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ORIGINAL ARTICLE

Urban agricultural economy of the Early Islamic southern Levant: a case study of Ashkelon

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Abstract
Archaeobotanical research in the southern Levant has focused on the development of agriculture and urban societies, but less so on how agriculture sustained long-lived cities during the 1st millennium CE. Recent empirical evidence for agriculture during the Early Islamic period (636–1099 CE) has resulted in the development of new models for urban agricultural economies for that period. This study draws on the spatial analysis of plant remains including wood charcoal collected from domestic, industrial, and refuse contexts in Early Islamic deposits at the city of Ashkelon to (1) characterize the agricultural system in place; (2) investigate local cultivation or importing of crops; and (3) determine preferential use of plants for food or fuel, as well as construction and craft applications. We identify household-based storage of cleaned wheat and barley, and the preferential use of pine and cedar of Lebanon timber in construction of a large residence. We also identify an overlap in discard location of waste from craft industries and kitchens, and a co-occurrence of fruit remains and wood charcoal that we interpret as evidence for local arboriculture, the cultivation of trees and vines for fruit and nuts. Our identification of the use of fruit endocarps as industrial fuel reveals the connection between artisan and agricultural economies.

Keywords Agricultural economy · Archaeobotany · Arboriculture · Islamic agriculture · Intrasite analysis · Ashkelon

Introduction

Agriculture and urbanism are hallmarks of hierarchical societies in the Near East, and are often investigated side by side to explain the development and growth of urban centers and empires (Smith 2004; Wilkinson 2010; Rosenzweig 2016; Farahani 2018; Fuller and Stevens 2019; Marston 2021). In the periods of late antiquity following the Roman period, agricultural systems and urban complexes were fully developed, but not static. People continued to adapt both agricultural and urban economies to accommodate changing cultural and environmental conditions in ways that left traces in architecture and material culture, including archaeobotanical remains. Archaeological research on the Early Islamic period (636–1099 CE) in the southern Levant has focused largely on understanding urban planning and the development of cities, with increasing attention paid to the agricultural economy. This time period is characterized as one of intensification of cultivation enabled by new water technologies such as *qanats* (underground irrigation systems) and watermills (Avni 2018, 2020) and of intensification in the use of built space, leading to the establishment of multi-use areas and clustered buildings that combined domestic spaces with workshops and market places (Avni 2014). This article investigates both topics, using settlement layout to illuminate the diversity of the agricultural economy through an intrasite analysis of archaeobotanical remains.

Decades of excavation and survey data on major cities in the Early Islamic southern Levant have been synthesized by Gideon Avni, who proposes a model of “intensification and abatement” to describe the settlement patterns of this era, in which some settlements grew in size and economic power while others shrank (Avni 2014, p 16). This model recognizes

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that the specific internal processes at settlements amid varying regional conditions influenced whether a settlement grew or shrank, and that there is no consistent pattern across the settled landscape. There is evidence, however, from the Early Islamic cities of Baysan/Beth Shean, Fihl/Pella, Caesarea Maritima, and Ashkelon, that the boundaries between private and public spaces became blurred, as illustrated by the combination of workshops and residences (Avni 2011a, b; Holum 2011; Patrich 2011; Walmsley 2011; Boehm et al. 2016). These data on the physical structures of individual sites and of settlement hierarchies across the landscape create a stage of settlement organization within which to trace the physical movement of agricultural products. By analyzing the locations of plant remains within particular urban spaces and structures, we can recreate the economic structure of the city. Recent archaeobotanical work in the Early Islamic southern Levant includes detailed studies of sites of varying socioeconomic status and environmental settings, ranging from farming villages in the Negev Desert (Fuks et al. 2016, 2020b; Dunseth et al. 2019; Butler et al. 2020; Fuks and Dunseth 2021; Langgut et al. 2021) to cities on the Mediterranean coast (Ramsay and Holum 2015; Forste and Marston 2019; Forste 2021). While these studies have interpreted the general agricultural economies of sites within these broader contexts, other studies have taken a more spatial approach, investigating the specific urban contexts of plant use and disposal, as seen in the study of an Abbasid era (750–969 CE) marketplace in the highland city of Jerusalem (Amichay et al. 2019; Amichay and Weiss 2020), and an Abbasid/Fatimid era neighborhood at Caesarea Maritima (Forste 2021).

In this article we employ intrasite analyses to illuminate patterns of plant deposition at Ashkelon, a city on the Mediterranean coast. Remains of buildings from the Early Islamic period were identified in two densely settled residential quarters, which include mixed residential and workshop areas, presenting the opportunity to analyze plant remains from both these various spaces. From these two areas, 99 flotation samples were recovered from a series of domestic, industrial, and refuse contexts The results of analyzing the remains of carbonized wood, seeds, fruits, crop processing debris and other plant remains are discussed here. We (1) characterize the suite of crops grown, agricultural strategies practiced, and the agricultural calendar used; (2) determine if the food plants were grown locally or brought from elsewhere; and (3) determine preferential use of plants in fuel, construction, and craft applications.

Early Islamic agriculture: theories, data, and legacies

Characterizing Early Islamic agriculture

The first holistic attempt to study agriculture in the Early Islamic period was synthesized by Andrew Watson in the 1970 and 1980s. He argued that as Muslims spread from Arabia across southwest Asia and beyond between the 7th and 10th centuries CE, they brought new sub-tropical crops such as *Oryza sativa* (rice), *Gossypium hirsutum* (cotton), *Saccharum officinarum* (sugarcane), *Colocasia esculenta* (taro), and *Solanum melongena* (eggplant), as well as innovations in irrigation that increased productivity. This led to widespread economic invigoration; a model he termed the "Arab Agricultural Revolution" (Watson 1974, 1983). His argument was based primarily on the historical sources available at the time, which do not accurately reflect all the details of agricultural practices or changes argued to have taken place across this vast region, characterized by a variety of geographical, environmental, and cultural conditions (Samuel 2001; Decker 2009a; van der Veen 2010; Brite and Marston 2013). While initially applied as a universal description of agriculture across the entire Early Islamic world, Watson's model is best understood as a synthesis of the historical evidence of crop introductions and farming methods. A more accurate understanding of local agriculture comes from archaeological investigations based on plant remains, which provide direct evidence of agricultural practices, such as the methods and the crops cultivated in the Islamic era.

Published archaeobotanical data from the Levant demonstrate that changes in agricultural economy were diffuse and gradual processes (Fig. 1; Samuel 2001, p 422) and that local conditions and technology helped propel the adoption of innovations (van der Veen 2010, pp 9–10). At Early Islamic Caesarea, Ramsay and Holum found no evidence for significant changes in agricultural practices from the preceding Byzantine period (Ramsay and Holum 2015, pp 668–669). Instead they found continuity in the staple crops of *Triticum* sp. (wheat), *Hordeum* sp. (barley), *Olea europaea* (olive), *Vitis vinifera* (grape), *Ficus carica* (fig), *Lens* sp. (lentil), and *Pisum* sp. (pea) throughout the Byzantine and Early Islamic periods, in contrast to the exotic crops of *Colocasia esculenta* (taro), *Saccharum officinarum* (sugarcane), and *Solanum melongena* (eggplant) that were found at Islamic Quseir al-Qadim, a port on the Red Sea coast of Egypt (van der Veen 2011; Ramsay and Holum 2015, p 670). Contrary to Watson's expectation for the introduction of new sub-tropical summer-grown crops with the spread of Islamic cultures, Samuel found that farmers in the middle Euphrates valley already had a well-established

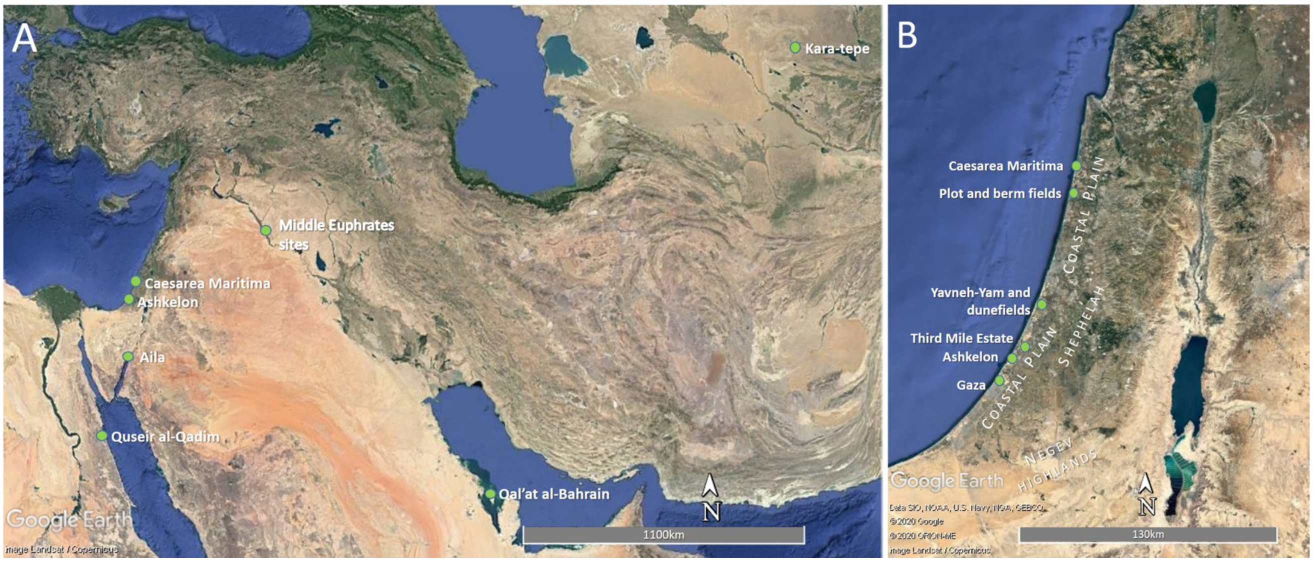

Fig. 1 **A**, map of southwest Asia; **B**, map of the southern Levant showing the sites and regions mentioned in the text

way of farming that included summer crops of *Oryza sativa* (rice), *Sesamum indicum* (sesame), and *Panicum miliaceum* (broomcorn millet) by the 7th century CE, indicating that these crops had become established before Islamic cultures spread to the region (Samuel 2001, p 359). Another new crop argued to have been spread and cultivated beyond its original range is *Gossypium hirsutum* (cotton) (Watson 1983), which powered an economic boom in Islamic Iran during the 9th and 10th centuries CE (Bulliet 2009). However, cotton seeds and textiles have been identified from as early as ca. 600 – 400 BCE at Qal'at al-Bahrain, on the Arabian Peninsula (Bouchaud et al. 2011), and cotton seeds have been identified from Roman (ca. 106–324 CE) deposits at hyper-arid Aila, on the Red Sea coast of Jordan (Ramsay and Parker 2016, p 105), indicating that cotton preceded the arrival of Muslims to southwest Asia. Even further afield, cotton seeds have been identified from 4th–6th century CE deposits at Kara-tepe in temperate western Uzbekistan (Brite and Marston 2013).

Archaeobotanical investigation of the agricultural economy

Influenced by Watson's historical narrative, a prominent archaeobotanical research aim has been to discover the introduction and adoption of new crops from southern and central Asia into the Levant and the Mediterranean region in the early Islamic period, and to assess whether such finds probably represent imported material or local cultivation (Zohary 1998; Fuks et al. 2020a). Criteria to distinguish local cultivation of annual crops have been derived through experimentation (Meurers-Balke and Lüning 1999), ethnographic observation (Hillman 1981, 1984), and archaeological analysis.

By matching environmental conditions (temperature, level of precipitation etc.) of the site under investigation with the ecological requirements of a crop, the plausibility of local cultivation can be determined. Local cultivation of annual crops is suggested by the presence of both edible and inedible crop products in an archaeobotanical assemblage, such as both the grains and chaff of cereals, based on the observation that chaff and weed seeds are typically separated from the crop close to the fields from which it was harvested (Hillman 1981, 1984; Bogaard et al. 1999, 2001; van der Veen and Jones 2006; Ramsay and Smith 2013). Annual crops do vary, however, in type and amounts of chaff produced and the locations of crop processing and chaff deposition, influencing the likelihood of chaff being preserved archaeologically. Furthermore, use of cereal processing by-products as fuel, fodder, or temper sets chaff on different depositional trajectories from seeds, decreasing its likelihood of recovery compared with grains (van der Veen 1999). Finally, while cereals such as *Triticum* (wheat) and *Hordeum* (barley) produce robust chaff assemblages, other annual crops, such as pulses and millets, produce less and more fragile chaff that is less likely to be preserved.

Similarly, archaeological models for recognizing local cultivation of perennial crops such as fruit and nut trees and vines have been developed and honed through the investigation of olive and grape cultivation in Anatolia, the Aegean, and the southern Levant (Walsh 2000; Foxhall 2007; White and Miller 2018; Valamoti et al. 2020). The archaeobotanical evidence required to discern local arboriculture or viticulture requires identification of by-products of the crops, such as olive pits (fruitstones) or grape pips, and also charcoal of the same taxa (Liphschitz 2007, pp 103–104; Bouchaud et al. 2017, p 236). The rationale for this second criterion is that if olive groves, vineyards and orchards regularly provided small branches from pruning, these could have been used nearby as a readily available and abundant fuel. Additionally, the identification of pollen from trees that corroborates with the records of fruit and charcoal taxa can sometimes provide further evidence for local cultivation (Langgut et al. 2021), depending on the pollen taxonomy and dispersal mechanism.

Recent investigations suggest that fruit trees, which were domesticated between 6000 and 3000 BCE in western Asia and Mesopotamia, may have played an important role in emerging urban societies alongside craft specialization (Stager 1985; Fuller and Stevens 2019). If arboriculture helped lay the economic foundations for hierarchical urban specialized societies, it is plausible that it could also have continued to play an integral role in the growing and flourishing of urban centers in later periods.

Agriculture on the coastal plain of the southern Levant

The coastal plain of the southern Levant and adjacent Shephelah foothills have a long legacy of large-scale farming. Most famous perhaps is the Gaza and Ashkelon wine industry that reached its apogee in the 5th and 6th centuries CE, linked to the Christian pilgrimage economy (Mayerson 1985). This wine was stored and distributed in eponymous "Gaza jars" and its quality and efficaciousness were touted in medical texts (Mayerson 1992, 1993). Recent archaeobotanical and pottery investigations link the commercial scale of grape cultivation and wine production in the Negev highlands with the large-scale wine trade across the southern Levant and Mediterranean (Fuks et al. 2020b). By the late 6th century CE the production and distribution of these wines declined as a result of market disruption caused by climate fluctuations, the Justinian plague outbreak of 541 CE, and the Sassanid conquest (Fuks et al. 2020b). The geographical distribution of Gaza jars was reduced and the kilns and wineries in which the jars and wine were made were abandoned before the end of the 7th century (Decker 2013).

A testament to the high agricultural and industrial productivity of the coastal plain is found at the "Third Mile Estate", a rural agricultural estate that operated from the Roman through the Byzantine period in the 1st to early 7th centuries CE (Israel and Erickson-Gini 2013). It is located 5 km northeast of the site of Ashkelon and housed numerous features associated with the processing of agricultural products, including an oil press, two wine presses, a grain mill, and several warehouses used to store the vast amounts of olive oil and wine produced, a kiln that produced the Gaza jars that held the wine and oil, along with a grand farmhouse and sophisticated bathhouse. The estate ceased to function in the early 7th century CE, a time when the region became less dependent on extensive agricultural estates. Indeed, survey data show the number of rural settlements thought to be centers of agricultural production decreased at this time (Huster 2015, pp 55–57).

Slightly further north along the Mediterranean coast, recent excavations in Yavneh have uncovered the largest Byzantine wine production complex found to date (Haddad et al. 2021; Ladav-Ziv et al. 2021; Staff 2021), attesting to the large-scale commercial capacity of viticulture in this region. Additionally, in the dune fields between Yavneh and the site of Caesarea Maritima, there is evidence of novel methods of agricultural extension that may have replaced large rural estates for locations of agriculture. These "plot-and-berm" fields are comprised of sunken plots lined with raised sand berms (banks), mulched with refuse and watered by shallow groundwater (Shtienberg et al. 2017; Taxel et al. 2018). Based on artifact and OSL dates, these plots date to the 10th through early 12th centuries CE. It would have taken decades to transform sand dunes into productive fields, indicating long-term use of this strategy. In fact, pottery in the mulch of this artifact-rich soil dates from the mid 7th or 8th centuries CE, suggesting approximate dates for the use of this agroecosystem (Taxel 2018, p 167; Taxel et al. 2018, p 554).

While archaeobotanical assemblages have not been studied from either the "Third Mile Estate" or the various plot-and-berm fields, they provide important data in understanding the organization of agricultural infrastructure in the region, for both the cultivation and processing of crops. Ongoing research of the Yavneh wine complex will further contribute to our understanding of commercial land use and agriculture during this period.

Site history and environmental background

The site of Ashkelon

Ashkelon is located on the southern Mediterranean coast of modern-day Israel. It has a long occupation history spanning the Middle Bronze Age to the Crusader period (ca. 2000 BCE - CE 1270) and was a major port that connected the Near East to the wider Mediterranean region (Stager and Schloen 2008, p 3). The site is directly on the coast, with two areas of concentrated human occupation forming tells within the fossilized D-shaped sand dunes. A range of residential, public, funerary, and commercial contexts from nearly all occupation periods were excavated and analyzed by the Leon Levy Expedition to Ashkelon in 1985–2016 (Hoffman 2019). The prominence of the city throughout its occupation is evidenced by the monumental buildings that include a Middle Bronze Age arched gate and ramparts, a Roman *bouleuterion* (meeting house) (Boehm et al. 2016), and Islamic and Crusader fortifications (Sharon 1995). During the Muslim advances from Arabia in the 7th century CE, Ashkelon was conquered by treaty in 640 CE and remained under the control of the Islamic dynasties (Umayyad 661–750 CE, Abbasid 750–969 CE, Fatimid 969–1153 CE) until the Crusader incursion in the 12th century CE (Stager and Schloen 2008, pp 9–10).

Ashkelon in the Early Islamic period was a wealthy cosmopolitan port renowned for its fertile fields, strong fortifications, and busy markets for fruit, clothes, and silk (al-Muqaddasī 2001). Resplendent with beautiful mosques, churches, and multistory buildings (Nāṣir-i Khusraw 1986; Piccirillo et al. 1993), the city was considered the gateway to Egypt, and under the Umayyads and Abbasids became an important fortified outpost on the Byzantine controlled Mediterranean Sea (Khalilieh 2008, p 163). Under the Fatimids, with the eastern Mediterranean firmly in their control, Ashkelon thrived as an important regional center for expanding trade networks that crossed to Egypt and North Africa, the Levant, and beyond, reaching all the way to China. The city also achieved new prominence as the highest ranking provincial governorship in the Fatimid Empire (Sharon 1995), a status that meant that Ashkelon continued to prosper at a time when many cities in the region were showing signs of decline.

Over the course of 30 seasons of excavation, the Leon Levy Expedition to Ashkelon conducted surveys and excavation across the site. With few exceptions, excavation revealed substantive, albeit disturbed and often fragmentary, material from the Islamic and Crusader periods (Hoffman 2019). Early Islamic material came almost exclusively from residential quarters, found in all areas of the site. Despite the descriptions of al-Muqaddasī and Nāṣir-i Khusraw, no remains of monumental public buildings were discovered. Instead, excavation uncovered densely settled residential quarters clustered on the two tells (in Grids 23, 38, 44, 57; Fig. 2) overlooking the Mediterranean Sea. Here, houses were found with small courtyards, in which wells, drains, sumps, and sewers were common, as were courtyard spaces shared between buildings. Larger courtyard houses were rare. The most well-preserved was a house with rooms organized around a paved central courtyard with a small painted pool, in Grid 37. Such houses were found away from the tells in less densely settled areas of the city. As the population grew, new residential quarters were constructed over the former Roman *bouleuterion* in Grid 47 near the city center and in areas just to its north in Grids 25 and 32. Houses in these quarters had the same features as those in the older, denser neighborhoods with the notable addition of water cisterns. In all areas, preservation was poor, but the small finds such as delicate glassware, elaborate decorative pieces of worked bone, and imported Chinese porcelains and *celadons* (green glazed Chinese pottery), as well as the expansion of residential quarters, reflect the city's prosperity during this period. Much of what is known about Islamic Ashkelon comes from the study of its garbage dumps, fills, and water and waste systems, as well as a limited number of surfaces found in residential areas. These nevertheless reveal a rich and varied record of material culture which illuminates daily life in Early Islamic Ashkelon and everyday aspects of the farming economy, including how people used plant products on an everyday basis, as well as at an industrial scale.

Environment

Ashkelon is located on the southern Mediterranean coastal plain, a transition zone between the temperate Mediterranean climate to the north and west, and the hot, arid Saharan desert climate to the south and east (Danin 1995). The coast is characterized by undulating sand dunes and *kurkar* (cemented sandstone) ridges and valleys that run parallel to the it, all of which are underlain by sandstone bedrock (Koucky 2008, p 13). The plain is bordered to the south by the Negev Desert and to the east by the fertile hilly countryside called the Shephelah or Shfela (Koucky 2008, p 13; Stager and Schloen 2008, p 3), which continues to be an important region for farming today.

The local climate is defined by two seasons: a mild rainy winter and a hot dry summer that lasts up to six months (Zohary 1973, pp 83, 130). The average temperature on the coast in January is 14 ºC, and in August 25 ºC (Koucky 2008, p 11), and this coastal climate is excellent for cereals which are sown in the autumn, watered by winter precipitation, and ripen for harvesting in the spring, and also for tree fruits when irrigation can supplement precipitation through the hot dry summer (Koucky 2008, p 11). Precipitation generally decreases to the south and east, ranging from 300 to 1,000 mm annually (Zohary 1973, p 130). On average, Ashkelon receives 350 mm annually over 45 days between November and February (Koucky 2008, p 11). Other sources of water available to the site include a freshwater aquifer and underground river systems that flow to the sea (Koucky 2008, p 13; Stager and Schloen 2008, p 3).

Multiple geographical and climatic zones converge in this area, creating a mosaic of vegetation communities with a rich variety of plants (Zohary 1973; Danin and Orshan 1999). The vegetation on the coast is typified by steppe and desert plants, with a gradual reduction of Mediterranean taxa further to the east and south (Zohary 1973, pp 132–133). The coast around Ashkelon is dominated by desert-type

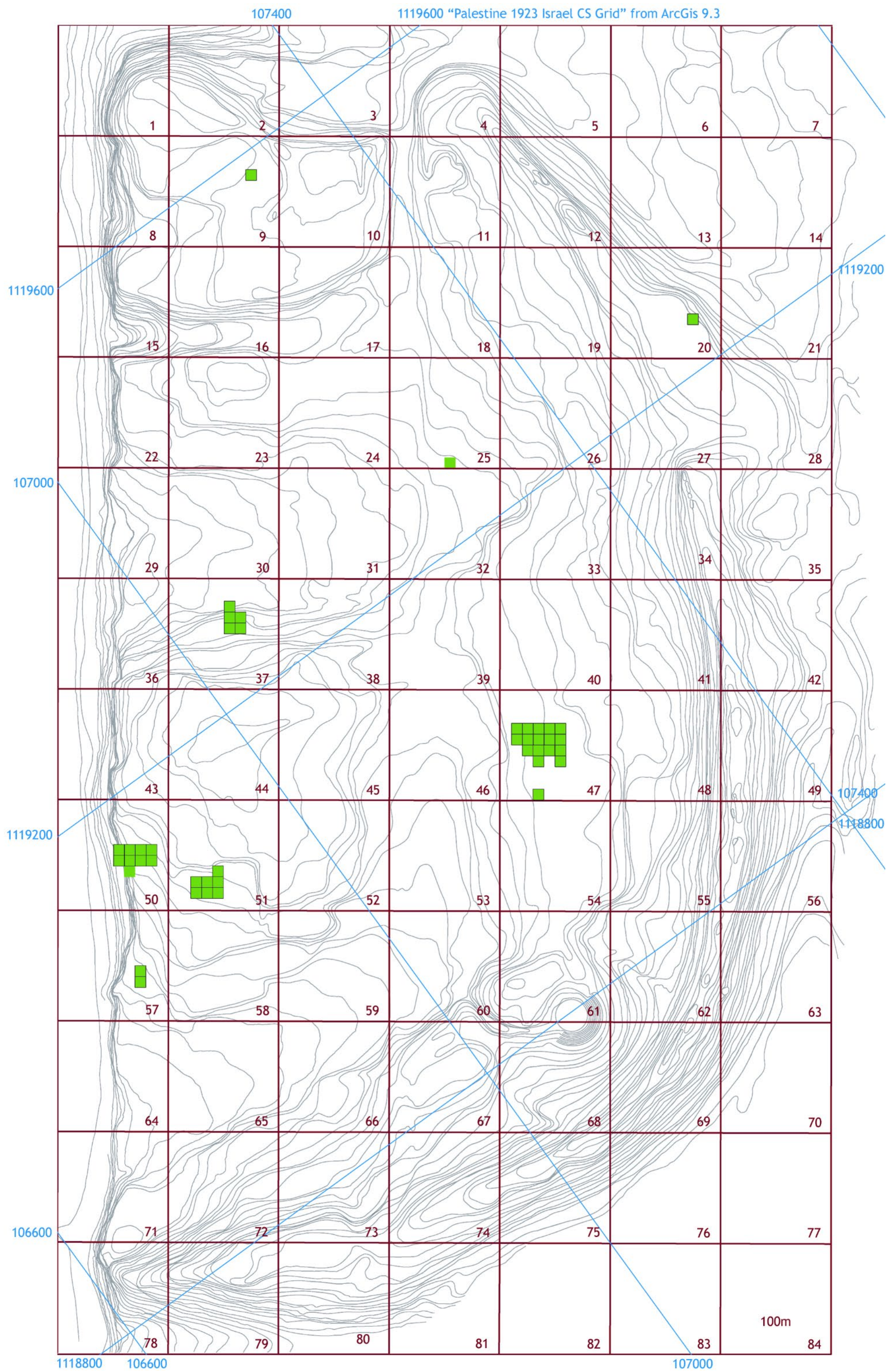

Fig. 2 Plan of the Ashkelon excavation grids showing Early Islamic deposits in green, by courtesy of the Leon Levy Expedition to Ashkelon

perennial grasses and shrubs including *Artemisia monosperma* (sagebrush), *Pistacia lentiscus* (mastic), and *Calicotome villosa* (spiny broom), as well as trees of *Ceratonia siliqua* (carob) (Danin and Orshan 1999, pp 20–27). In the Shephelah to the east, native trees like *Quercus ithaburensis* (Tabur oak), *Ziziphus spina-christi* (Christ's thorn jujube), and *Acacia raddiana* (twisted acacia) grow among vegetation from human activities (Danin and Orshan 1999, p 32). Cultivated trees such as *Olea europaea* (olive), *Prunus dulcis* (almond), and *Ficus carica* (fig) are also widespread on the coastal plain and *Phoenix dactylifera* (date palm) is found in arid areas (Liphschitz 2007, pp 103–110).

Table 1 Sample contexts and time periods from Early Islamic Ashkelon

Excavation Grid	Grid 9	Grid 20*	Grid 25*	Grid 37	Grid 47*	Grid 50	Grid 51	Grid 57	Total
Context	Workshop	Fortification	Mixed-use building	Large residence	Residential quarter	Pits and robber trenches	Pits and robber trenches	Mixed-use resid. quarter and refuse dump	
Time Period	Fatimid	Early Islamic**	Fatimid	Fatimid	Fatimid	Fatimid/ Crusader	Fatimid/ Crusader	Fatimid/ Crusader	
Ash dump								1	1
Cesspit/dump					2				2
Clay					1				1
Destruction debris			10	2					12
Deliberate fill	2	1		18	2	3	4	25	55
Floor			3	2					5
Natural fill				3					3
Pit				1				15	16
Robber trench				1		1			2
Uncertain/unknown	2								2
Total no of samples	4	1	13	27	5	4	4	41	99

* flotation samples from these grids were processed with a FloteTech machine

** stratigraphy highly disturbed and does not allow further chronological refinement

Materials and methods

Samples and contexts

A total of 132 flotation samples were collected from Early Islamic deposits at Ashkelon, although ten of these lack secure dates and contextual information and so were excluded from subsequent analyses. When multiple samples were taken from a context, we combined them into a single sample to avoid over-representing specific contexts, resulting in a total of 99 combined samples considered in this analysis, as described in detail by Forste and Marston (2019, pp 649–650). These samples come from a variety of contexts in eight excavation grids across the site (Fig. 2), mostly from deliberate fill (occupational debris used as fills), pits, destruction debris, floors, naturally deposited fills, an ash dump, a cesspit/sump, and robber trenches (Table 1). The specific time span assigned to each grid is based on stratigraphic chronology, as well as the abundance and quality of securely dateable material culture (primarily pottery).

Sampling strategy and processing

From 1986 to 2011, flotation samples and hand-picked botanical samples were collected at the discretion of the excavators, primarily from areas of concentrated burning where preservation of carbonized plants was likely, from layers identified as floors, and in some areas from every layer and feature (Lass 1994, p 24). Samples were processed with a manual flotation method developed by Robert Stewart at Tell el-Hesi (Stewart and Robertson 1973) in which a tub with a mesh bottom was inserted into a barrel of water and the soil sample then put into the tub, which was then shaken to release the silt into the water, similar to the IDOT method used in the United States (Wagner 1976, 1977, 1979; Pearsall 2015). The heavy fraction was caught on the 1.5 mm mesh at the bottom of the tub and the floating light fraction was skimmed off of the water surface with a 0.5 mm mesh scoop (Lass 1994, 2008). All samples were dried and stored on site. The volumes of soil in the original flotation samples were not recorded. Samples from Grids 9, 37, 50, 51, and 57 were collected and processed with these methods.

From 2012 and later, an overall blanket strategy was employed in which flotation samples with a standard volume of 10 L were collected from all units and features. The volume of soil was recorded for each sample before it was processed with a FloteTech machine (Hunter and Gassner 1998; Rossen 1999). The light fraction was collected using a sieve with a < 0.1 mm mesh, dried on site and packed for later analysis. The non-floating heavy fraction was collected using window screen material with a 1.5 mm mesh, dried, and sorted on site. Samples from Grids 20, 25, and 47 were collected and processed with these methods.

Post-excavation treatment

All samples were stored on site until they were sent to the Environmental Archaeology Laboratory at Boston University in the USA for analysis. Damage to storage containers by pests under uncontrolled storage conditions on site resulted in some spillage and crushing of plant remains in a number of samples from earlier excavation seasons; as a result, some samples lost an unquantifiable amount of the light fraction material prior to analysis (Forste and Marston 2019).

Identification, quantification, and analysis

Macrobotanical remains were examined using Leica stereo microscopes with a magnification range of 6–90×. The samples were sieved into four size classes (> 2 mm, > 1 mm, > 0.5 mm, < 0.5 mm) to facilitate sorting and to provide more refined information about the size of taxa recovered that could be used to make inferences about their cultivated or wild status and the formation processes of the archaeobotanical record (van der Veen and Fieller 1982; Bogaard et al. 1999, 2005). Botanical remains were identified using collections of comparative material in the Environmental Archaeology Laboratory, including experimentally carbonized modern specimens, seed atlases (Schoch et al. 1988; Nesbitt 2006; Cappers et al. 2009), identification keys (Jacomet 2006), and comparative published reports of Islamic period botanical finds from the Near East (van der Veen 2011; Ramsay and Bedal 2015; Ramsay and Eger 2015; Ramsay and Holum 2015). Plant names follow *Flora Palaestina* (Zohary and Feinbrun-Dothan 1966-86).

Seeds of both cultivated and wild plants were counted when more than 50% of the original seed or endocarp (also called a pit or fruitstone) was intact. Exceptions are cereal grains, which were counted only when the embryo end of the caryopsis was present, regardless of its state of completeness, and pulses which were counted in units of halves. Only intact seeds and countable plant parts were extracted from size fractions < 1 mm. Weights were recorded for both whole and fragmented cultivated plant remains: cereals, pulses, and fruit remains including durable endocarps, such as *Prunus persica* (peach), *Olea europaea*, and *Phoenix dactylifera*, and pip fragments, such as those of *Vitis vinifera* (grape). Only whole non-economic seeds were counted, as well as countable plant parts such as cereal rachis fragments and grape pedicels.

Wood charcoal fragments > 2 mm were counted, weighed, and examined using Leica stereomicroscopes with a magnification range of 6–90× and a Leica DM2700 incident light microscope with 50×, 100×, 200×, and 500× magnification. The charcoal was identified using experimentally carbonized modern specimens and standard wood anatomy references (Fahn et al. 1986; Schweingruber 1990; Akkemik and Yaman 2012; Crivellaro and Schweingruber 2013). To account for differential preservation of woody taxa due to variance in fragmentation rates, density, response to combustion, and other depositional factors (Théry-Parisot et al. 2010), both charcoal fragment counts and weight (g) are reported here.

Most of the samples were collected prior to 2012 and lack recorded soil volumes, precluding standardization and comparison of relative abundance between samples of different volumes (Miller 1988; Marston 2014, pp 166–167). Given the variation in preservation and presumed variation in soil sample volume, relative measurements such as ratios are most useful to elucidate patterns in this assemblage. Relative abundances and ubiquity by category of remains were calculated to better understand the distribution of plant remains across the site. Qualitative characteristics of identified taxa were recorded in order to elucidate features of the agricultural calendar and harvesting techniques, including life cycle information such as flowering and harvest times, as well as average plant height.

Results

Sitewide analyses

Overview of the assemblage

Overall, the assemblage of carbonized plant remains is relatively well preserved: delicate chaff remains and oily (therefore highly combustible) endosperms have survived, as well as seeds of wild plants > 1 mm. Few weed seeds < 1 mm were recovered, suggesting two possibilities: that those recovered represent the larger crop weeds (generally 1-1.5 mm) which were separated during a late stage cleaning of sieved grains (Jones 1987; Fuller et al. 2014), or that small seeds were lost during flotation (0.5 mm mesh used) or while in storage. More than 4,500 remains of crops, 136 of wild plants, and 424 plant parts were identified (Table 2). Economic plants dominate the assemblage, specifically cereals, fruit, and nuts (Fig. 3). Cereals comprise 50% of the assemblage by count and 32% of the assemblage by weight. Fruit and nuts comprise 38% of the assemblage by count and 56% by weight. Few pulses were recovered (n = 14) resulting in a relative percentage of < 1%, but they comprise 2% of the assemblage by weight. Weed seeds are only present in the calculations of counts, of which they constitute 3%. Other plant parts (including chaff, listed at the bottom of Table 2) constitute 8% of the assemblage by count and 10% by weight. Ubiquity calculations show that fruit and nuts are the most frequent, occurring in 47% of samples, followed by cereals, pulses, wild plants, and other plant parts (Fig. 4).

Charcoal remains, in contrast, were highly friable and fragmented, making identification difficult even to family or genus level. The charcoal assemblage is dominated by gymnosperms, which amount to nearly 60% of identified fragments by count (Fig. 5). These include *Cedrus libani* (cedar of Lebanon), *Pinus* sp. (pine), one piece of *Ephedra alata* (ephedra), and indeterminate specimens (Table 3). Angiosperms comprise approximately 40%, as measured by both count and weight (Fig. 5), with a much larger taxonomic diversity (Table 3). Scant remains of *Phoenix dactylifera*

Table 2 Total plant remains except wood charcoal from Early Islamic Ashkelon; zero indicates a weight too small to register on scale

Taxon, type of remain	Family	Common Name	Count	Weight (g)	Ubiquity (n=99)
Cereals					
Hordeum vulgare, grain (cf.)	Poaceae	Barley	349	1.81 (0.03)	10% (1%)
Triticum aestivum/durum, grain (cf.)	Poaceae	Bread/hard wheat	2,189	42.26 (0)	9% (1%)
Triticum sp., grain (Cereal indet.)	Poaceae	Wheat	12 (24)	0.27 (1.95)	5% (20%)
Total			2,574	46.31	
Pulses					
Lens culinaris, seed	Fabaceae	Lentil	8	0.03	3%
Pisum sativum, seed (*Pisum* sp.)	Fabaceae	Pea	4	0.16 (0.73)	4% (3%)
cf. *Vigna unguiculata* ssp. *unguiculata*, seed	Fabaceae	Possible cow pea	2	0.15	1%
Vicia faba, seed	Fabaceae	Fava bean	0.5	0.07	1%
Pulse, seed (cf.)	Fabaceae		1 (0.5)	0.66 (0.02)	2% (1%)
cf. Fabaceae, seed	Fabaceae		1	0.34	1%
Total			16	3.43	
Fruits and Nuts					
Phoenix dactylifera, endocarp	Arecaceae	Date	37	19.64	18%
cf. *Juglans regia*, endocarp	Juglandaceae	Possible walnut		0.53	3%
Melia azedarach, endocarp	Meliaceae	Chinaberry/rosary bead tree	1	0.901	1%
Ficus carica, fruit (seed)	Moraceae	Fig	(1,711)	0.7 (0.51)	3% (8%)
Olea europaea, endocarp	Oleaceae	Olive	66	23.08	
Pinus pinea/halepensis, nutshell (cf.)	Pinaceae	Stone/Aleppo pine		1.66 (0.47)	(41%)
Crataegus sp., endocarp	Rhamnaceae	Hawthorn	1	0.14	2%
Ziziphus spina-christi, endocarp	Rhamnaceae	Christ's thorn jujube	16	4.59	13%
Amygdalus dulcis, endocarp	Rosaceae	Almond		3.01	6%
Prunus cf. *cerasus/avium*, endosperm (fruit)	Rosaceae	Possible sour/sweet cherry	3	0.09 (0.37)	2% (2%)
Prunus cf. *domestica*, endocarp	Rosaceae	Possible plum	14	10	
Prunus cf. *domestica*, endosperm (fruit)	Rosaceae	Possible plum	1	0.02 (0.4)	1% (7%)
Prunus persica, endocarp	Rosaceae	Peach	2	8.5	6%
cf. *Prunus* sp., fruit	Rosaceae	Possible plum/cherry		0.4	2%
Vitis vinifera, pip (pip and fruit)	Vitaceae	Grape	73 (1)	1.21 (0.05)	22% (1%)
Indet., endocarp				3.47	14%
cf. fruit (cf. bark)				1.27 (1.65)	2% (2%)
Total			1,925	81.10	
Wild Seeds					
Chenopodium sp., seed	Amaranthaceae		1		1%
cf. Apiaceae indet., mericarp	Apiaceae		2		1%
cf. *Anthemis* sp., achene (cf. Asteraceae)	Asteraceae		2 (1)		2% (1%)
Artemisia sp., achene	Asteraceae		1		1%
Glebionis coronaria, achene	Asteraceae		1		1%
cf. *Camelina* sp., seed	Brassicaceae		1		1%
cf. *Descurainia Sophia*, seed	Brassicaceae		23		1%
Raphanus raphanistrum, seed	Brassicaceae		1		1%
Rapistrum rugosum, seed	Brassicaceae		17		2%
Capparis sp., seed	Capparaceae		1		1%
Gypsophilia sp., seed	Caryophyllaceae		1		1%
cf. *Astragalus* sp., seed (Fabaceae indet.)	Fabaceae		1 (7)		1% (1%)
Medicago sp., seed	Fabaceae		2		2%
Melilotus/Trifolium sp., seed (cf. *Trifolium* sp.)	Fabaceae		1 (6)		1% (1%)
cf. *Trigonella* sp., seed	Fabaceae		2		1%
Malva sp., seed	Malvaceae		10		2%
Fumaria sp., seed	Papaveraceae		2		2%
cf. *Alopecurus* sp., caryopsis (cf. *Cynodon* sp.)	Poaceae		4 (6)		1% (2%)
Bromus sp., caryopsis	Poaceae		2		2%
Eleusine sp., caryopsis	Poaceae		1		1%
Rumex sp., nutlet	Polygonaceae		2		1%
Adonis sp., nutlet	Ranunculaceae		9		2%
cf. *Ranunculus* sp., nutlet	Ranunculaceae		23		1%
cf. *Galium* sp., mericarp	Rubiaceae		2		1%
Thymelaea sp., seed	Thymelaeaceae		6		2%
Unknown			32		6%
Total			170		
Plant Parts					
cf. Fabaceae, pod fragment	Fabaceae		1		1%
Pinus pinea/halepensis, cone scale	Pinaceae	Stone/Aleppo pine	55	1.64	4%
Cereal indet., embryo (glume base)	Poaceae		51 (1)		3% (1%)
Cereal indet., lemma/palea (culm node)	Poaceae		1 (6)		1% (1%)
Hordeum sp., rachis frag.	Poaceae	Barley	1		1%
Triticum aestivum/durum, embryo	Poaceae	Bread/hard wheat	226		1%
Vitis vinifera, stem (pedicel)	Vitaceae	Grape	3 (18)		1% (1%)
cf. nutshell			49		1%
Unknown, fruit (calyx)			1 (3)		1% (1%)
Unknown, unknown			8		1%
Total			424		

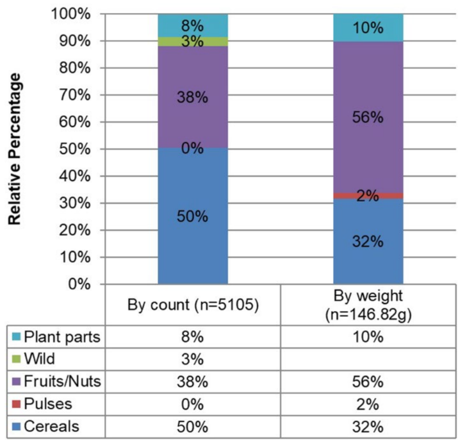

Fig. 3 Relative abundance of non-wood plant remains in the entire assemblage by count and weight. Pulses account for <1% of the assemblage by weight and therefore are listed as 0%

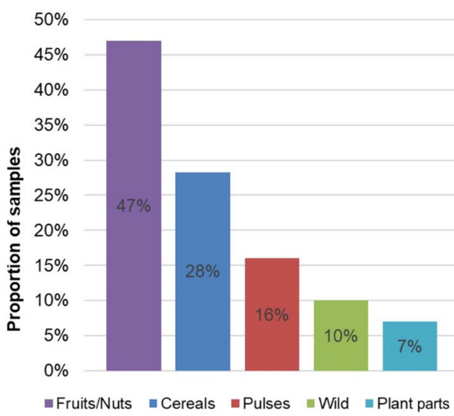

Fig. 4 Ubiquity of non-wood plant remains

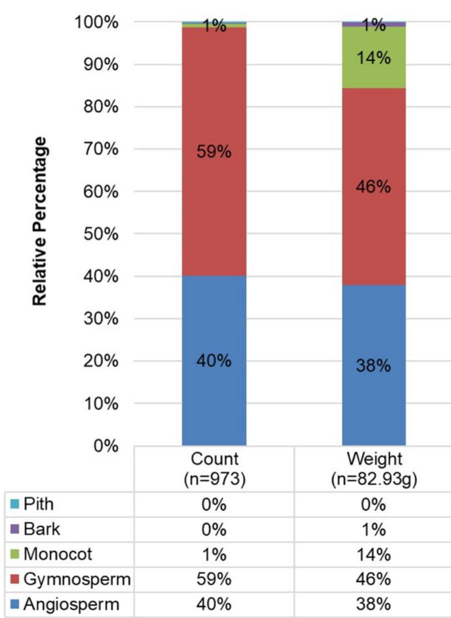

Fig. 5 Relative percentages by weight and by count of Early Islamic wood charcoal

and indeterminate monocots are present, as well as very few pieces of bark and potential pith (Fig. 5; Table 3). The angiosperm taxa identified represent a mix of natural vegetation commonly found on the coastal plain and in surrounding environmental zones, such as *Tamarix* sp. (tamarisk), *Ziziphus/Paliurus*, the evergreen oaks *Quercus calliprinos* and *Q. ithaburensis/libani*, and domesticated taxa, including *Olea europaea, Pistacia*, various Rosaceae taxa (including Prunoideae and Maloideae), possible *Vitis vinifera*, and *Ficus* cf. *sycomorus* (sycomore fig) (Table 3). Full sample by sample details of both seed and wood remains are provided in ESM 1.

Botanical analyses of wild taxa

The flowering times and average plant heights of the 32 wild taxa identified were recorded. Phytogeographic data for species within each identified genus were considered, although those that grow outside the ecological zones around Ashkelon, such as desert plants, were not included. The wild taxa were classified into height categories based on analyses of European Neolithic assemblages (Kreuz et al. 2005; Allen 2017): "tall" (>80 cm), "medium" (50–80 cm), and "low" (<50 cm). Two intermediate categories were also included: "medium-low" and "tall-medium" (ESM 2).

Because many plant remains were identified to genus rather than species, the range of heights was recorded for all phytogeographically appropriate species in genera that are listed in *Flora Palaestina* (Zohary 1966, 1987; Feinbrun-Dothan 1978, 1986). Of the 32 taxa, 22% were low, 47% medium-low, 3% were tall-medium, and 28% had heights that spanned the entire range (<50 cm to >80 cm). The preponderance of weeds shorter than 80 cm suggests harvesting of annual crops relatively low to the ground, as opposed to harvesting only the ears of cereals, indicating that the straw was collected in addition to the grains.

The majority of the wild taxa flower in the spring and summer (March to June) (Fig. 6) and, assuming that they were collected together with annual agricultural crops, they can be used as proxies for date of harvest (Hansen 1991; Bogaard et al. 2001; Kreuz et al. 2005; McCorriston 2006; Allen 2017). Using plant life histories to estimate fruiting period, seeds were ripe approximately a month after flowering, in late spring and summer, which coincides with the harvest of cereals in the spring (April to May) and pulses in the summer (June to August) in this region (Samuel 2001; Zohary et al. 2012).

Orchard and grape harvest

In addition to the information on the season of harvest interpreted from the weed seeds, the timing of harvest and labor

Table 3 Wood charcoal

Taxon	Family	Common Name	Count	Weight (g)	Ubiquity (n = 27)
Angiosperms					
cf. Anacardiaceae	Anacardiaceae		4	0.16	4%
Pistacia cf. *atlantica*	Anacardiaceae	Possible mastic	1	0.32	4%
Pistacia cf. *palaestina*	Anacardiaceae	Possible terebinth	3	0.10	4%
Pistacia sp. (cf.)	Anacardiaceae	Pistachio	27 (1)	2.1 (0.07)	4% (4%)
Asteraceae	Asteraceae		3	0.08	4%
cf. *Arbutus* sp.	Ericaceae	Possible strawberry tree	1	0.25	4%
Fagaceae	Fagaceae		1	0.32	4%
Quercus calliprinos (cf.)	Fagaceae	Kermes/Palestine oak	19 (13)	2.68 (2.47)	15% (4%)
Q. ithaburensis/libani	Fagaceae	Tabor/Lebanon oak	5	0.39	4%
cf. *Punica granatum*	Lythraceae	Possible pomegranate	2	0.48	7%
Ficus cf. *sycomorus*	Moraceae	Possible sycamore fig	2	0.7	4%
Fraxinus sp.	Oleaceae	Ash	3	0.51	4%
Olea europaea (cf.)	Oleaceae	Olive	26 (21)	5.37 (1.11)	15% (7%)
Ziziphus/Paliurus (cf.)	Rhamnaceae	Christ's thorn	37 (16)	2.78 (0.59)	37% (7%)
Amygdalus dulcis/Prunus persica	Rosaceae	Almond/Peach	1	0.55	4%
cf. Maloideae	Rosaceae		1	0.29	4%
Prunoideae (cf.)	Rosaceae		2 (12)	0.15 (0.45)	7% (7%)
cf. Rosaceae	Rosaceae		40	1.2	33%
Tamarix sp. (cf.)	Tamaricaceae	Tamarisk	8 (17)	0.19 (0.25)	7% (11%)
Ulmaceae	Ulmaceae		1	0.67	4%
Vitis vinifera (cf.)	Vitaceae	Grape	1 (1)	0.08 (0.04)	4% (4%)
Angiosperm indet. (unknown)			61 (60)	2.71 (4.19)	30% (48)
Total			390	31.25	
Gymnosperms					
Ephedra alata	Ephedraceae		1	0.42	
Cedrus libani (cf.)	Pinaceae	Cedar of Lebanon	39 (30)	4.22 (1.08)	22% (30%)
Pinus sp. (cf.)	Pinaceae	Pine	264 (36)	17.634 (1.84)	52% (19%)
Gymnosperm indet. (unknown)			183 (18)	11.86 (1.18)	56% (7%)
Total			571	38.22	
Monocots					
cf. *Phoenix dactylifera* (vascular bundles)	Arecaceae			11.83	4%
cf. *Phragmites* sp.	Poaceae		2	0.001	7%
Unknown monocot			6	0.03	4%
Total			8	11.86	
Other					
Bark			1	0.91	4%
cf. Pith			3	0.07	7%
TOTAL			973	82.31	

were estimated for the 15 perennial orchard and vine crops identified. The remains of nutshells, pits or pips of 12 taxa were identified (Table 4); grape, fig, and cherry were also attested by carbonized fruit flesh. The harvest of these fruits mainly occurs in the summer and autumn (July to October) (Fig. 6), between the harvesting and sowing of annual crops, although olives provide a substantial harvest of fruit only every other year and they are often gathered during the autumn and winter in the southern Levant (Foxhall 2007, p 7; Decker 2009b, pp 150–152; Ebeling 2016). One notable

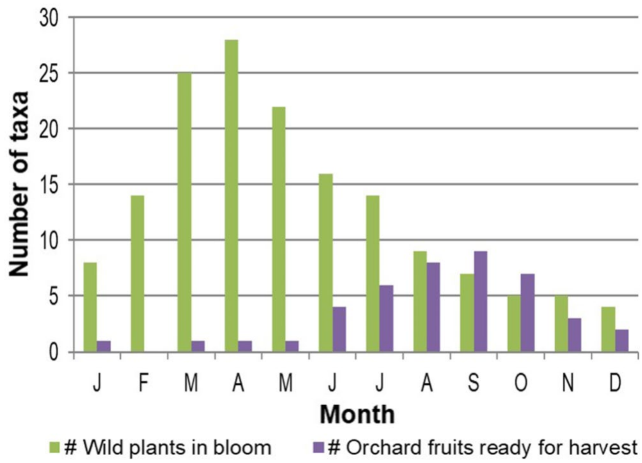

Fig. 6 Timing of the agricultural cycle based on flowering times of wild plants identified in the assemblage (green) and harvesting times of orchard crops in the assemblage (purple)

Table 4 Presence of tree and vine crop parts. Anatomical distinctions from Fahn et al. (1986), Schweingruber (1990) and Crivellaro and Schweingruber (2013). "X?" indicates possible identification

Taxon	Endocarp, seed	Fruit flesh	Wood
Olea europaea	X		X
Vitis vinifera	X	X	
Phoenix dactylifera	X		X
Ziziphus/Paliurus spina-christi	X		X
Ficus carica	X	X	
Ficus cf. *sycomorus*			X
Prunus domestica	X		X?
Prunus persica	X		X?
Prunus dulcis	X		X?
Prunus avium/cerasus	X	X	X?
Punica granatum			X?
Juglans regia	X		
Crataegus sp.	X		X?
Melia azedarach	X		
Pistacia spp.			X

exception is date palm, which is harvested in autumn and winter (September to January) (Tengberg 2012). While routine tasks such as watering would have been done during the dry months, the more labor intensive pruning of trees and vines is done twice a year: in the spring before the fruit begins to grow, and in the autumn and winter after the fruit is harvested (Samuel 2001; Foxhall 2007), which overlaps with both the harvest and the sowing of autumn sown annual crops such as wheat and barley.

In addition to nutshell, pits, and fruit flesh remains, fruit and nut taxa have been identified from their charcoal, with as many as 12 taxa (Table 4). Some charcoal pieces were identifiable only to subfamily or genus level. There is potential corroboration between pit remains and charcoal identifications for eight taxa, and perhaps a ninth, as *Ficus* seeds were identified as *F. carica*, the typical cultivar of the region, but the wood was *F.* cf. *sycomorus*, a tree native to east Africa and grown in parts of the southern Levant (Zohary 1966, p 38). Another corroboration of charcoal with fruit remains, although more speculative, is *Ziziphus spina-christi*. While the pits are distinctive, the wood of *Ziziphus* and *Paliurus* cannot be distinguished by anatomy alone (Fahn et al. 1986, pp 141–145).

Contextual analyses

When this assemblage is analyzed by context, three excavation areas stand out in terms of integrity of context and sample contents: Grid 25 revealed the remains of a large mixed-use building, Grid 37 a large residence, and Grid 57 a mixed-use residential quarter and refuse dump. While there are no samples from contexts identified as kitchens or workshops, which are taphonomically favorable for the preservation of plant remains, the contexts represented here preserve possible stores of food plants, distinct structural debris, as well as refuse from household and industrial activities.

Mixed-use building (Grid 25)

Sparse remains of *Vitis*, *Pisum sativum* (pea), *Hordeum*, *Triticum aestivum/durum* (bread/hard wheat), and indeterminate cereals, as well as a solitary *Fumaria* seed were recovered from the remains of this building. The most interesting finds from the destruction debris of this building are the charcoal of *Cedrus libani*, *Pinus* sp. and various angiosperms that could represent local vegetation (*Tamarix* sp., *Quercus ithaburensis/libani*, and *Ziziphus/Paliurus*) as well as domesticated taxa such as Rosaceae, Prunoideae, possible *Punica granatum* (pomegranate), and possible Anacardiaceae.

Large residence (Grid 37)

The two samples from Grid 37 were recovered from two adjacent rooms, accessible from the courtyard of a large residence (Fig. 7). The sample from the interior of Room 10 was comprised almost entirely of economic seeds: 238 whole grains totaling 0.98 g of *Hordeum*, and 1,942 whole grains totaling 39.38 g of *T. aestivum/durum*, with an additional 0.06 g of fragmented cereal grains and 226 broken *T. aestivum/durum* embryos. This large concentration of cereals is 84.7% of all whole, counted cereal grains in the assemblage, and 87.2% of all cereal grains in the assemblage by weight. Various pulses were also recovered, including *Pisum*, along with *Ficus carica* and *Olea europaea* remains. The seeds of cf. *Cynodon* sp., *Bromus*, Apiaceae represent

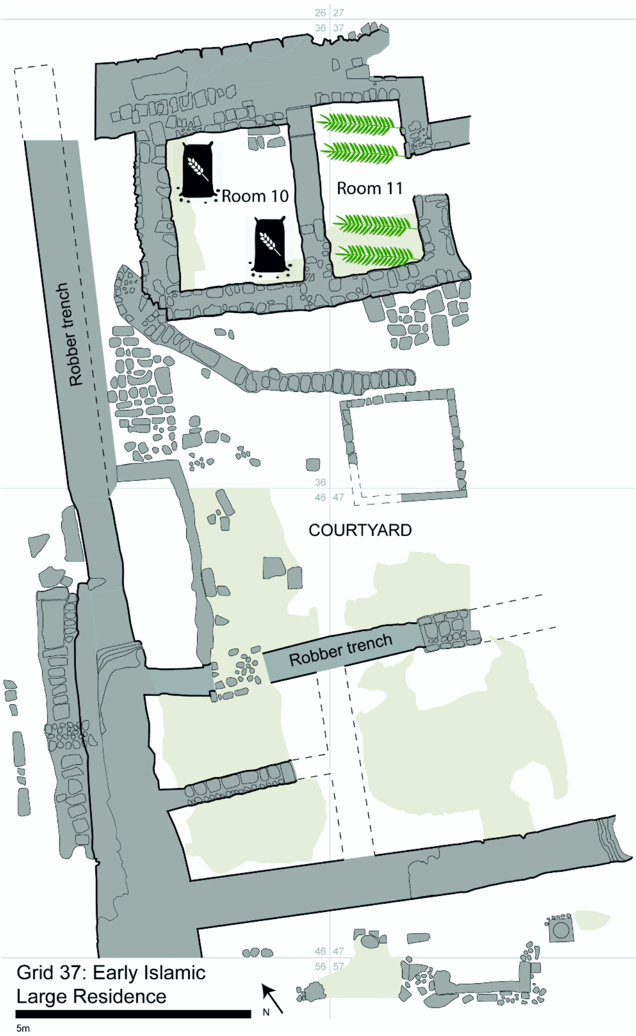

Fig. 7 Excavation plan of the large residence in Grid 37, showing the location of the outdoor rooms off the courtyard. The barley and wheat in Room 10 are represented by sacks of grain, and the possible date palm vascular bundles in Room 11 are represented by palm leaves, after Hoffman (2019, Fig. 9.2), by courtesy of the Leon Levy Expedition to Ashkelon

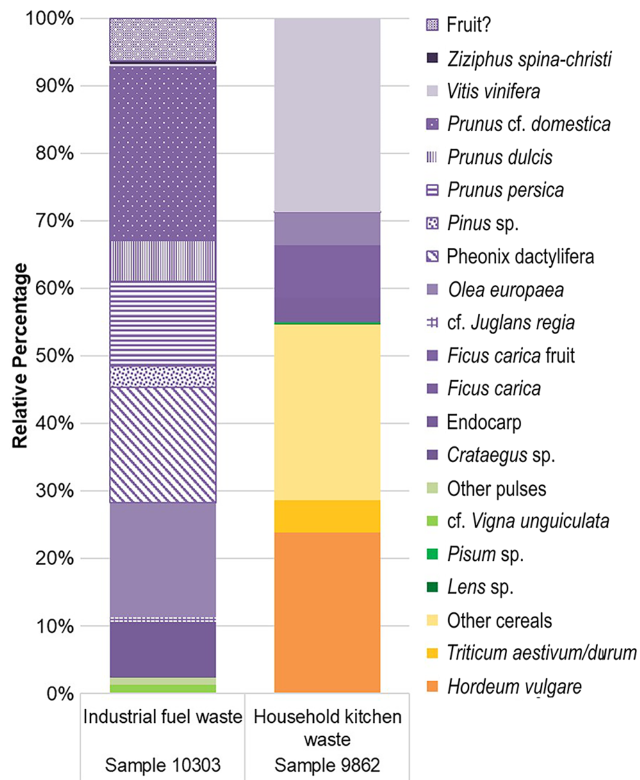

Fig. 8 Contents of two samples from Grid 57 that illustrate the differences between industrial fuel waste and household kitchen waste

common agricultural weeds on the coastal plain (Feinbrun-Dothan 1978; Zohary 1987).

In stark contrast, the sample from Room 11 contained no edible plants and was instead comprised of wood charcoal and leaf stem remains from destruction debris. The wood charcoal was dominated by indeterminate gymnosperm (conifer/softwood). Vascular bundles from the structural vessels of leaves of cf. *Phoenix dactylifera* were also identified (11.83 g).

Mixed-use residential quarter and refuse dump (Grid 57)

Samples collected from the refuse dump south of the main neighborhoods of the site contained a wide variety of plant remains, including solitary finds of taxa present nowhere else on the site. However, the majority of the samples are dominated by fruit remains, mostly endocarps (Table 2), and contain few edible economic seeds. Taphonomically, these inedible dense endocarps are more likely to preserve than less dense cereals and pulses. Only two samples are dominated by cereals, and they contain minimal or no fruit remains. Additionally, the samples from this grid contain the charred wood and vascular bundles from fruit trees (Table 3).

Two samples from Grid 57 were taken from a single refuse pit and are distinctly different in their contents (Fig. 8). Sample 9862 contained a large amount and variety of carbonized edible economic plants, including *Hordeum vulgare*, *Triticum aestivum/durum*, indeterminate *Triticum* and cereal, *Lens culinaris* (lentil), *Pisum sativum*, *Ficus carica*, *Olea europaea*, *Phoenix dactylifera*, *Vitis vinifera*, and a half *Vicia faba* (fava bean). In contrast, Sample 10,303 is dominated by fruit endocarps, including four *Prunus* taxa, *Olea*, *Crataegus* (hawthorn), *Phoenix*, as well as *Juglans regia* (walnut) shell and *Pinus* sp. cone scales. However, it was from this sample, with its near absence of edible plants, that two *Vigna* cf. *unguiculata* ssp. *unguiculata* (cow pea) were recovered (Fig. 9 A). These remains were identified by their irregular barrel-shaped cross section, relatively rectangular shape, and the location of the hilum on the end

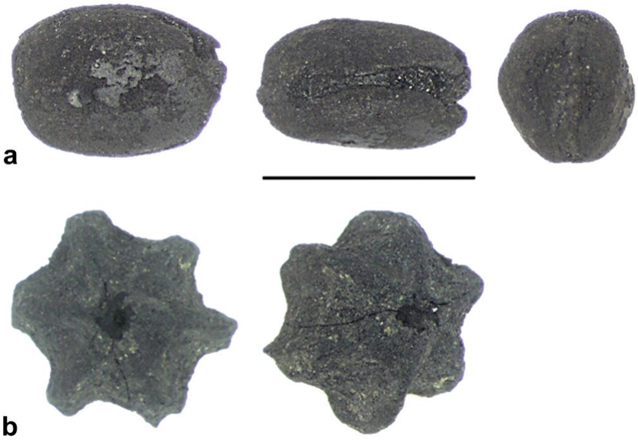

Fig. 9 Charred archaeological remains of A, *Vigna* cf. *unguiculata* ssp. *unguiculata* seed, lateral, top, and end views; B, *Melia azedarach* endocarp, top and slightly oblique views. Scale bar 5 mm

of the cotyledon as opposed to the center (Samuel 2001, p 454; D'Andrea et al. 2007, pp 688–690; Fuller 2020, pp 150–156).

Pinus cone scales were also found in samples 9862 and 10,303. An additional unique find (from another deliberate fill in Grid 57) is a solitary carbonized endocarp of *Melia azedarach* (Chinaberry tree or rosary tree) (Fig. 9B), which is identified by its globular shape and six symmetrical lobes, which appear as a six-pointed star in cross section (USDA 2022), which was recovered along with many other endocarps, especially those of *Prunus* spp.

Discussion

The preserved Early Islamic contexts at Ashkelon provide a unique opportunity to investigate the remains of plants utilized in the daily life of domestic areas and workshops, and to investigate the rhythm of economic plant production and consumption in an Early Islamic city. The analysis of plants from this site, and interpretation of them with respect to their contexts in domestic, industrial or refuse deposits, allows us to understand the organization of agricultural production and consumption. From there we can begin to understand the value that people at Ashkelon saw in these plants, as they were preferentially used in various areas of the city, and how these plants reflect local agriculture and trade connections for exotic plant-based goods.

Agricultural suite, strategies, and calendar

The agricultural suite of crops identified here include those typical of the eastern Mediterranean, with the staples at Ashkelon identified as bread or hard wheat, barley, olive, grape, date, fig, *Ziziphus spina-christi*, a variety of stone fruits, and a small selection of pulses that includes lentil and pea, and *Vigna* cf. *unguiculata* and *Vicia faba*. Taphonomic factors are the likely cause of the scarcity and fragmentation of cereals and pulses recovered across the site, the exception being two samples from the large residence in Grid 37 and the single sample from the mixed use residential quarter and refuse dump in Grid 57. It is unlikely that the scarcity of these economic staples reflects a low relative importance of annual crops in the economy of this site. Pulses are often under-represented at sites around the Mediterranean (Sarpaki 1992, pp 71–72; van der Veen 2007, p 978), making the several *Vigna* cf. *unguiculata* seeds particularly interesting finds. The weed height evidence points to the harvesting of annual crops low to the ground, indicating the economic value that people placed on straw and chaff for use as fodder, fuel, industrial or construction material.

The agricultural cycle that supplied the inhabitants of Ashkelon with their plant resources is typical for the region and would have provided harvests of fresh produce nearly year-round. Cereals and pulses were grown over winter and harvested in the spring and summer, while fruits were harvested in the summer, autumn and into the winter.

Local cultivation?

While cereals were a major staple in the Early Islamic economy and diet, current evidence from this assemblage does not allow us to determine whether they were grown locally, that is within the immediate vicinity of the ancient city of Ashkelon, or whether they were brought in from regions neighboring the coastal plain. This is in contrast to Weiss and Kislev's analysis of an Iron Age assemblage from this site, in which they were able to determine through phyto-ecological analysis of the weed seeds that the grain in the assemblage was imported from the Shephelah, the Judean Hills, and perhaps even Samaria and the Sharon Plain along with the northern and western Negev (Weiss and Kislev 2004; Weiss et al. 2011). Importantly, they also argue the possibility that the fields were located between the sand dunes which surround the tell, concluding that the agricultural hinterland of Ashkelon in the Iron Age was "partially local and partially distant" (Weiss and Kislev 2004, p 12).

The smaller corpus of ecological data gleaned from the plants from the Early Islamic site does not indicate whether annual crops were probably grown locally or elsewhere, as the wild taxa identified in this assemblage have broad ecological ranges, and include many common ruderal plants found across the whole Near East (Miller 2010; Forste and Marston 2019, p 652). It is interesting to note that one wild plant tentatively identified in this assemblage, *Descurainia sophia*, has been identified at Neolithic Çatalhoyuk from storage bins, suggesting its deliberate collection and storage for possible use as a flavoring agent together with other Brassicaceae taxa (Fairbairn et al. 2007; González Carretero et al. 2017). In this case, however, the limited number of possible *D. sophia* seeds here and their co-occurrence with ecologically similar taxa makes it more likely instead that these were field weeds.

There are, however, some annual crops which are unique to this assemblage and have not been found elsewhere across the southern coastal plain of this area, that merit additional discussion. *Vigna* cf. *unguiculata* ssp. *unguiculata* (cow pea, black-eyed pea, etc.) is a domesticate from sub-Saharan Africa that spread to India through trade across the Red Sea and Indian Ocean in the 2nd millennium BCE (D'Andrea et al. 2007; Boivin et al. 2014). While the exact timing and route of introduction into the Levant is uncertain (Heinrich and Wilkins 2014), *V. unguiculata* was also identified from Early Islamic farming villages in the middle Euphrates valley as a summer-grown legume (Samuel 2001) and from the Islamic Red Sea port of Quseir al-Qadim as an imported foodstuff (van der Veen 2011). Earlier evidence, both textual and archaeological, of *V. unguiculata* ssp. *unguiculata* in the wider Mediterranean world is debated (Heinrich and Wilkins 2014) and current evidence from this assemblage is insufficient to determine if these pulses were being grown locally or imported as dried foodstuffs.

On the other hand, there is substantial evidence among the perennial crops (fruit and nuts) indicating local arboriculture and viticulture. While a total of 15 fruit and nut taxa have been identified, 12 have been identified from nutshells, endocarps, or seeds, and of those, grape, fig, and cherry also from carbonized fruit flesh. Nine of these 12 taxa have also been identified from their charcoal, with two of them, *Pistacia* sp. and *Punica granatum*, only found as charcoal (Table 4). While some of the charcoal identifications do not match the taxonomic level to which the endocarp and nutshells were identified, the charcoal identifications do indicate that Prunoideae trees were grown nearby, even if we cannot specify the precise taxa.

Our interpretation of local arboriculture is strengthened when this direct archaeobotanical evidence is combined with textual evidence. A 6th century CE treatise from the urban architect Julian of Ascalon describes spacing and placement requirements for tree and vine plots, suggesting that they existed in and around the city at that time (Hakim 2001). Furthermore, the 10th century CE geographer al-Muqaddasī observed during his visit to Ashkelon that "fruit is here in plenty, especially that of the Sycamore-tree", interpreted to be *Ficus sycomorus* (al-Muqaddasī 1886, p 54).

One tree species present in this assemblage that is most probably not local is *Melia azedarach*. A native of the Himalaya region and southeast Asia, it was grown ornamentally in al-Andalus (Umayyad Iberia) by the 11th century CE (Bermejo and Sánchez 1998), but fell out of use by the 16th century when the Muslims were expelled from Spain (Hernández Bermejo 2009). It is tenuously suggested to have been introduced into the Levant by the 16th century (Danin 2004), and by the 20th century it was used as an ornamental shade tree in Iraq (Townsend et al. 1980, p 478) and around the Mediterranean region (Heywood 2017). Its timber is considered of moderate quality for construction, but while its fruits are toxic to humans, its pits are used as beads for rosaries and necklaces (Townsend et al. 1980, p 478).

Preferential use of plants for food, construction and fuel materials

Edible plant remains are found from across all excavation areas but are often scattered and in the form of sparse fragments of charred cereal grains or olive pits. The best evidence of food plants is found in samples from the large residence in Grid 37 and in the mixed-use residential quarter and refuse dump in Grid 57. In Grid 37, the store of *T. aestivum/durum* and *H. vulgare* in rooms around the large courtyard suggest specific food storage and can be extended to infer that houses had their own grain stores, but the location of food storage places in the rest of the living space is not known, because of the incomplete excavation of that house (Fig. 7). The weed seeds (cf. *Cynodon* sp., *Bromus* sp., Apiaceae) from this context could be remains from cleaning grain before it was put into storage. Two samples from Grid 57 we interpret to be the remains of household kitchen waste: mostly grains of *T. aestivum/durum* and *H. vulgare*, as well as fragments of pulses, a few fig, olive, pine nutshell and cone fragments, grape pips, and chaff. Weed seeds may have been discarded from a final hand-sorting before preparing grains for consumption (Fig. 8). While not recovered from a kitchen in situ, their recovery in a refuse area outside the main occupation area of the tell provides insight into waste disposal practices at Ashkelon.

The identification of the timber used in construction is made possible by the fact that wood charcoal was recovered from primary refuse or short-term deposits (Chabal et al. 1999; Asouti and Austin 2005, p 4) in the form of destruction debris from the two buildings, the mixed-use building in Grid 25 and the large residence in Grid 37. Carbonized *Cedrus* was recovered from the mixed-use building, and cedar has a history of being a much sought-after timber for use as beams in monumental buildings (Liphschitz 2007, pp 121–124).

In addition to hardwoods and conifers, the vascular bundles of *Phoenix dactylifera* leaf ribs were recovered from the destruction debris in a courtyard room of the large residence in Grid 37 (Fig. 7). Archaeological and ethnographic evidence from Egypt shows that date palm was used for roofing, furniture, woven baskets or mats (Zohary et al. 2012, p 131; Stevens and Clapham 2014, p 156).

Fruitstones are dense, highly combustible material that has been used for industrial fuel. Olive pits and pressing waste are well-known to have been used as fuel throughout the ancient world (Rowan 2015). Date stones were also the preferred fuel used by Babylonian silversmiths according to Strabo in *Geography* 16.1.4 (Jones 1930) and continued to be used by traditional Iraqi silversmiths into the 20th century (Townsend and Guest 1985). They were also used as fuel in Early Islamic Jarma, northern Libya (Pelling 2013). Keeping these characteristics and history in mind, the concentration of charcoal and endocarps of 12 fruit taxa in this refuse pit support their use as industrial fuel. This interpretation is further strengthened by the co-occurrence of discarded scraps of worked bone and metal slag in these samples. While these samples come from secondary and even tertiary or long-term deposits (Chabal et al. 1999), the "composition of the charcoal assemblage is likely to reflect lasting patterns of firewood selection and consumption" (Asouti and Austin 2005, p 4), making it possible to infer that even if fruit tree charcoal is low in relative abundance, the taphonomic and depositional details offer evidence that it was a regularly used resource. Furthermore, the refuse pits in Grid 57 containing both industrial and domestic waste point to a single stream of refuse discard outside of the major neighborhoods, suggesting that these waste products came from nearby spaces and indicating the purposeful separation of living and working spaces from waste dumps.

The agricultural package at early islamic Ashkelon

Considering the botanical data with the faunal data allows us to make inferences about large-scale agricultural practices at Early Islamic Ashkelon. The relatively small number of cattle bones suggests limited availability of working animals for plowing and pulling carts, which points to relatively extensive modes of field crop cultivation (Hesse and Fulton 2019, p 670). This, taken together with the evidence of bone working and metallurgy in the city, suggests a focus on small industry rather than agriculture (Hesse and Fulton 2019, p 670). The Yavneh dune fields are the nearest studied sites of cultivation. More specifically, we find that the agricultural economy at Ashkelon concentrated on the various products of orchards, olive groves and vineyards that supplied two economic sectors, consumable food commodities and industrial combustibles, and the latter literally fueled the metal and bone working craft industries.

Conclusion

This analysis of the botanical remains from Ashkelon provides new data about urban agricultural economies of the Early Islamic period and the use of plants within specific residential and industrial contexts. The crop plants recovered here are typical of the region but also include unusual finds of *Vigna* cf. *unguiculata* and *Melia azederach* that hint at long distance trade connections which are not yet clear from the archaeological record.

Considering the specific information from Ashkelon with that from the wider region, a new interpretation of the character of the economy can be put forward. This archaeobotanical evidence shows agricultural production of more than edible portions meant for human consumption. The harvesting of cereals low on the stalk suggests that straw was collected for other uses, while tree fruit cultivation also produced a source of fuel for metallurgy and bone-working. Taken together with extensive ways of farming shown by the plot-and-berm fields, the regional agricultural economy thrived during the Early Islamic period thanks to the innovation of farmers and agricultural decision makers. At the same time, Ashkelon remained a major urban hub and maintained its status and population as a city, as an example of the "intensification" portion of Avni's "intensification and abatement" settlement model.

The inconclusive ecological information from wild plants combined with the faunal evidence of few cattle available for working on the surrounding land suggest that the Early Islamic agricultural economy of Ashkelon was less dependent on the local cultivation of annual crops than other sites, or than it was during other periods such as in the Iron Age (Weiss and Kislev 2004) and Hellenistic period (Marston and Birney 2022). We suggest that the economy instead specialized in arboriculture, as described above, which provided edible fruit and secondary products as well as fuel to support the expanding small industries of bone working and metallurgy. Archaeobotanical remains help to detect activity areas, especially in the mixed-use places and spaces used for multiple activities that are so common at Ashkelon, as at other Early Islamic cities. By identifying the spatial distribution of archaeobotanical remains, we identified several discrete ways in which people used plants at Ashkelon. By distinguishing between industrial, domestic, and refuse spaces, we can begin to understand the value of specific plants and their various products among these various economic areas of the city. Furthermore, knowing the specific find locations and associations of plants provides information about which plants might have been used together.

Accordingly, we identified the storage of cleaned wheat and barley in individual households, and the preferential use of pine and cedar of Lebanon timber in construction of a large house. We also identified an overlap in discard location of waste from craft industries and kitchens, and a co-occurrence of taxa identified from fruit endocarps and charcoal that evidence local arboriculture. Our identification of endocarps as industrial fuel remains, based on concentrations of dense and highly combustible material and the presence of discarded scraps of worked bone and metal slag, reveals the overlap between industrial and agricultural production, and of artisan and agricultural economies.

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Data Availability Botanical data and wild plant heights available in Electronic Supplementary Material.

Declarations

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