Genetic Resources Institute, Rome, pp 41-100

Nicoli' M, Riehl S, Webster L, Streit K, Höflmayer F (2022) Agricultural resources in the Bronze Age city of Tel Lachish, Veget Hist Archaeobothttps://doi.org/10.1007/s00334-022-00873-2

Orendi A (2020) Flax cultivation in the southern levant and its development during the Bronze and iron age. Quat Int 545:63–72

Orendi A, Deckers K (2018) Agricultural resources on the coastal plain of Sidon during the Late Iron Age: archaeobotanical investigations at Phoenician Tell el Burak, Lebanon. Veg Hist Archaeobot 27:717e736 https://doi.org/10.1007/s00334-018-0667-x

Orendi A, Smejda L, McKinny C, Cassuto D, Sharp C, Shai I (2017) The agricultural landscape of Tel Burna: ecology and economy of a Bronze Age/Iron Age settlement in the Southern Levant. J Land Econ 10(3):165–188

Olsvig-Whittaker L, Maeir A, Weiss E, Frumin S, Ackermann O, Horwitz LK (2015) Ecology of the Past – Late Bronze and Iron Age Landscapes, People and Climate Change in Philistia (The Southern Coastal Plain and Shephelah). Israel. J Mediterranean Ecol 13:57–75

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. PhD, University of Paris I

Post GE (1980 rep.) Flora of Syria, Palestine and Sinai. Syrian protestant college, Beirut

Prausnitz MW (1959) Kabri. Israel Explor J 9:268–269

Prausnitz MW (1969) The excavations at Kabri. Eretz-Israel 9:122–129

Prausnitz MW, Kempinski A (1977) Kabri 1976. Israel Explor J 27:165–166

Ramsay JH, Mueller N (2016) Telling seeds: archaeobotanical investigations at Tall al-'Umayri, Jordan. In: McGeough K (ed) The Archaeology of Agro-Pastoralist Economies in Jordan. Oxbow Books, Boston, pp 1–16

Riehl S (1999) Bronze Age environment and economy in the Troad: the archaeobotany of Kumtepe and Troy. Mo Vince, Tübingen

Riehl S (2000) Erste Ergebnisse der archäobotanischen Untersuchungen am Tall Mozan/Urkesh. Mitt Dtsch Orient-Gesellschaft Zu Berlin 132:229–238

Riehl S (2001) Vorbericht der archäobotanischen Bestandsaufnahme in Emar. Baghdader Mitteilungen 32:157–172

Riehl S (2004) Archaeobotany at the Early Bronze Age settlement of Hirbet ez-Zeraqon: a preliminary report. Z Dtsch Palästina-Vereins 120(2):102–122

Riehl S (2007) Preliminary archaeobotanical results from the palace at Qatna (Tell Mishrifeh). In: Bonacossi D M (ed) Urban and natural landscapes of an ancient Syrian capital. Settlement and Environment at Tell Mishrifeh/Qatna and in Central-Western Syria. Studi archeologici su Qatna 1, Forum, Udine, pp 145–152

Riehl S (2008) Climate and agriculture in the ancient Near East: a synthesis of the archaeobotanical and stable carbon isotope evidence. Veg Hist Arch 17:S43–S51

Riehl S (2009) Archaeobotanical evidence for the interrelationship of agricultural decision-making and climate change in the ancient Near East. Quat Int 197:93–114

Riehl S (2010) Funde aus der Kampagne 2009 in Qubur al Walaydah. Welt Orients 40:259–267

Riehl S, Deckers K (2009) The botanical finds from the 2007 and 2008 seasons of excavations. In: Genz H (ed) Excavations at Tell Fadous – Kfarabida: Preliminary report on the 2009 seasons of excavations, vol. 13. BAAL, Beirut, pp. 110–116

Riehl S (2017) Regional environments and human perception: The two most important variables in adaptation to climate change. In: Höflmayer F (ed) The late third millennium in the ancient Near East: Chronology, C14, and climate change. The Oriental Institute of the University of Chicago, Chicago, Illinois, pp 237–260

Riehl S (2019) Resource management at Tell el-'Abd. Economic specialization despite or because of environmental limitations? (ch. 12). In: Finkbeiner U (ed) Final reports of the Syrian German excavations at Tell el-'Abd. Zaphon, Münster, pp 169–185

Riehl S (2020) Stable isotopes in ancient agriculture (ch.4). In: Hollander D and Howe T (eds.) A companion to ancient agriculture. John Wiley & Sons, Hoboken

Riehl S, Bryson R, Pustovoytov K (2007) Changing growing conditions for crops during the Near Eastern Bronze Age (3000–1200 BC): the stable carbon isotope evidence. J Archaeol Sci 35:1011–1022

Riehl S, Pustovoytov KE, Weippert H, Klett S, Hole F (2014) Drought stress variability in ancient Near Eastern agricultural systems evidenced by δ13C in barley grain. Proc Natl Acad Sci 111:12348–12353

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. Veg Hist Archaeobotany 17(Suppl 1):S53–S61

Schiebel V, Litt T (2017) Holocene vegetation history of the southern Levant based on pollen record from Lake Kinneret (Sea of Galilee), Israel. Veg Hist Arch 27:577–590

Schilman B, Ayalon A, Bar-Matthews M, Kagan EJ, Almogi Labin A (2002) Sea-land paleoclimate correlation in the Eastern Mediterranean region during the Late Holocene. Isr J Earth Sci 51:181–190

Shalem D (2009) Results of a salvage excavation at Tel Kabri. Atiqot 61:19–39

Simchoni O, Kislev ME, Melamed Y (2007) Botanical remains: Beth-Shean as a trade center for crops in the bronze age, botanical and entomological evidence. In: Mazar A, Mullins RA (eds) Excavation at Tell Beth-Shean 1989–1996, vol 2. Israel Exploration Society and the Hebrew University of Jerusalem, Jerusalem, pp 702–715

Sofo A, Manfreda S, Fiorentino M, Dichio B, Xiloyannis C (2008) The olive tree: a paradigm for drought tolerance in Mediterranean climates. Hydrol Earth Syst Sci 12:293–301

Smith A (2005) Climate, culture, and agriculture: examining change in the Near East during the Bronze and Iron Ages. PhD, Boston University

Smith A, Munro ND (2009) A holistic approach to examining ancient agriculture: a case study from the Bronze and Iron Age Near East. Curr Anthrop 50:925–936

Smithline H (2007) Tel Kabri Final Report, Hadashot Arkheologiyot, (www.hadashot-esi.org.il). Accessed Dec 2021

Stekelis M (1958) An obsidian core found at Kibbutz Kabri, Eretz-Israel, vol. 5, pp 35–37

Stern B, Heron C, Tellefsen T, Serpico M (2008) New investigations into the Uluburun resin cargo. J Arch Sci 35:2188–2203

Styring A, Manning H, Fraser R, Wallace M, Jones G, Charles M, Heaton THE, Bogaard A, Evershed RP (2013) The effect of charring and burial on the biochemical composition of cereal grains: investigating the integrity of archaeological plant mate-rial. J Archaeol Sci 40:4,767–4,779

Styring AK, Charles M, Fantone F, Hald MM, McMahon A, Meadow RH, Nicholls GK, Patel AK, Pitre MC, Smith A, Sołtysiak A, Stein G, Weber JA, Weiss H, Bogaard A (2017) Isotope evidence for agricultural extensification reveals how the world's first cities were fed. Nat Plants 3:17076

Tsuk T (2002) Chapter 3: The springs of Kabri. In: Kempinski A (ed) Tel Kabri: The 1986–1993 excavations seasons, Tel Aviv, pp. 15–18

Vaiglova P, Snoeck C, Nitsch E, Bogaard A, Lee-Thorp J (2014) Impact of contamination and pretreatment on stable carbon and nitrogen isotopic composition of charred plant remains. Rapid Commun Mass Spectrom. https://doi.org/10.1002/rcm.7044

Van Zeist W (1999/2000) Third to first millennium BC plant cultivation on the Khabur, Northeastern Syria. Palaeohist 41/42:111–125

Van Zeist W, Heeres JAH (1973) Paleobotanical studies of Deir 'Alla, Jordan. Paléorient 1:21–37

Van Zeist W, Bakker-Heeres JAH (1985) Archaeobotanical studies in the Levant 4. Bronze Age sites on the north Syrian Euphrates. Palaeohis 27:247–316

Van Zeist W, Waterbolk-van Rooijen W et al (1988) Some notes on the plant husbandry of Tell Hammam et-Turkmen. Hammam et-Turkmen. Report of the University of Amsterdam's 1981 84 excavations in Syria II. M. N. van Loon. Nederlands Historisch-Archeologisch Instituut te Istanbul, Istanbul, 705–715

Vermeersch S, Riehl S, Starkovich BM, Kamlah J (2021) Developments in subsistence during the Early Bronze Age through the Iron Age in the southern and central Levant: Integration of faunal and botanical remains using multivariate statistics. Quat Sci Rev 253:1–20

Vignola C, Masi A, Balossi Restelli F, Frangipane M, Marzaioli F, Passariello I, Stellato L, Terrasi F, Sadori L (2017) δ13C and δ15N from 14C-AMS dated cereal grains reveal agricultural practices during 4300–2000BC at Arslantepe (Turkey). Rev Palaeobot Palynol 247(164):174

Wachter-Sarkady C (1998) Archaeobotanical investigations. In: Cecchini SM, Mazzoni S (eds) Tell Afis (Siria). Scavi sull'acropoli 1988–1992. ETS, Pisa, pp 451–480

Wachter-Sarkady C (2013) Consuming plants. Archaeobotanical samples from royal palace G and building P4. In: Matthiae P, Marchetti N (eds) Ebla and its landscapes. Early state formation in the Ancient near east. Routledge, New York, pp 459–462

Wang C, Wang X, Liu D, Wu H, Lü X, Fang Y, Cheng W, Luo W, Jiang P, Shi J, Yin H, Zhou J, Han X, Bai E (2014) Aridity threshold in controlling ecosystem nitrogen cycling in arid and semi-arid grasslands. Nat Commun 5:4799

Weiss E (2017) Palaeolithic Vegetal diet in the Southern Levant. In: Enzel Y, Bar-Yosef O (eds) Quaternary of the Levant: environments, climate change and humans. Cambridge University Press, Cambridge, pp 329–335

White CE, Miller NF (2018) The archaeobotany of grape and wine in Hittite Anatolia. Die Welt Des Orients 48:209–224

White CE, Chesson MS, Schaub T (2014) A recipe for disaster: emerging urbanism and unsustainable plant economies at Early Bronze Age Ras an-Numayra, Jordan. Antiquity 88(340):363–377

Wilcox G (1992) Archaeobotanical investigations at Pella (1983). In: McNicoll AW, Edwards PC, Hanburz-TenisonJ, Hennessy JB, Potts TF, Smith RH, Walmsley A, Watson P (eds) Pella in Jordan 2. Mediterranean archaeology supplement 2, Sidney, pp 253–256

Yasur-Landau A, Cline E H (2020) Excavation at Tel Kabri. The 2005–2011 Season. Brill, https://doi.org/10.1163/9789004425729

Yasur-Landau A, Cline EH, Koh AJ, Ratzlaff A, Goshen N, Susnow M, Waiman-Barak P, Crandall AM (2018) The wine storage complexes at the Middle Bronze II Palace of Tel Kabri: results of the 2013 and 2015 season. Am J Archaeol 122:309–338

Zohary M (1962) Plant life of Palestine. Wiley & Sons, New York

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Table of Contents

List of Illustrations

Ladislav Čapek

Catarina Karlsson

ANNA MARIA GRASSO, SILVIA D'AQUINO,
ELIGIO VACCA, MARCO NICOLI,
MILENA PRIMAVERA, AND
GIROLAMO FIORENTINO

Innovation: Turning Something Old into Something New. *Vicia faba* var. *major*

▾ **ABSTRACT** The sixteenth century was a period of fundamental change and transformation that revolutionized many aspects of life. Innovations were seen in a range of areas, including agriculture: the Age of Exploration had already started and new plants were being introduced from the New World to the Old. From an archaeobotanical point of view, however, were these innovations exclusively linked to the introduction of new plant species or could they also be attributed to a process of finding ways for 'old' species to fulfil new needs? If so, how can such innovations be identified using plant remains?

This paper attempts to answer these questions with reference to biometric and shape analyses of charred remains of *Vicia faba* (broad bean) specimens (152 seeds) collected from five archaeological sites located in south-east Puglia (Italy) dated to a range of periods. The geographical homogeneity and chronological separation of the data

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are expected to enable recognition of any improvements/enhancements suggested by the shape and/or size of the crop investigated. The data reveal the presence in the analysed assemblage of two different morphotypes, chronologically separated by the twelfth century. A secondary feature is a gradual increase in the cotyledon size of the more recent morphotype. This paper discusses a possible transition period, from the twelfth to the sixteenth centuries, in which selective breeding led to a new faba cultivar (*Vicia faba* var. *major*) in the Salento area.

▾ **KEYWORDS** Faba bean, shape analysis, archaeobotany, agricultural innovation, Salento Peninsula

Introduction

In the last decade, studies of the history of agriculture, rural workers, and rural societies have tended to become increasingly integrated, with the traditional topics of agricultural productivity, crop organization, and ownership patterns seen in relation to social, economic, institutional, ecological, and cultural dynamics.[1] The approach adopted is often comparative,[2] i.e. based on a systematic comparison by theme, dynamics, and chronology of distinct areas. Obviously, this requires a body of data that is not always available for all geographical areas and historical periods, hence the need for further regional studies and the choice of a well-defined field of action as the object of the research.

One theme that often draws the interest of scholars of rural history is that of innovation processes, because they are perceived as elements of rupture with respect to the preceding period. In reality these processes have almost always been gradual, characterized by micro-changes and the adaptation of pre-existing forms to tackle emerging new requirements. Generally speaking, it is only when a series of originally separate improvements to the agricultural system have been accepted and adopted as a whole — with profound economic and social consequences — that macro-variations in the historical record become visible.[3]

Such a situation may have occurred in southern Puglia (Italy) around the late Middle Ages and the beginning of the modern era. The period

1 For a summary see Cristoferi, 'La storia agraria dal medioevo all'età moderna'.

2 Cf. Congost and Luna, 'Agrarian Change and Imperfect Property Emphyteusis in Europe (16th to 19th Centuries)'; Klapste, 'Agrarian Technology in the Medieval Landscape, Agrartechnik in Mittelalterlichen Landschaften'; Thoen and Soens, 'Struggling with the Environment'.

3 Van der Veen, 'Agricultural Innovation', p. 7.

from the mid-fifteenth century onwards saw a reorganization of the Salento sub-region, perhaps driven by its Aragonese rulers who, thanks to the end of their conflicts with the Angevins and the decline of the minor feudal lords, were seeking to re-establish their control over the territory.[4] This reorganization, which took place in a context of a gradual increase in the cultivation of olives (which had begun in the tenth–eleventh centuries) and cereals,[5] led to the abandonment of numerous villages and the foundation of the so-called *Terre Murate* (walled towns), characterized by deliberate urban planning.[6] In addition, many abandoned villages were replaced by the farmsteads known as *masserie*, suggesting that the farmland was not abandoned but rather that there was a transformation in the approach to its management.[7] The tangible consequences of these changes in terms of agrarian production would begin to be seen in the late fifteenth and early sixteenth centuries, with the creation of underground oil presses, *masserie* with large circular farmyards paved with flagstones, and the proliferation of regional fairs as a consequence of the renewed availability of saleable agricultural surpluses.[8]

Further archaeological evidence of these innovations comes from recent archaeobotanical discoveries, which led to the identification of the first evidence of cultivation in the Mediterranean of the broad bean (*Vicia faba* var. *major*).[9] In Mediterranean countries, this crop is used as a source of protein for both people and livestock, thanks to the high nutritional value of its seeds.[10] In addition, its cultivation improves the productivity of the soil, thanks to nitrogen fixation by symbiotic bacteria in the plant's roots, which enables it to thrive in poor soils and render them more fertile.[11] For this reason, it has been used for example in crop rotation systems, which have existed since the Roman period.[12]

Three main varieties of *Vicia faba* are currently recognized, distinguished on the basis of the size of the seeds: the bell bean (*V. faba* var. *minor*), the horse bean (*V. faba* var. *equina*), and the broad bean (*V. faba* var. *major*). The

4 Cf. Vetere and others, eds, *Storia di Lecce*.

5 Di Rita and Magri, 'Holocene Drought, Deforestation and Evergreen Vegetation Development in the Central Mediterranean', p. 301; Grasso, Primavera, and Fiorentino, 'Ambiente, clima e agricoltura del Salento medievale', p. 315.

6 Arthur, 'L'Archeologia del Villaggio Medievale in Puglia'; Arthur, Bruno, and Alfarano, *Archeologia urbana a Borgo Terra*.

7 Visceglia, 'Territorio feudo e potere locale: Terra d'Otranto tra medioevo ed età moderna', p. 123; Arthur and others, 'Crisi o resilienza nel Salento del Quattordicesimo secolo?', p. 48.

8 Arthur and others, 'Crisi o resilienza nel Salento del Quattordicesimo secolo?', p. 49.

9 D'Aquino and others, 'Tecniche agricole e miglioramento varietale nel Salento Basso medievale'.

10 Mejri and others, 'Variation in Quantitative Characters of Faba Bean after Seed Irradiation and Associated Molecular Changes'.

11 Jensen, Peoples, and Hauggaard-Nielsen, 'Faba Bean in Cropping Systems'.

12 White, 'Fallowing, Crop Rotation, and Crop Yields in Roman Times'.

latter two varieties may be interfertile cultivars derived from the bell bean.[13] This hypothesis is partly based on archaeobotanical evidence suggesting that the bell bean was the only variety present in Europe and the Mediterranean until the end of the early Middle Ages,[14] and it continues to be the most diffused bean variety during all the Middle Ages.[15] The interfertility of the varieties is a complex issue,[16] not yet resolved.[17] Although opinions on the origins of the larger-seeded varieties vary, there is broad agreement that they are the result of selection by people.[18] This is believed to have led to the spread of the *major* cultivar in Mediterranean countries and China, *equina* in the Middle East, North Africa, and Australia, and *minor* in Ethiopia and northern Europe.[19] Hence,

> Two main faba bean types have been proposed for Europe: a Central and Northwest European gene pool, consisting of *V. faba* var. *minor* and *V. faba* var. *major* types, and a Mediterranean gene pool which includes the former types but also *V. faba* var. *equina*,[20]

a suggestion confirmed by numerous genetic studies.[21] Indeed, when comparing geographical and genetic diversity among modern faba bean samples, continental aggregation was observed. Instead, there was no identifiable correlation between seed size (i.e. *minor*, *equina*, *major*) and faba bean sample clustering. This seems to be particularly true in the case of the medium-sized (*equina*) and large (*major*) seeds.[22] Therefore, despite seed size being the current criterion for the agronomic variety distinction used also by archaeobotanists, there is no certain correlation between this phenotypic feature and their genotypes.[23]

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13 Cubero, 'On the Evolution of *Vicia faba* L.'.

14 Schultze-Motel, 'Die archäologischen Reste der Ackerbohne, *Vicia faba* L. und die Genese der Art'; Zohary and Hopf, *Domestication of Plants in the Old World*; Caracuta and others, 'The Onset of Faba Bean Farming in the Southern Levant'.

15 Grasso and Fiorentino, 'Studi archeobotanici per l'Italia medievale'.

16 Bond and Poulsen, 'Pollination'; Le Guen, 'Incompatibilité unilatérale chez *Vicia faba* L. I. Analyse globale de croisements intraspécifiques entre quatre sous-espèces'; Suso and others, 'New Strategies for Increasing Heterozygosity in Crops'.

17 O'Sullivan and Angra, 'Advances in Faba Bean Genetics and Genomics'.

18 Tanno and Willcox, 'The Origins of Cultivation of *Cicer arietinum* L. and *Vicia faba* L.'.

19 Duc, 'Faba Bean (*Vicia faba* L.)'.

20 Oliveira and others, 'Genetic Diversity and Population Structure in *Vicia faba* L. Landraces and Wild Related Species Assessed by Nuclear SSRs'.

21 Terzopoulos and Bebeli, 'Genetic Diversity of Mediterranean Faba Bean (*Vicia faba* L.) with ISSR Markers'; Wang and others, 'Genetic Diversity and Relationship of Global Faba Bean (*Vicia faba* L.) Germplasm Revealed by ISSR Markers'; Akash and others, 'Exploring Genetic Variations in Faba Bean (*Vicia faba* L.) Accessions'.

22 Göl, Doğanlar, and Frary, 'Relationship between Geographical Origin, Seed Size and Genetic Diversity in Faba Bean (*Vicia faba* L.) as Revealed by SSR Markers'.

23 Cf. Zohary and Hopf, 'Domestication of Plants in the Old World'.

In the light of these considerations, the aim of the present study is to use the recent discoveries of faba seeds in late medieval and early modern archaeological contexts in the Salento Peninsula in order to:

– formulate hypotheses regarding where and when the varieties with medium-sized and large seeds were selected;
– contribute to the taxonomic debate via the study of the size and shape of the seeds;
– assess whether and how the new data on the history of this crop relate to the complex debate over innovations affecting the rural world of the Salento in the sixteenth century.

Materials

A total of 152 intact *Vicia faba* seeds were analysed, all from archaeological contexts in Salento (Fig. 7.1), dated to a period from protohistory until the modern era and preserved thanks to their carbonization. The finds were analysed with reference to traditional morpho-biometric parameters and the morphological characteristics of the hilum, and in accordance with a new morphological-geometric approach. Specifically, the finds included:

1. Thirty-five bell bean cotyledons (*V. faba* var. *minor*) from the site of Roca Vecchia (Sample 1), recovered from a layer of infill material in a votive pit rich in combusted plant remains (such as caryopses of different cereals, olive stones, and acorns fruits) dated to the Recent Bronze Age (thirteenth–twelfth centuries BC).[24]
2. Thirty-five bell bean cotyledons (*V. faba* var. *minor*) from the site of Oria-Monte Papalucio (Sample 2), recovered from a layer of infill material in a pit that contained plant offerings (charred caryopses of different cereals together with other charred fruits such as grapes, figs, olives, dates, apples) from a Hellenistic sanctuary dedicated to Demeter (fourth–third centuries BC).[25]
3. Thirty-five cotyledons of an indeterminate faba variety from what may be fortifications predating the current Carlo V castle complex in Lecce[26] (Sample 3). Hand-collected samples from layers dated to the second quarter of the twelfth century,[27] the beans are found together with caryopses of wheat and barley, bitter vetch, small grass seeds, and chaff remains. Plant remains were associated with locally produced ceramics, enamelled ceramics that

24 Primavera, 'Roca'; Primavera, *Roca e le dinamiche uomo-ambiente in Puglia durante l'Età del Bronzo*.

25 Fiorentino, 'Paleoambiente e aspetti rituali in un insediamento archeologico tra fase arcaica ed ellenistica'.

26 Arthur, 'Dieci anni di archeologia al castello di Lecce'.

27 Nicolì, 'Analisi archeobotaniche nel castello "Carlo V" di Lecce: il livello di XII secolo'.

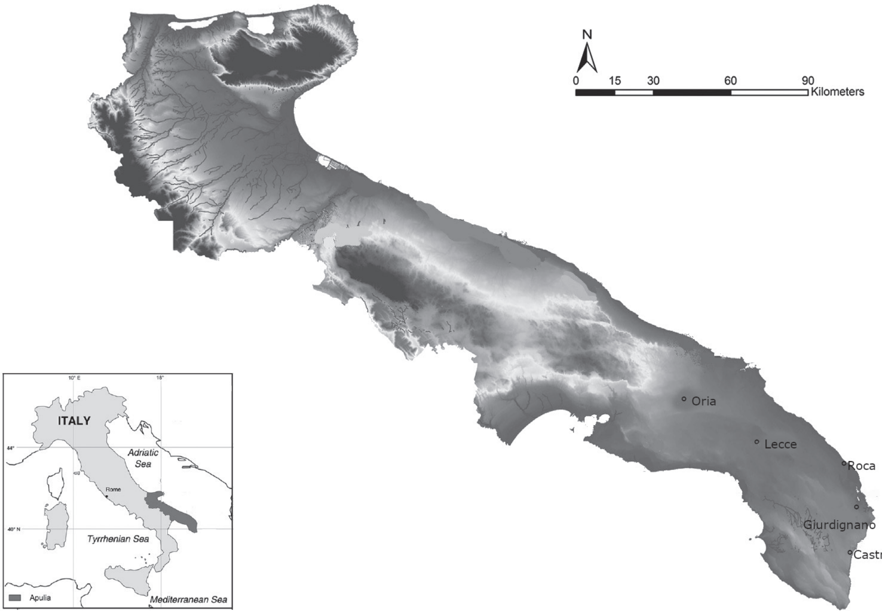

Figure 7.1. Map of Apulia and location of the archaeological sites cited in the text. Map by authors.

were widespread in central Greece, and fragments of amphorae generally associated with ceramics from the Sicily-Maghreb area.[28]

4. Two cotyledons of an indeterminate faba variety from the Capanne district of Castro, a pluri-stratified settlement that saw various phases of occupation from the Messapian period until the late Middle Ages (Sample 4),[29] recovered from levels dated to the first half of the twelfth century.[30]
5. Six cotyledons of an indeterminate faba variety associated with a small number of fruit fragments, almonds, and acorns from Giurdignano (Sample 5), found in the infill material of a small artificial chamber dated to the fifteenth century and identified during roadworks in a street of the old town (Via Chiesa).[31]
6. Four cotyledons of an indeterminate faba variety, which constituted the whole archaeobotanical assemblage recovered[32] from levels of a block in

28 Arthur and Imperiale, 'Mettendo a fuoco il XII secolo', pp. 356–59.
29 D'Andria, *Castrum Minervae*.
30 D'Aquino, 'Analisi archeobotaniche del sito pluristratificato di Castro, località Capanne'.
31 Primavera Milena, unpublished data.
32 Primavera Milena, unpublished data.

the previously cited context of Roca Vecchia, containing dwellings dated to the late fifteenth or early sixteenth century (Sample 6).[33]

7. Lastly, thirty-five cotyledons of an indeterminate faba variety, again from the Capanne district of Castro but in levels dated to the first half of the sixteenth century (Sample 7). The beans are found together with caryopses of wheat and barley, lentil, pea, and flax.[34]

Unfortunately, the sample sizes were not always as large as we would have liked; in addition, the need to use only intact seeds without distortions further limited the size of the available samples.

Methods

For each seed, the length, width, and thickness were measured using callipers in order to create a biometric dataset. The basic descriptive statistics were obtained for the dimensional data and to compare the differences of the group means the one-way analysis of variance (ANOVA) was performed. The Levene's test was used to check for equality of variances before the application of the appropriate post-hoc test. Subsequently, their biological shape was evaluated in ventral view (Fig. 7.2). Using the SHAPE program,[35] the digital images of all the seeds were converted into chain codes[36] and the chain code file was then used to calculate the Elliptic Fourier Descriptors (EFDs).[37] The coefficients of the EFDs were normalized to avoid variation related to the size, rotation, and starting point of the contour traces, the shape of each seed was approximated by the first twenty harmonics, and eighty standardized EFDs were calculated. These data were then used to perform Principal Component Analysis (PCA) using Momocs[38] in order to highlight any relationships among the data.

Results

Descriptive statistics of the biometric data for the seven archaeological contexts are reported in Table 7.1. Considering the data and observing the sample distributions reported in Figure 7.3, the thickness variable does not seem to have clear diagnostic value. Samples from different locations and periods show areas of overlap. In contrast, the length and width variables more clearly point to

33 Güll and others, 'I materiali ceramici degli scavi di Roca (Melendugno, Lecce)', pp. 439–51.
34 D'Aquino, 'Analisi archeobotaniche del sito pluristratificato di Castro, località Capanne'.
35 Iwata and Ukai, 'SHAPE'.
36 Freeman, 'Computer Processing of Line Drawing Images'.
37 Kuhl and Giardina, 'Elliptic Fourier Features of a Closed Contour'.
38 Bonhomme and others, 'Momocs'.

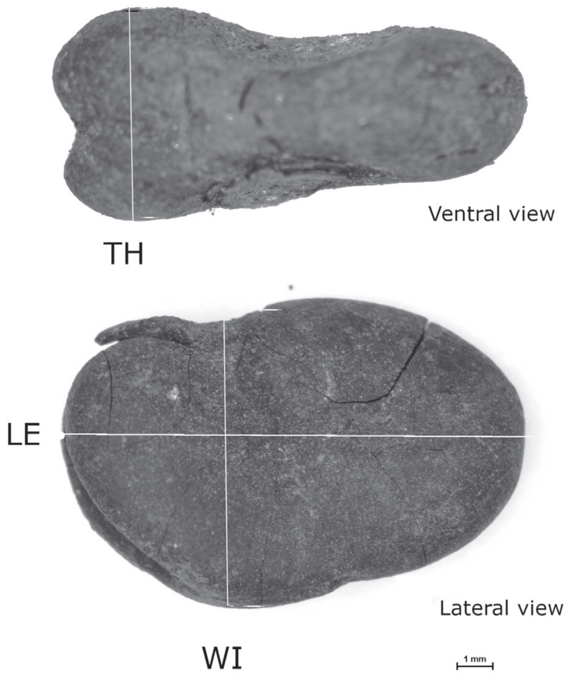

Figure 7.2. Archaeological faba bean from Castro (sixteenth century), photographed in ventral and lateral view; in evidence the biometrical features measured: LE = length, WI = width, TH = thickness. Figure by authors.

the presence of two size groups, one containing the protohistoric samples from Roca (Sample 1) and the Hellenistic samples from Oria (Sample 2), and another containing the remaining samples from the medieval and late medieval sites.

This evidence is generally confirmed by the statistically significant differences between all the group means as determined by one-way ANOVA (Welch's ANOVA $p<0.001$) for all the biometric data (Table 7.2). According to Tamhane's post-hoc test, the Roca and Oria specimens can be considered homogeneous as they do not differ significantly in any of the three variables. Both, however, differ significantly from samples from all the other sites. Only the thickness from Roca thirteenth–twelfth-century samples does not differ significantly from Roca sixteenth-century samples. Some differences are also present between specimens from medieval and late medieval sites. The Lecce's sample, in particular, because of its smaller size, is different from the one from sixteenth-century Castro in all variables, and also from Giurdignano but only in thickness. Basically, the two groups differ mainly in length and width, and the most variable are differences in thickness.

Sites		**Length (cm)**				**Width (cm)**				**Thickness (cm)**			
	n	**min**	**max**	**mean**	**SD**	**min**	**max**	**mean**	**SD**	**min**	**max**	**mean**	**SD**
1	35	0.56	0.78	0.67	0.059	0.44	0.62	0.53	0.042	0.46	0.60	0.52	0.035
2	35	0.52	0.87	0.67	0.071	0.41	0.62	0.52	0.053	0.40	0.60	0.51	0.056
3	35	1.05	1.56	1.22	0.141	0.70	1.17	0.88	0.109	0.50	0.83	0.61	0.098
4	2	1.02	1.47	1.24	0.318	0.81	1.03	0.92	0.156	0.50	0.80	0.65	0.212
5	6	1.20	1.79	1.57	0.201	0.83	1.22	1.08	0.139	0.58	0.84	0.76	0.094
6	4	1.17	1.46	1.35	0.127	0.93	1.02	0.98	0.040	0.55	0.74	0.63	0.088
7	35	0.98	1.70	1.44	0.166	0.70	1.21	0.96	0.115	0.45	0.92	0.68	0.110

Table 7.1. Descriptive statistics of biometric data, I.D. sites: 1) Roca, 13th–12th c. BC; 2) Oria, 4th–3rd c. BC; 3) Lecce, 12th c.; 4) Castro, 12th c.; 5) Giurdignano, 15th c.; 6) Roca, 16th c.; 7) Castro, 16th c.

	2) Oria, 4th–3rd c. BC	**3) Lecce, 12th c.**	**5) Giurdignano, 15th c.**	**6) Roca, 16th c.**	**7) Castro, 16th c.**
	Length — Welch's F (6, 10.05) = 159.5, p <0.001				
1) Roca, 13th–12th c. BC	ns	***	**	**	**
2) Oria, 4th–3rd c. BC		***	**	**	***
3) Lecce, 12th c.			ns	ns	***
5) Giurdignano, 15th c.				ns	ns
6) Roca, 16th c.					ns
	Width — Welch's F(6, 10.25) = 148.3, p <0.001				
1) Roca, 13th–12th c. BC	ns	***	**	***	***
2) Oria, 4th–3rd c. BC		***	**	***	***
3) Lecce, 12th c.			ns	ns	*
5) Giurdignano, 15th c.				ns	ns
6) Roca, 16th c.					ns
	Thickness — Welch's F(6, 10.05) = 16.6, p <0.001				
1) Roca, 13th–12th c. BC	ns	***	**	ns	***
2) Oria, 4th–3rd c. BC		***	**	***	***
3) Lecce, 12th c.			**	ns	***
5) Giurdignano, 15th c.				ns	ns
6) Roca, 16th c.					ns

Table 7.2. Welch's ANOVA test of Equality of Means, Pairwise multiple comparisons and p-values obtained by Tamhane's post-hoc test (significance values: ns = not significant; * = p<0.05; ** = p<0.01; *** = p<0.001). The seeds from twelfth-century Castro were excluded, as they consisted of only two specimens.

The scatter plot, based on the two diagnostic variables, highlights a characteristic of the two groups: the first (Samples 1 and 2) is broadly homogeneous, while the second group shows a trend in size increase from the twelfth (Sample 3) to the sixteenth centuries (Sample 7) (Fig. 7.4).

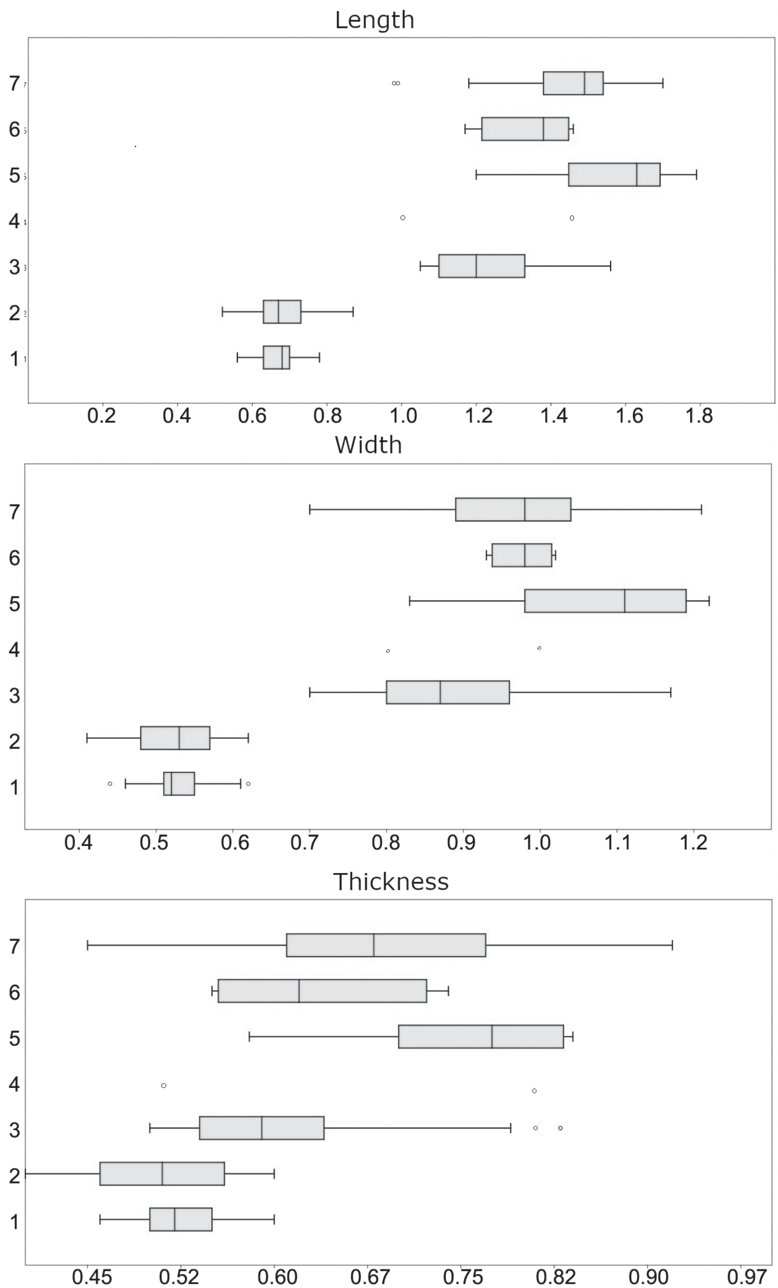

Figure 7.3. Box plot of the biometrical analysis results (1 = Roca, thirteenth–twelfth centuries BC; 2 = Oria, fourth–third centuries BC; 3 = Lecce, twelfth century; 4 = Castro, twelfth century; 5 = Giurdignano, fifteenth century; 6 = Roca, sixteenth century; 7 = Castro, sixteenth century); unit of measurement: cm. Figure by authors.

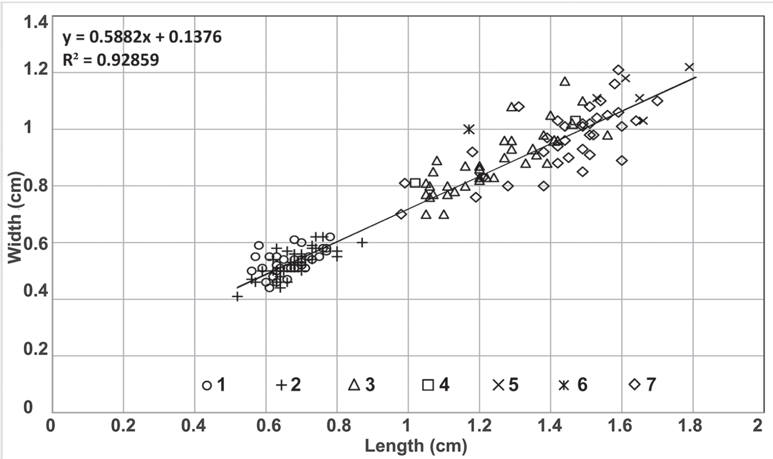

Figure 7.4. Dispersion graph of the length–width relationship (1 = Roca, thirteenth–twelfth centuries BC; 2 = Oria, fourth–third centuries BC; 3 = Lecce, twelfth century; 4 = Castro, twelfth century; 5 = Giurdignano, fifteenth century; 6 = Roca, sixteenth century; 7 = Castro, sixteenth century). Figure by authors.

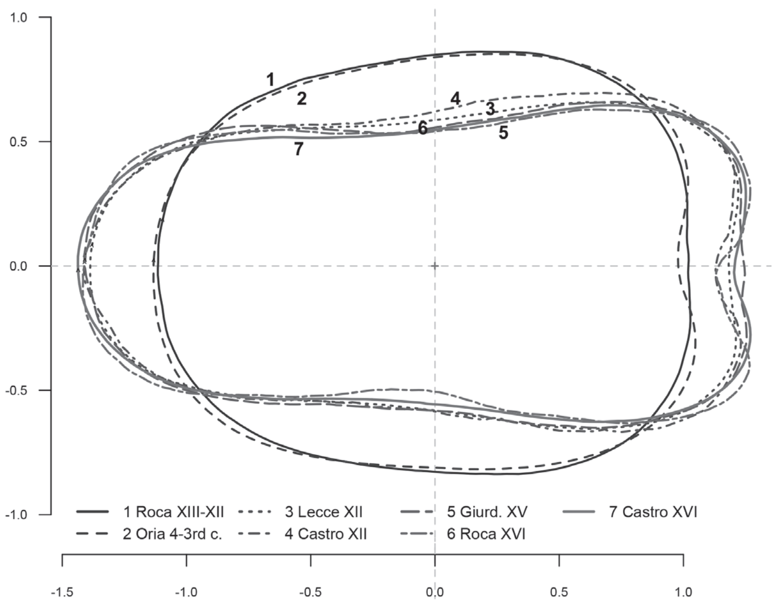

Figure 7.5. *Vicia* beans, average shapes obtained for each archaeological site; the overlaid outlines are scaled and centred to highlight differences. Figure by authors.

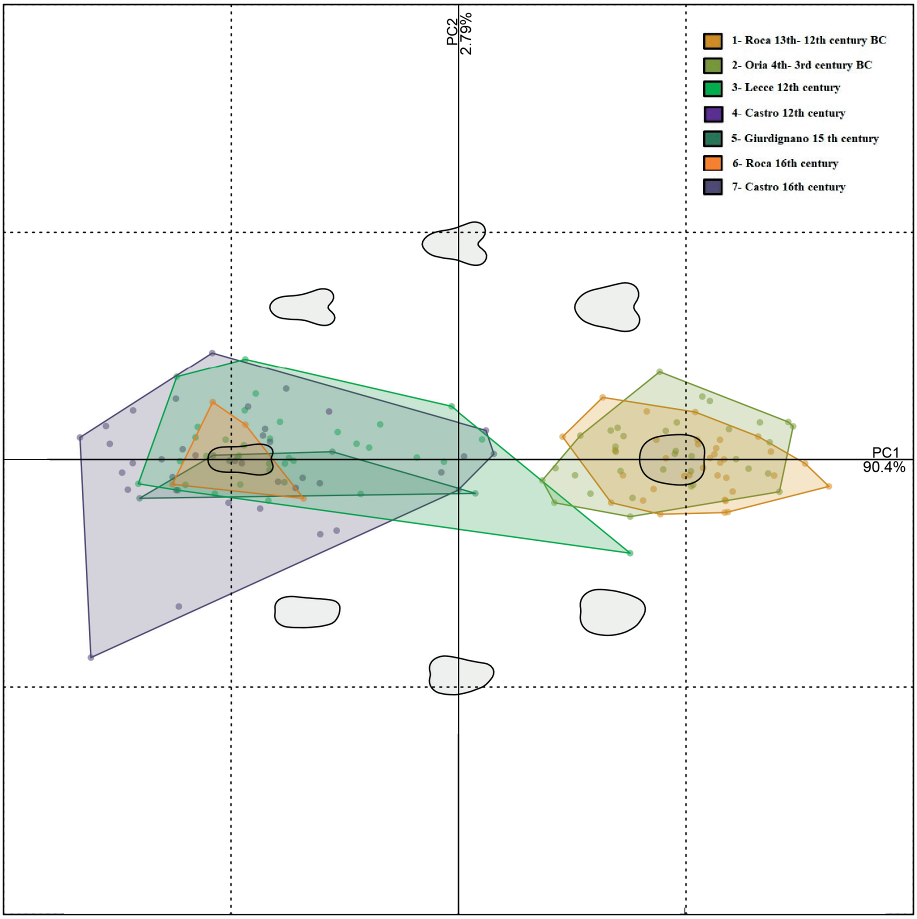

Figure 7.6. Principal Component Analysis score plot, the first and second PCs accounted for 93 per cent of total variance; each specimen is reported in the morphospace of elliptical Fourier descriptors. Figure by authors.

The study of the shape of the seeds (Fig. 7.5) made it possible to identify two types: the first is sub-circular and is found in the protohistoric samples from Roca and the Hellenistic samples from Oria, while the second is sub-rectangular and includes all the medieval and post-medieval samples. As well as being flatter, this second type is characterized by a pronounced dip in the area of the hilum, the beginnings of which can also be seen in the samples from Oria.

To characterize the shape of the seeds, the first ten Fourier components covering more than 99 per cent of cumulated harmonic power were estimated sufficient for an effective description. The Principal Components Analysis, performed using the Fourier coefficients as variables, made it possible to understand where the samples lie within the morphological space (Fig. 7.6). The most important variations are along the PC1 axis (90.4 per cent of the total variance) and concern the shape, which shifts from roughly round-ellipsoid to flattened-rectangular in the other samples, confirming the presence of just two morphotypes. Additional local variations in the hilum and head are modulated by the second PC axis (2.8 per cent of the total variance).

Discussion

The faba variety with small seeds and a sub-circular shape (cf. *V. faba* var. *minor*) has morphometric characteristics that are almost identical in samples that are chronologically separated by a millennium. The single faba seed discovered in Oria-Piazza Cattedrale, a context dated to the tenth century,[39] which was not considered in this study due to the insufficient size of the sample, fits perfectly within the variation identified for the more ancient samples.

The twelfth century saw the appearance in southern Puglia of seeds of a different shape (sub-rectangular) and larger size than the bell bean, although they were not yet as large as those of the fifteenth century. Seeds with similar characteristics are also said to have been identified in Suleimaniyah (eastern Iraqi Kurdistan), in a context dated to the eleventh century,[40] for which however it was not possible to verify the original data, and in Dury (north-eastern France), in a context of the twelfth century,[41] where the only seed of larger size was associated with five seeds of the smaller variety. It is thus possible that in the eleventh and twelfth centuries, at least in the Near East and Europe, a new variety with a shape that was clearly distinct from that of the bell bean and halfway size between *minor* and *major* (possibly *equina*?) was circulating. We may speculate that it arrived in Puglia from nearby Greece or more probably from Sicily, brought perhaps by the region's new overlords, the Normans,[42] together with other innovations, such as lead-glazed ceramics and ceramic forms that were clearly of Sicily-Maghreb origin.[43] Thus, while our samples do not allow us to contribute to the debate about the evolution

39 D'Aquino and others, 'Tecniche agricole e miglioramento varietale nel Salento Basso medievale'.

40 Helbaek, 'Isin-Larsan and Horian Food Remains at Tell Bazmosian in the Dokan Valley'; Schultze-Motel, 'Die archäologischen Reste der Ackerbohne, *Vicia faba* L. und die Genese der Art'.

41 Bakels, 'Dury "Le Moulin"'.

42 Cf. Pistarino, 'Commercio e vie marittime di comunicazione all'epoca di Ruggero II'.

43 Arthur and Imperiale, 'Mettendo a fuoco il XII secolo'.

of *V. faba* var. *major* and *equina* from *V. faba minor*,[44] it does suggest possible vectors of dissemination.

The results of our analyses also show that from the twelfth to the sixteenth centuries, the sub-rectangular morphotype increased in size. The length and width of the seeds are strongly correlated, as highlighted by the arrangement of the data along a single line on the scatter plot (Fig. 7.4).[45] We propose therefore that the increase in size may have been in response to a signal of an epigenetic nature, given that the shape remained roughly stable over time[46] and — as we have already mentioned in the introduction — there are no clear differences among the genotypes. This might also explain the discrepancy between the genetic analyses and the taxonomy applied in the agronomic field and also adopted by the archaeobotanists.

Aside from these considerations, it is in any case clear that we are dealing with a process of varietal improvement of *Vicia faba* leading to the emergence of the *major* cultivar, the earliest specimens of which, to our knowledge, are seen in this geographical area.[47] This observation raises further questions concerning the causes and mechanisms of the process identified. First and foremost, whether the selection was deliberately applied by the cultivators or was merely favoured by changes in agricultural techniques, such as deeper tilling of the soil, which may have entailed a selective advantage for larger seeds,[48] although in the case of the Fabaceae, this is unlikely.[49] The hypothesis of conscious selection would thus seem more plausible. Action of this type is generally aimed at increasing yields or facilitating the harvest of the final product, thus suggesting that over time the cultivators favoured taller plants with bigger pods in order to speed up the harvest.[50] Lastly, it is possible that favourable environmental conditions[51] and perhaps a nicer taste or particular vicine and convicine content (affecting G6PD deficiency and hence sensitivity to favism in particular population groups) led to its definitive rise.

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44 Cubero, 'On the Evolution of *Vicia faba* L.'; Serradilla, De Mora, and Moreno, 'Geographic Dispersion and Varietal Diversity in *Vicia faba* L.'.

45 Cf. Schluter, 'Adaptive Radiation along Genetic Lines of Least Resistance'.

46 Klingenberg, 'Evolution and Development of Shape'.

47 Moricca and others have recently found *V. faba* var. *major* in a cardinal's residence in Rome, but they are dated to the second half of the sixteenth century: Moricca and others, 'Early Arrival of New World Species Enriching the Biological Assemblage of the Santi Quattro Coronati Complex (Rome, Italy)'.

48 Fuller and Harvey, 'The Archaeobotany of Indian Pulses'.

49 Kluyver and others, 'Did Greater Burial Depth Increase the Seed Size of Domesticated Legumes?'.

50 Purugganan and Fuller, 'The Nature of Selection during Plant Domestication'; cf. Caracuta and others, 'The Onset of Faba Bean Farming in the Southern Levant'.

51 Al-Rifaee, Turk, and Tawaha, 'Effect of Seed Size and Plant Population Density on Yield and Yield Component of Local Faba Bean (*Vicia faba* L. *major*)'.

Conclusion

The research presented in this paper demonstrates that in the twelfth century a new morphotype of the faba bean began to circulate in the Salento Peninsula. We are not yet able to state with certainty whether this corresponds to the *equina* (horse bean) agronomic variety, a question that can only be solved by further studies that will need to quantify the size and shape of the modern varieties to be used for comparison. In any case it would seem that this morphotype underwent a process of deliberate improvement that led to the creation *in loco* of the *major* variety. It is possible that the rich biodiversity of *Vicia faba* L. that we still find to this day in this geographical area[52] is both the cause and the consequence of this phenomenon.

The process of generating a new variety must have been long and gradual, since it develops via the identification, within the existing genetic variability, of useful features and their subsequent introgression by means of backcrossing and their consequent selection and stabilization in successive generations. Given the consequent labour costs, it is possible the breeding process was promoted by local elites, who, as we have seen, were implementing a series of modifications in land use and production techniques in the region. These modifications would lay the foundations of the economy of modern Europe, as well as the landscape of the Salento today, characterized by extensive olive groves. In addition, the improvement of existing species and the introduction of new ones[53] would help to establish the characteristic food habits of the local population.

Hence, although we do not yet know by which avenues and by which mechanisms, it appears that the *major* variety of the faba bean spread to the point that it was one of the species that were exported to the New World in the sixteenth century.

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Author Contributions

A.M.G. and G.F. designed the research; A.M.G., S. D'A., G.F., M.N., and M.P. collected the evidence, A.M.G. and E.V. analysed data, A.M.G. wrote the article.

52 Renna and others, 'BiodiverSO'.

53 Grasso and others, 'Ambiente, clima e agricoltura del Salento medievale', p. 315.

Works Cited

Al-Rifaee, Mohd, Munir A. Turk, and Abdel Rahman M. Tawaha, 'Effect of Seed Size and Plant Population Density on Yield and Yield Component of Local Faba Bean (*Vicia faba* L. *major*)', *International Journal of Agriculture & Biology*, 6 (2004), 294–99

Akash, Muhanad W., Wajdy Al-Awaida, Ahmad Ateyyeh, Hmoud Al-Debei, Mohammed Saleh, Ahmad Zatimeh, Naser Salameh, Mohammad Alawin, and Shireen M. Hasan, 'Exploring Genetic Variations in Faba Bean (*Vicia faba* L.) Accessions Using Newly Developed EST-SSR Markers', *Pakistan Journal of Botany*, 49 (2017), 667–72

Arthur, Paul, 'L'archeologia del villaggio medievale in Puglia', in *Vita e morte dei villaggi rurali tra Medioevo ed Età Moderna: dallo scavo della villa de Geriti ad una pianificazione della tutela e della conoscenza dei villaggi abbandonati della Sardegna*, ed. by Milanese Marco (Florence: All'insegna del giglio, 2006), pp. 97–121

———, 'Dieci anni di archeologia al castello di Lecce', in *Il castello Carlo V: tracce, memorie, protagonisti*, ed. by Canestrini Francesco and Cacudi Giovanna (Galatina: Congedo, 2014), pp. 29–35

Arthur, Paul, Brunella Bruno, Girolamo Fiorentino, Marco Leo Imperiale, Giuseppe Muci, Maria Rita Pasimeni, Irene Petrosillo, and Milena Primavera, 'Crisi o resilienza nel Salento del quattordicesimo secolo?', *Archeologia medievale*, 43 (2016), 41–55

Arthur, Paul, Brunella Bruno, and Stefania Alfarano, eds, *Archeologia urbana a Borgo Terra* (Florence: All'Insegna del Giglio, 2017)

Arthur, Paul, and Marco Leo Imperiale, 'Mettendo a fuoco il XII secolo: rinvenimenti di età normanna nel castello di Lecce', in *VIII Congresso nazionale di archeologia medievale (Matera, 12–15 settembre 2018)*, ed. by Francesca Sogliani, Brunella Gargiulo, Ester Annunziata, and Valentino Vitale (Florence: All'Insegna del Giglio, 2018), pp. 356–59

Bakels, Corrie, 'Dury Le Moulin. Étude des restes botaniques', *Revue archéologique de Picardie*, 1–2 (1999), 237–45

Bond, David A., and M. H. Poulsen, 'Pollination', in *The Faba Bean (Vicia faba L.)*, ed. by Paul D. Hebblethwaite (London: Collins, 1983), pp. 77–101

Bonhomme, Vincent, Sandrine Picq, Cédric Gaucherel, and Julien Claude, 'Momocs: Outline Analysis Using R.', *Journal of Statistical Software*, 56.13 (2014), 1–24

Caracuta, Valentina, Omry Barzilai, Hamudi Khalaily, Ianir Milevski, Yitzhak Paz, Jacob Vardi, Lior Regev, and Elisabetta Boaretto, 'The Onset of Faba Bean Farming in the Southern Levant', *Scientific Reports*, 5 (2015), 14370

Congost, Rosa, and Pablo Luna, *Agrarian Change and Imperfect Property Emphyteusis in Europe (16th to 19th Centuries)* (Turnhout: Brepols, 2018)

Cristoferi, Davide, 'La storia agraria dal medioevo all'età moderna: una rassegna sulla storiografia degli ultimi venti anni in alcuni paesi europei', *Ricerche storiche*, 46 (2016), 87–120

Cubero, José, 'On the Evolution of *Vicia faba* L.', *Theoretical and Applied Genetics*, 45 (1974), 47–51

D'Andria, Francesco, *Castrum Minervae* (Galatina: Congedo, 2009)

D'Aquino, Silvia, 'Analisi archeobotaniche del sito pluristratificato di Castro, località Capanne' (unpublished master's thesis, Università del Salento, 2016)

D'Aquino, Silvia, Marco Nicolì, Milena Primavera, and Girolamo Fiorentino, 'Tecniche agricole e miglioramento varietale nel Salento Basso medievale: il caso della fava', in *VIII Congresso nazionale di archeologia medievale (Matera, 12–15 settembre 2018)*, ed. by Francesca Sogliani, Brunella Gargiulo, Ester Annunziata, and Valentino Vitale (Florence: All'Insegna del Giglio, 2018), pp. 365–68

Di Rita, Federico, and Donatella Magri, 'Holocene Drought, Deforestation and Evergreen Vegetation Development in the Central Mediterranean: A 5500 Year Record from Lago Alimini Piccolo, Apulia, Southeast Italy', *The Holocene*, 19 (2009), 295–306

Duc, Gerard, 'Faba Bean (*Vicia faba* L.)', *Field Crops Research*, 53 (1997), 99–109

Fiorentino, Girolamo, 'Paleoambiente e aspetti rituali in un insediamento archeologico tra fase arcaica ed ellenistica: nuove analisi archeobotaniche ad Oria – Papalucio (BR)', in *Uomini, Piante ed Animali nella dimensione del sacro: atti del Seminario di studi di bioarcheologia, Cavallino 28–29 giugno 2002*, ed. by Francesca Sogliani, Brunella Gargiulo, Ester Annunziata, and Valentino Vitale (Bari: Edipuglia, 2008), pp. 97–109

Freeman, Herbert, 'Computer Processing of Line Drawing Images', *Computing Surveys*, 6 (1974), 57–97

Fuller, Dorian, and Emma Harvey, 'The Archaeobotany of Indian Pulses: Identification, Processing and Evidence for Cultivation', *Environmental Archaeology*, 11 (2006), 219–46

Göl, Şurhan, Sami Doğanlar, and Anne Frary, 'Relationship between Geographical Origin, Seed Size and Genetic Diversity in Faba Bean (*Vicia faba* L.) as Revealed by SSR Markers', *Molecular Genetics and Genomics*, 292 (2017), 991–99

Grasso, Anna Maria, and Girolamo Fiorentino, 'Studi archeobotanici per l'Italia medievale: una sintesi', in *V Congresso nazionale di archeologia medievale, 30 settembre-3 ottobre 2009*, ed. by Giuliano Volpeand Pasquale Favia (Florence: All'Insegna del Giglio, 2009), pp. 120–26

Grasso, Anna Maria, Milena Primavera, and Girolamo Fiorentino, 'Ambiente, clima e agricoltura del Salento medievale: le dinamiche di un millennio alla luce dei dati paleo-archeobotanici', in *Storia e archeologia globale dei paesaggi rurali in Italia fra Tardoantico e Medioevo*, ed. by Giuliano Volpe (Bari: Edipuglia, 2018), pp. 309–22

Güll, Paolo, Elena M. Bianchi, Valeria Della Penna, Eda Kulja, and Paola Tagliente, 'I materiali ceramici degli scavi di Roca (Melendugno, Lecce): nuovi elementi per la conoscenza della ceramica tardomedievale nella Puglia meridionale', in *Atti del IX Congresso internazionale sulla ceramica medievale nel Mediterraneo, Venezia 23–27 novembre 2009*, ed. by Sauro Gelichi (Florence: All'insegna del giglio, 2009), pp. 439–51

Helbaek, Hans, 'Isin-Larsan and Horian Food Remains at Tell Bazmosian in the Dokan Valley', *Sumer*, 19 (1963), 27–35

Iwata, Hiroyoshi, and Yasuo Ukai, 'SHAPE: A Computer Program Package for Quantitative Evaluation of Biological Shapes Based on Elliptic Fourier Descriptors', *Journal of Heredity*, 93 (2002), 384–85

Jensen, Erik S., Mark B. Peoples, and Henrik Hauggaard-Nielsen, 'Faba Bean in Cropping Systems', *Field Crops Research*, 115 (2010), 203–16

Klapste, Jan, *Agrarian Technology in the Medieval Landscape* (Turnhout: Brepols, 2016)

Klingenberg, Chris P., 'Evolution and Development of Shape: Integrating Quantitative Approaches', *Nature Reviews Genetics*, 11 (2010), 623–35

Kluyver, Thomas A., Michael Charles, Glynis Jones, Mark Rees, and Colin P. Osborne, 'Did Greater Burial Depth Increase the Seed Size of Domesticated Legumes?', *Journal of Experimental Botany*, 64 (2013), 4101–08

Kuhl, Frank P., and Charles R. Giardina, 'Elliptic Fourier Features of a Closed Contour', *Computer Graphics and Image Process*, 18 (1982), 236–58

Le Guen, Joël, 'Incompatibilité unilatérale chez *Vicia faba* L. I. Analyse globale de croisements intraspécifiques entre quatre sous-espèces', *Agronomie*, 3 (1983), 443–49

Mejri, Sonia, Yassine Mabrouk, Marie Voisin, Philippe Delavault, Philippe Simier, Mouldi Saidi, and Omrane Belhadj, 'Variation in Quantitative Characters of Faba Bean after Seed Irradiation and Associated Molecular Changes', *African Journal of Biotechnology*, 11 (2012), 8383–90

Moricca, Claudia, Francesca Alhaique, Lia Barelli, Alessia Masi, Simona Morretta, Raffaele Pugliese, and Laura Sadori, 'Early Arrival of New World Species Enriching the Biological Assemblage of the Santi Quattro Coronati Complex (Rome, Italy)', *Interdisciplinaria archaeologica: Natural Sciences in Archaeology*, 9 (2018), 191–203

Nicolì, Marco, 'Analisi archeobotaniche nel castello "Carlo V" di Lecce: il livello di XII secolo' (unpublished master's thesis, Università del Salento, 2015)

Oliveira, Hugo R., Diana Tomás, Manuela Silva, Susana Lopes, Wanda Viegas, and Maria Manuela Veloso, 'Genetic Diversity and Population Structure in *Vicia faba* L. Landraces and Wild Related Species Assessed by Nuclear SSRs', *Plos One*, 11 (2016) <https://doi.org/10.1371/journal.pone.0154801>

O'Sullivan, Donald M., and Deepti Angra, 'Advances in Faba Bean Genetics and Genomics', *Frontiers in Genetics*, 7 (2016) <https://doi.org/10.3389/fgene.2016.00150>

Pistarino, Geo, 'Commercio e vie marittime di comunicazione all'epoca di Ruggero II', in *Società, potere e popolo nell'età di Ruggero II* (Bari: Dedalo, 1979), pp. 239–58

Primavera, Milena, 'Roca. Le indagini archeobotaniche del saggio IX: un contributo alla ricostruzione del paleo ambiente in epoca protostorica', *Annali della Scuola normale superiore di Pisa: classe di lettere e filosofia*, 5 (2013), 115–28

———, *Roca e le dinamiche uomo-ambiente in Puglia durante l'Età del Bronzo: le piante e l'uomo tra ambiente, paesaggio, economia e culto* (Monteroni di Lecce: Edizioni Esperidi, 2018)

Purugganan, Michael D., and Dorian Q. Fuller, 'The Nature of Selection during Plant Domestication', *Nature*, 457 (2009), 843–48

Renna, Massimiliano, Francesco F. Montesano, Angelo Signore, Maria Gonnella, and Pietro Santamaria, 'BiodiverSO: A Case Study of Integrated Project to Preserve the Biodiversity of Vegetable Crops in Puglia (Southern Italy)', *Agriculture*, 8 (2018), 128 <https://doi.org/10.3390/agriculture8080128>

Schluter, Dolph, 'Adaptive Radiation along Genetic Lines of Least Resistance', *Evolution*, 50 (1996), 1766–74

Schultze-Motel, Jürgen, 'Die archäologischen Reste der Ackerbohne, *Vicia faba* L. und die Genese der Art', *Kulturpflanze*, 19 (1972), 321–58

Serradilla, Joaquin M., T. De Mora, and M. T. Moreno, 'Geographic Dispersion and Varietal Diversity in *Vicia faba* L.', *Genetic Resources and Crop Evolution*, 40 (1993), 143–51

Suso, Maria José, Lawrence Harder, M. T. Moreno, and Fouad Maalouf, 'New Strategies for Increasing Heterozygosity in Crops: *Vicia faba* Mating System as a Study Case', *Euphytica*, 143 (2005), 51–65

Tanno, Kemichi, and George Willcox, 'The Origins of Cultivation of *Cicer arietinum* L. and *Vicia faba* L.: Early Finds from Tell el Kerkh, North-West Syria, Late 10th Millennium BP', *Vegetation History and Archaeobotany*, 15 (2006), 197–204

Terzopoulos, Panagiotis J., and Penelope J. Bebeli, 'Genetic Diversity of Mediterranean Faba Bean (*Vicia faba* L.) with ISSR Markers', *Field Crops Research*, 108 (2008), 39–44

Thoen, Erik, and Tim Soens, *Struggling with the Environment: Land Use and Productivity* (Turnhout: Brepols, 2015)

Veen, Marijke van der, 'Agricultural Innovation: Invention and Adoption or Change and Adaptation?', *World Archaeology*, 42 (2010), 1–12

Vetere, Benedetto, Bruno Pellegrino, and M. Marcella Rizzo, eds, *Storia di Lecce*, I: *Dai bizantini agli aragonesi* (Bari: Laterza, 1993)

Visceglia, Maria Antonietta, *Territorio feudo e potere locale: terra d'Otranto tra medioevo ed età moderna* (Naples: Guida, 1988)

Wang, Hai-Fei, Xu-xiao Zong, Jian-ping Guan, Tao Yang, Xue-lian Sun, Yu Ma, and Robert Redden, 'Genetic Diversity and Relationship of Global Faba Bean (*Vicia faba* L.) Germplasm Revealed by ISSR Markers', *Theoretical and Applied Genetics*, 124 (2012), 789–97

White, Kenneth D., 'Fallowing, Crop Rotation, and Crop Yields in Roman Times', *Agricultural History*, 44–43 (1970), 281–90

Zohary, Daniel, and Maria Hopf, *Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin*, 3rd edn (Oxford: Oxford University Press, 2000)