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Hellenistic agricultural economies at Ashkelon, Southern Levant

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Abstract
Agricultural economies of the Hellenistic era (323–30 BCE) are poorly understood from primary plant and animal remains despite the extent of sites and rich historical records dating to this period. Here we present archaeobotanical remains from Hellenistic Ashkelon, an urban centre on the Mediterranean coast of the southern Levant, in comparison with a survey of the extant literature on Hellenistic archaeobotany across the eastern Mediterranean. Agricultural systems at Ashkelon focused on the cultivation of cereals, pulses, grapes, and figs, as did those of many other Hellenistic sites. We identify *Triticum dicoccum* (emmer) as a core component of agriculture at Ashkelon, a new finding for the period. Re-examination of other published Hellenistic assemblages from the southern Levant additionally suggests that *T. dicoccum* cultivation has been underappreciated to date and may have been regionally widespread, a legacy of Ptolemaic Egyptian control of the region in the early Hellenistic. A spatial and diachronic analysis of archaeobotanical remains in conjunction with the archaeological evidence at Ashkelon indicates a shift in practices of domestic food preparation towards increasing commercialization of food preparation. Further detailed archaeobotanical study of other Hellenistic cities is needed to establish whether this trend extends beyond Ashkelon during the period.

Keywords Agriculture · Archaeobotany · Cooking · *Triticum dicoccum* · Hellenistic · Political economy

Introduction

The Hellenistic era (323–30 BCE) was a period of considerable social and economic change for many inhabitants of the eastern Mediterranean and western Asia, as economic and cultural networks realigned from Persian to Macedonian Greek control (Rostovtzeff 1941; Bugh 2006). Agricultural economies were no exception; numerous textual sources that survive from this period, especially in Hellenistic Egypt and Mesopotamia, provide insight into changed aspects of land tenure and agricultural policies (Aperghis 2004; van der Spek 2007; Bagnall and Derow 2008). Missing from these accounts, however, is detailed evidence for community-level agricultural systems outside of Egypt and parts of Babylonia. At the same time, archaeological studies of Hellenistic agriculture are few, rendering our understanding of the diversity of agricultural systems in the Hellenistic world incomplete.

Three lines of archaeological evidence contribute to a discussion of agricultural systems in the Hellenistic: studies of durable agricultural installations (e.g. grain mills, wine and olive presses), zooarchaeological remains, and archaeobotanical remains. A few synthetic studies of agricultural installations exist (Isager and Skydsgaard 1992; Foxhall 2007; Ayalon et al. 2009), alongside a rare few syntheses at the regional scale of the animal (e.g. Lev-Tov 2003) and botanical components (e.g. Margaritis 2016; Orendi et al. 2021) of Hellenistic agropastoral systems. Both zooarchaeological and archaeobotanical syntheses, however, are limited for the Hellenistic in comparison to earlier and later periods. Archaeobotanical studies are particularly rare, with scattered reports from Macedonia (Margaritis and Jones 2008; Margaritis 2014, 2015) to Kuwait (Willcox 1990) that focus on the analysis of single or closely clustered sites.

In this article, we address this gap by providing a systematic review of published archaeobotanical evidence for

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agriculture across the Hellenistic world, building on recent work by Orendi et al. (2021), and into that discussion contribute new archaeobotanical evidence from Hellenistic period occupation of Ashkelon, a major urban centre on the southern Levantine coast. Through intra-site spatial analysis of the deposition of botanical remains and comparison with comparative published assemblages, we assess local agricultural strategies and both overland and seaborne trade in the Hellenistic southern Levant, a contested borderland between the Seleucid and Ptolemaic kingdoms. This study thus informs ongoing dialogues regarding political economy and agriculture of urban centres under empire (Marston 2017b, in press; Lentz et al. 2018; Morehart 2018; Rosenzweig and Marston 2018).

Archaeological evidence for Hellenistic farming practices

Evidence from Macedonia and Greece

The most robust archaeological evidence for Hellenistic agriculture comes from the excavation of several urban and country estate contexts in Pieria, southern coastal Macedonia, at which Evi Margaritis conducted extensive archaeobotanical research (Margaritis and Jones 2008; Fig. 1; Margaritis 2014, 2015, 2016). Margaritis' study includes one urban context, a *kapeleio* (tavern) of Krania, the harbour district of the city of Heraklio (Margaritis 2014, 2015), and three rural estates, Platania (Margaritis and Jones 2008; Margaritis 2015, 2016), Kompoloi (Margaritis and Jones 2006; Margaritis 2015, 2016), and Duvari, a smaller farmhouse that may have been located within the agricultural territory of Kompoloi (Margaritis 2016, p. 347). Summary results from these analyses are presented in Table 1, in comparison to results from other regions described below.

The *kapeleio* of Krania was devoted to cooking and destroyed by fire, providing a rich assemblage of plant remains, though mostly in secondary depositional contexts (Margaritis 2014, 2015, pp. 343–344). The sesame seeds and pine bracts were found in pure deposits in one room, suggesting storage for food preparation in that space (Margaritis 2014, pp. 109–110, 113–114). The most common cereal across all deposits was *Hordeum vulgare* (barley), with free-threshing wheat (*Triticum aestivum* or *T. durum*, the seeds

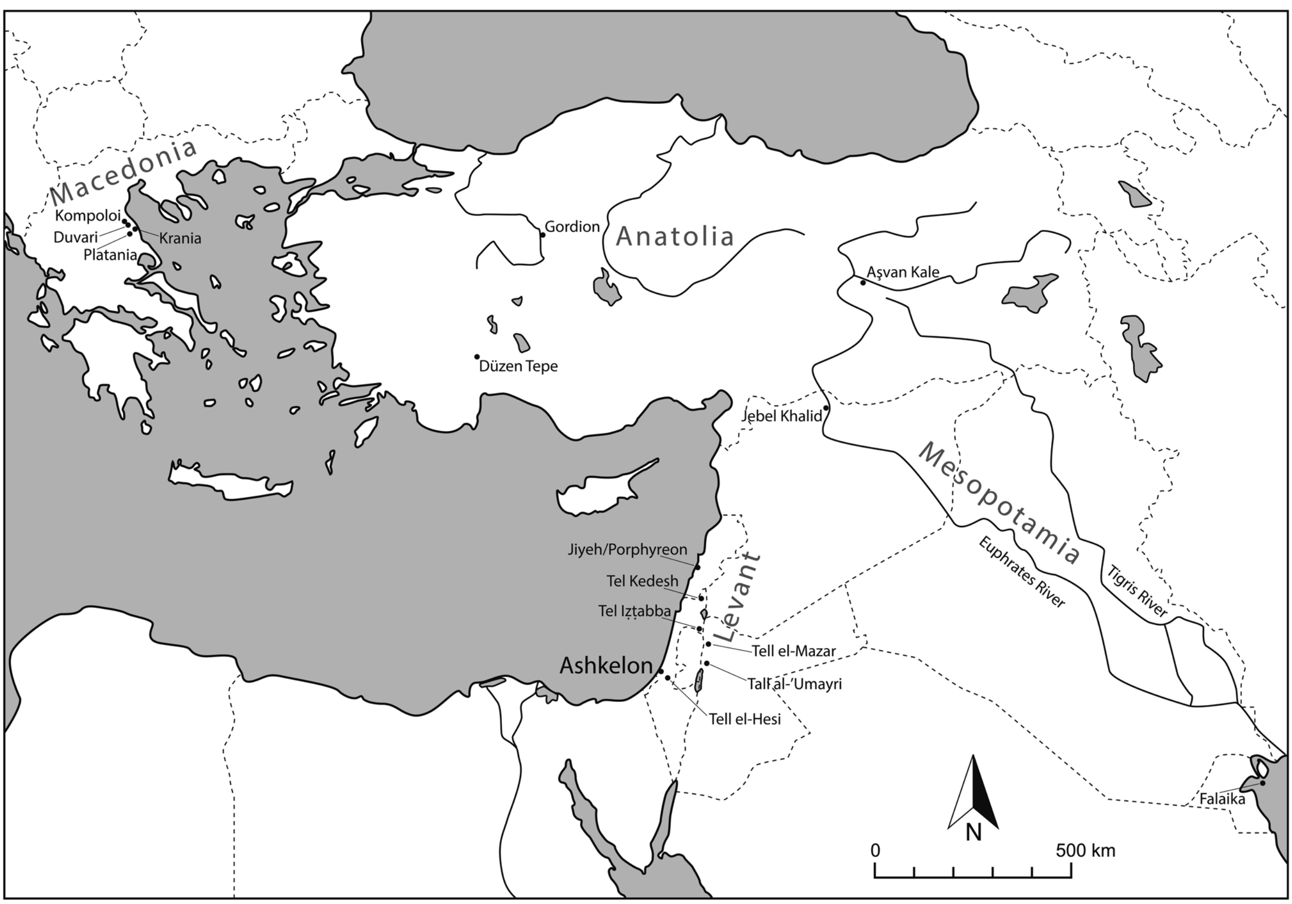

Fig. 1 Map of the eastern Mediterranean and Southwest Asia, indicating the location of sites and regions mentioned in the text

Table 1 Presence of food plants at Hellenistic sites in the Eastern Mediterranean, by region. Ashkelon results from this study; data from other sites from sources cited in the text

Region	Macedonia				Anatolia			Levant							Gulf
Site	Krania	Duvari	Kompoloi	Platania	Düzen Tepe	Gordion	Aşvan Kale	Tell el-Hesi	Ashkelon	Tel Kedesh	Tall al-ʻUmayri	Tell el-Mazar	Tell Iẓṭabba	Jiyeh/ Por-phyreon	Falaika
Cereals															
Avena sativa	x			x		x									
Hordeum vulgare	xx			xx	xx					xx	x		x	x	
H. vulgare ssp. *distichum*						xx	xx					x			x
H. vulgare ssp. *hexastichum*						xx	xx	xx	xx						
H. vulgare var. *nudum*	x			x			x		x						x
Panicum miliaceum						x	xx								
Secale cereale	x			x		x									
Setaria italica						xx	xx								
Triticum aestivum			x	x		xx				x*					x
T. aestivum/durum	xx			xx	xx		xx	xx	xx	xx		xx	xx		
T. durum				xx									x		
T. dicoccum	x			x		x		x	xx	x		x	xx		
T. monococcum	x			x		x			x						
T. spelta	x			x											
Pulses															
Cicer arietinum					x	x	xx	x	x		x				x
Lens culinaris	xx		x	xx	x	xx	xx	xx	xx	x	x	x	xx		x
Lathyrus sativus	xx							x			x	x			
Pisum sativum	xx				x		xx	x	x				x		
Vicia ervilia	xx			xx	xx	xx	xx	xx	x	x	x	x	x		
Vicia faba	x							x				x			
Fruits															
Cornus mas				x											
Ficus carica	x		x	x					xx	xx	x		xx	xx	
Olea europaea	x		x	xx				xx	x	x	x		xx	xx	
Phoenix dactylifera													x		x
Pistacia sp.							x		x	x					
Pyrus sp.										x					
Rubus fruticosus				x											
Sambucus ebulus	x			x											
Vitis vinifera	x	xx	xx	xx	x	x	xx	xx	xx	x	x		xx	xx	
Ziziphus spina-christi				x					x						
Nuts															
Corylus avellana	x			x											
Juglans regia	x			x											
Pinus pinea	x														
Prunus dulcis	x			x			x								
Oil Seeds															
Carthamus tinctorius						x									
Lallemantia iberica					x										
Linum usitatissimum	x						xx	xx				xx	x		
Sesamum indicum	xx														

x = present; xx = numerous enough to be considered a crop (by original authors); * = identification from phytolith analysis of which are indistinguishable) also ubiquitous, and *Lens culinaris* (lentil) the most common pulse, followed by *Vicia ervilia* (bitter vetch), *Pisum sativum* (pea), and *Lathyrus sativus* (grass pea).

The rural estates of Platania, Kompoloi, and Duvari possessed varied agricultural economies. At Duvari, the smallest of these, hundreds of grape pips (*Vitis vinifera*) were found within and around a *pithos*, suggesting wine production and storage (Margaritis and Jones 2006; Margaritis 2015, p. 341). Kompoloi, a country estate with both living and storage areas, was centred on wine production (Margaritis and Jones 2006; Margaritis 2015, pp. 340–341). Trampling of grapes took place offsite, presumably in the fields in stone presses or portable vats, followed by transport to the estate, where fermentation in *pithoi*, retrieval (and eventual combustion) of wine dregs during decanting and, finally, export of the wine as a commercial enterprise occurred (Margaritis 2016, p. 191). Notably, all other archaeobotanical finds from Kompoloi were found near a hearth within the living quarters, and no evidence exists for on-site crop processing of any product beyond wine (Margaritis 2015, p. 341, 2016, p. 192).

Evidence from Platania indicates a more diverse agricultural strategy. The site, contemporaneous to Kompoloi, consists of a main structure, a walled courtyard used for domestic activities, and numerous exterior structures for agricultural activities (Margaritis 2016, pp. 193–194). An analysis of wild seeds and cereal chaff fragments indicates that initial threshing took place to the south of the main building with later stages of crop processing elsewhere in the building (Margaritis 2015, p. 342, 2016, p. 196). Grapes were widely consumed, likely both as fruit and wine, and the presence of pure concentrations of thousands of seeds in one area of the building indicates wine production onsite, though of a much smaller scale than at Kompoloi (Margaritis 2016, p. 196). *Olea europaea* (olive) endocarps represent the product of olive oil production and the subsequent combustion of the remaining flesh and seeds as fuel (Margaritis and Jones 2008; Rowan 2015; Braadbaart et al. 2016). Taken together, these studies illustrate the range of foods used in Hellenistic Macedonian cooking, the scale of the olive oil and wine industries, and the agricultural staples of Macedonia: *Triticum aestivum/durum* and *Hordeum vulgare*, *Lens culinaris* and *Vicia ervilia*, *Olea europaea* and *Vitis vinifera*.

Evidence from Anatolia

Two robust Hellenistic assemblages have been published from Anatolia: those of Gordion, in central Turkey (Miller 2010; Marston 2017a), and Aşvan Kale, in eastern Turkey (Nesbitt et al. 2017), in addition to summary botanical remains from the site of Düzen Tepe, in southwestern Turkey (Fuller et al. 2012; Cleymans et al. 2017). At Gordion, cereal agriculture focused on *Triticum aestivum* (bread wheat) and both *Hordeum vulgare* subsp. *distichum* (two-row barley) and *H. vulgare* subsp. *hexastichum* (six-row barley), with millet (mostly *Setaria italica*, foxtail millet) a secondary crop; other cereals were likely contaminants of wheat and barley fields (Marston 2017a, pp. 108–109). Grape seeds were infrequent but more common during the Hellenistic than earlier or later; the few *Carthamus tinctorium* (safflower) achenes may represent a plant grown locally for oil in an environment where olives do not thrive (Marinova and Riehl 2009). Analysis of wild seeds indicates that dung fuel use was relatively high during the Hellenistic (Marston 2011; Miller and Marston 2012).

Aşvan Kale was destroyed by fire in 66 BCE during a Roman military campaign, preserving rich archaeobotanical deposits in a wealthy Late Hellenistic house (Nesbitt et al. 2017, pp. 10, 16). Burned caches of stored seeds include *Hordeum vulgare* (hulled, primarily two-row), *T. aestivum/durum*, *Panicum miliaceum* (broomcorn millet), *Setaria italica*, *Cicer arietinum* (chickpea), *Vicia ervilia*, and *Linum usitatissimum* (flax). Other deposits derive from crop-processing waste and incidental inclusions of seeds of other cultivated taxa. There is no evidence of dung fuel use during the Hellenistic period. The authors conclude that *H. vulgare*, especially the two-row type, was the most important cereal crop during the Hellenistic, followed by *T. aestivum/durum, P. miliaceum* and *S. italica*; *L. culinaris* and *V. ervilia* were the primary pulses grown, with *P. sativum* and *C. arietinum* also cultivated; *L. usitatissimum* and *V. vinifera* were significant oil and fruit crops (Nesbitt et al. 2017).

Botanical evidence from Düzen Tepe (ca. 400–200 BCE) has been published only in summary within comprehensive studies of agropastoral systems (Fuller et al. 2012) and foodways (Cleymans et al. 2017). Few charred plant remains were recovered: 515 countable macroremains from 876 L of sediment, fewer than 1 seed/L (Cleymans et al. 2017, p. 67). *T. aestivum/durum* and an unspecified type of domesticated *H. vulgare*, at a ratio of 1.6:1, were the primary cereal crops, with pulses (primarily *V. ervilia*) constituting 16% of total finds (Cleymans et al. 2017, p. 77). *Vitis vinifera* remains are confirmed as local products as a trace of grapevine pollen was found in nearby pollen cores dating to this period (Vermoere 2004), indicating local cultivation as grapevine deposits pollen only in immediate proximity of the plant's flowers.

Evidence from the Levant and Gulf

We include here six published studies of macrobotanical remains from the Hellenistic period Levant: Tell el-Hesi, 20 km inland of Ashkelon (Stewart 1978); Tel Kedesh (Berlin et al. 2003; Borojevic 2011) and Tell Iẓṭabba (Orendi et al. 2021), in northern Israel; Tall al- ʻUmayri (Ramsay and Mueller 2016) and Tell el-Mazar (Yassine and Steen 2012), in western Jordan; and Jiyeh/Porphyreon (Badura et al. 2016), in Lebanon. While there are several other published botanical reports from the area (recently summarized by Orendi et al. 2021), others include few samples or finds, and so we include here only those with more than ten published samples and at least partially quantitative reporting of results. Reporting varies substantially among these reports. Tell Iẓṭabba and Tell Kedesh are the most numerous in sample count and robust in sample reporting, although the Tel Kedesh assemblage includes evidence of bioturbation, complicating chronological attribution of the seed remains. Jiyeh/Porphyreon includes many samples of uncertain chronological assignment; in Table 1 we include only samples solely and definitively identified as Hellenistic, for both Tel Kedesh and Jiyeh/Porphyreon. Both Tell el-Mazar and Tall al- ‘Umayri are small assemblages, with only 11 samples each, but they differ significantly in the number of seeds recovered, with only a few dozen seeds recorded from Tall al- ‘Umayri while Tell el-Mazar includes large storage caches of *Linum usitatissimum* and *T. aestivum/durum* numbering more than 10,000 seeds. Results from Tell el-Hesi are not presented using sample-by-sample reporting and standardized volume measurements expected by modern standards of quantitative analysis (Marston 2014; Pearsall 2015). As a result, direct quantitative comparison of the remains from Ashkelon (and other sites) to this assemblage is not possible, which is disappointing as it is the closest geographically to Ashkelon.

Although Tell el-Hesi and Ashkelon lie close to one another, they differ in climate. In most years, Tell el-Hesi receives a Mediterranean climate, with 300–400 mm of rain between November and April, the prime growth period for winter wheat and barley. The site falls along the edge of the Negev, however, and during more than one in ten years (based on 1930–1960 data) rainfall totalled < 200 mm (Stager 1971, p. 86), insufficient for rainfed *Triticum* and *Hordeum* cultivation (Riehl et al. 2014). Archaeobotanical remains at Tell el-Hesi come primarily from a series of Persian-era storage pits, roughly 1–2 m in diameter and 2–2.5 m deep, with fills dated to the early Hellenistic period (synchronous with Ashkelon Period VIII described below) based on pottery and interpreted as containing the long-term deposition of domestic waste (Stewart 1978, pp. 379–380; Blakely and Horton Jr. 2001). Subsistence was based on locally cultivated cereals (*T. aestivum/durum* and six-row *H. vulgare*), pulses (*V. ervilia* and *L. culinaris*), and *V. vinifera*, which Stewart suggests was “probably brought from nearby areas where moisture was a bit more dependable” (1978, p. 380). Wheat was the preferred cereal grain by a more than 2:1 ratio over barley, and Stewart interprets *Triticum dicoccum* (emmer) present in these samples as “probably a weed” (1978, p. 380). He also notes numerous wild seeds, especially *Lolium temulentum*, a common weed of cereals, which was present in substantially greater numbers than all other wild seeds combined.

Macrobotanical evidence from the second century BCE administrative complex at Tel Kedesh suggests that *T. aestivum/durum* and *H. vulgare* were crops, as was *Ficus carica* (fig) (Borojevic 2011). A parallel phytolith study of vessel contents from large storage jars identifies phytoliths of *T. aestivum* and argues that crop was stored within the vessels (Berlin et al. 2003). Berlin et al. (2003) then connect *T. aestivum* with the ambiguous crop “Syrian wheat” that is described in contemporary Ptolemaic papyri. They argue that this species would have been unfamiliar to most Egyptians at the time, who relied on *T. durum* (hard wheat) and *T. dicoccum* for their staple bread (Crawford 1979; Thompson 1999; Mayerson 2002), hence the regional descriptor.

Tell Iẓṭabba, part of the settlement of Beth She’an (historically known as Nysa-Scythopolis), lies across the Ḥarod River from the main site and was settled only intermittently, including a discrete, short-lived second century BCE Seleucid settlement (Orendi et al. 2021). Botanical samples come from secure, well-dated contexts constituting floors and associated occupational fills of residential courtyard houses, destroyed during the expansion of the Hasmonean kingdom under John Hyrcanus in 108/107 BCE. Samples averaged 6.5–13 L in volume and were hand floated; the greatest density of finds comes from an extensively sampled silo, in which more than half of all seeds were found but still in relatively low densities (Orendi et al. 2021). The silo contained primarily *T. aestivum/durum* grains and hulled wheat chaff, as well as small quantities of seeds of *Lens culinaris*, *Vicia faba* (fava bean), *Linum usitatissimum*, *Ficus carica*, *Olea europaea*, *T. dicoccum* grains, *H. vulgare*, and *Vitis vinifera*; charred wild seeds are primarily field weeds, especially *Lolium temulentum*, *Trifolium* spp. (clover), and other grasses. This diversity of finds suggests that the silo fills are redeposited waste from domestic food preparation, including final processing stages of hulled wheat preparation. Botanical finds from floor contexts are more poorly preserved and include barley, free-threshing and hulled wheats, lentil, olive, and grape, alongside numerous wild plant seeds. The authors note that the preference for wheat over barley matches regional patterns in the southern Levant wherein areas with more abundant water supplies (such as Tell Iẓṭabba) preferred the cultivation of *Triticum* over *Hordeum*.

Less substantive are the small assemblages from Tall al- ‘Umayri, Tell el-Mazar, and Jiyeh/Porphyreon. Tell el-Mazar includes botanical data only as an appendix, with little discussion of stratigraphy and no discussion of the botanical finds themselves, yet includes two samples with massive, nearly pure concentrations of seeds: one of *T. aestivum/durum* and one of *L. usitatissimum* (Yassine and Steen 2012, pp. 163–166). These must result from burned storage contexts, presumably the original contents of one of the storage silos/pits that comprise the Hellenistic Stratum I at the site and are thus highly suggestive of local cultivation of these two crops, potentially among others. The authors attribute the site's function to a supply depot, perhaps for administrative (i.e. tax collection) or military use, during the Hellenistic period (Yassine and Steen 2012, pp. 14–15). The few samples from Tall al- 'Umayri and Jiyeh/Porphyreon contain sparse finds that suggest the consumption of cultivated *Olea europaea*, *Vitis vinifera*, and *Ficus carica* at Jiyeh/Porphyreon. The variety of pulse and fruit remains found at Tall al- 'Umayri, despite the low number of finds, is intriguing, although the limited number of seeds recovered (45 in total; Ramsay and Mueller 2016, p. 19) precludes identification of local agricultural practices. These authors note, however, that wine presses attributed to the Hellenistic period are found locally, suggesting local wine production and thus also local cultivation of grape (Ramsay and Mueller 2016, p. 16).

Finally, the site of Failaka in Kuwait presents an unusual assemblage (Willcox 1990). Archaeobotanical samples come from features identified as domestic ovens, but total only eight samples. Crops include *T. aestivum*, two-row hulled *H. vulgare* and naked *H. vulgare* (var. *nudum*), as well as a small-seeded variety of *Lens culinaris*. Numerous small-seeded wild legumes are attributed to the remnants of dung burned as fuel (Miller and Smart 1984; Miller and Marston 2012). With the exception of *Phoenix dactylifera* (date), all crops would have required irrigation to grow in this arid environment, as mean annual precipitation is only 100 mm, insufficient for rainfed cereal or pulse farming (Willcox 1990, p. 43). Willcox (1990, p. 48) argues that the lack of agricultural weeds indicates that local agriculture was limited and the grain likely processed elsewhere and imported.

Expectations for Ashkelon

Despite the scarcity of Hellenistic assemblages published from the Levant, commonalities across other areas of the Hellenistic world provide a comparative context in which to place the agricultural system of Hellenistic Ashkelon (Table 1). Synthesizing these data, we see a focus on cereal agriculture of *T. aestivum* and *H. vulgare* (including six- and two-row hulled, and, in at least two instances, a naked variety), pulse agriculture focusing on *Lens culinaris* (with varying importance of others, especially *Vicia ervilia*), with contributions from fruit and oil plants limited by local environmental factors (e.g. no olive and fig outside the Mediterranean littoral). *Vitis vinifera*, *Ficus carica*, and *Olea europaea* appear to be common where they could be grown. *H. vulgare*, especially six-row types, which were numerous at Gordion, Aşvan Kale, and Tell el-Hesi, is commonly used as animal fodder as well as human food, while naked *H. vulgare* (present at Platania, Krania, and Failaka) is considered a crop grown for human consumption (Willcox 1990, p. 46). Similarly, *V. ervilia* is often grown as fodder for ruminant animals, though it was also widely consumed by people in antiquity, albeit sometimes under conditions of scarcity (Miller and Enneking 2014). The widespread co-presence of *H. vulgare* and *V. ervilia* suggests the cultivation of fodder crops on a regional scale. *T. dicoccum* was clearly not grown as a crop at Gordion or in Macedonia, and though its precise frequency is not recorded at Tell el-Hesi (lumped with "other crops"; Stewart 1978, p. 381), it was certainly much less numerous than *T. aestivum/durum* and hulled *H. vulgare*, as was the case at Tel Kedesh (Borojevic 2011) and Tell Iẓṭabba (Orendi et al. 2021). Thus, we expected to find *T. aestivum/durum* and *H. vulgare*, *Lens culinaris*, and *Vitis vinifera* and *Olea europaea* as the primary plants consumed at Hellenistic Ashkelon, with the possibility of *V. ervilia*, *T. dicoccum*, and other fruit (especially *Phoenix dactylifera* and *Ficus carica*) as significant contributions to the diet. Additionally, chance finds of less commonly preserved botanical remains, including oil seeds (e.g. *L. usitatissimum* or *Sesamum indicum,* sesame) and vegetables, might be expected based on historical records from Ptolemaic Egypt and Seleucid Babylonia that detail minor field crops and gardens planted at the household scale (Grainger 1999; Thompson 1999; Aperghis 2004; Monson 2012).

The archaeology of Hellenistic Ashkelon

Geography and ecology

Ashkelon sits directly on the modern coastline of southern Israel. The city was built atop a bedrock of loosely cemented sandstone (termed *kurkar*), which also forms a series of high ridges used as the base for city fortifications over multiple periods (Koucky 2008). The sediments on which the city was built include a combination of Pleistocene palaeosols, early- to mid-Holocene alluvial and estuarine deposits, and scattered mid- to late-Holocene sand dunes (Rosen 2008). Rainfall in the region is limited, averaging 350 mm per year, with rainfall concentrated during winter months but morning dew a constant factor through the summer (Koucky 2008). Additional water is supplied by a high water table with substantial flows easily accessible through wells; this water appears to have been an integral component of agricultural systems, used for late-spring/summer irrigation (Nir 2008).

Today, the Ashkelon region contains distinct plant communities growing as ruderals, field weeds, and on dunes. Contemporary wild plant ecology, however, differs substantially from that prior to the introduction of mechanization and herbicides, and expanded urbanization, since the mid-20th century. Surveys of vegetation communities prior to that date and in the early period of industrialization (e.g. Eig 1939; Zohary 1950, 1962, 1973) are more informative than modern surveys as to the nature of crop weeds, as well as wild plant community composition. Zohary (1973, p. 264) concludes that the Coastal Plain was never naturally wooded and identifies two plant communities that match the inland geology of Ashkelon: Prosopidion farcatae and Eragrostion bipinnatae. The former association is found on alluvial and colluvial soils and is both widespread and diverse, with some 200 species of plants, including cosmopolitan noxious weeds and locally numerous annuals and perennials; it is typified by *Prosopis farcta*, a deep-rooted mesquite shrub (Zohary 1950, pp. 394–396, Table 1). The latter association is confined to sandier soils and is primarily a Saharo-Sindian plant community of savannas and saline soils (Zohary 1950, pp. 403–405, 407–408). Further characterization of local sand dune vegetation communities by Zohary (1962, 1973, p. 264) includes description of dune-binding plants that are currently widespread, but likely were not characteristic species of the area of Ashkelon prior to the Byzantine period, as geological studies and historical sources alike indicate that dunes were later arrivals (Koucky 2008, p. 12) and Hellenistic texts describe a regional landscape characterized by seasonal watercourses and estuaries (*Letter of Aristeas* 113.117). It does appear, however, that sandy areas were periodically mined for construction fills in antiquity, as argued by Weiss and colleagues (Weiss et al. 2011, pp. 603–605) based on the presence of nutlets of *Echiochilon fruticosum* var. *sieberi* (an obligate dune plant) within Persian floors of Ashkelon.

Urban organisation

Throughout most of the Hellenistic period, occupation at Ashkelon was concentrated on the South Tell, one of two enclosed within the raised kurkar ridge that encircled the city on three sides (Fig. 2). The Hellenistic city maintained the urban plan established in the preceding Persian period, a design first laid out by the Phoenician architects who rebuilt Ashkelon when the city was resettled in the fifth century BCE after a period of abandonment. The new city on the South Tell was built on a largely orthogonal grid, possibly encircled by a ring road, and organized into constructed neighbourhoods of *insulae* separated by north–south streets and east–west alleys of roughly uniform width.

Four Hellenistic neighbourhoods were excavated on the South Tell (Fig. 2). In excavation Grid 38, cut into the north slope of the South Tell, work exposed sections of two *insulae* separated by an east–west street. The *insulae* in Grid 38 had a higher proportion of coins, imported fine tablewares, and the only definitive evidence for interior decoration of any of the residences across the site, including a private bath decorated in Masonry Style (Birney 2017), suggesting that it housed the city's upper-middle-class citizens. The three neighbourhoods on the tell's southern edge (in Grids 50, 51, and 57) seemed comparatively less wealthy throughout the Hellenistic period, perhaps reflecting their proximity to the city's docks and industrial spaces. In Grid 50, situated on the western edge of the South Tell, excavations revealed a large portion of one large *insula* including at least three distinct apartment/commercial units, and the southern edge of a second *insula*, with the two separated by an east–west street. Excavations in Grid 57 exposed 12 rooms of another *insula*. Just to the east, in Grid 51, portions of two *insulae* separated by a north–south street were uncovered. The footprints of all *insulae* were largely maintained throughout the Hellenistic and Roman periods. *Insulae* in Grids 38 and 51, however, became increasingly subdivided into smaller units in the later second century BCE (Period VIIA, Table 2), suggesting an increase in population and urban density.

Excavation distinguished three periods of Hellenistic occupation (Table 2). Period VIII began in the last decades of the fourth century BCE and was characterized in all neighbourhoods by the continued domestic use of earlier Persian *insulae* following a transition to Hellenistic rule under the Ptolemies after Alexander's death. Period VIII came to an end with a site-wide destruction during the First Syrian War between the Ptolemaic and Seleucid kingdoms, a conflict resolved in 271 BCE; this date is well established by numismatic evidence from coins found in destruction debris in Grids 57 and Grid 38 (Ariel 2021, pp cat. nos. 101, 104). Period VIIB spanned the transition from Ptolemaic to Seleucid control, with the city reoccupied after a brief period of abandonment following the 271 BCE destruction. Buildings were repaired or rebuilt where necessary, but largely maintained the original Persian-era plans. Silver tetradrachma minted at Ashkelon for Ptolemy IV in 219/218 BCE, likely for payment of mercenaries in his service, mark the city as a possible garrison at this time. In 201 BCE, the city came under Seleucid control after the seizure of Gaza by Seleucid ruler Antiochus III. Again, however, there was no coincident shift in the city's plan, nor alterations in the use of urban space. In the last decades of the second century BCE, Ashkelon was granted autonomy by Antiochus VIII, a status celebrated with the minting of new coinage in which the city proclaimed itself "autonomous" and "holy and inviolate" (Spaer 1984, p. 239). Autonomy found tangible expression in the raising of circuit walls and towers, and the first deviation from the urban syntax in over 500 years. Civic buildings were constructed in the previously unused plain east of the settlement (Grid 47). Comprehensive renovations of *insulae* occurred, but most efforts were instead focused on

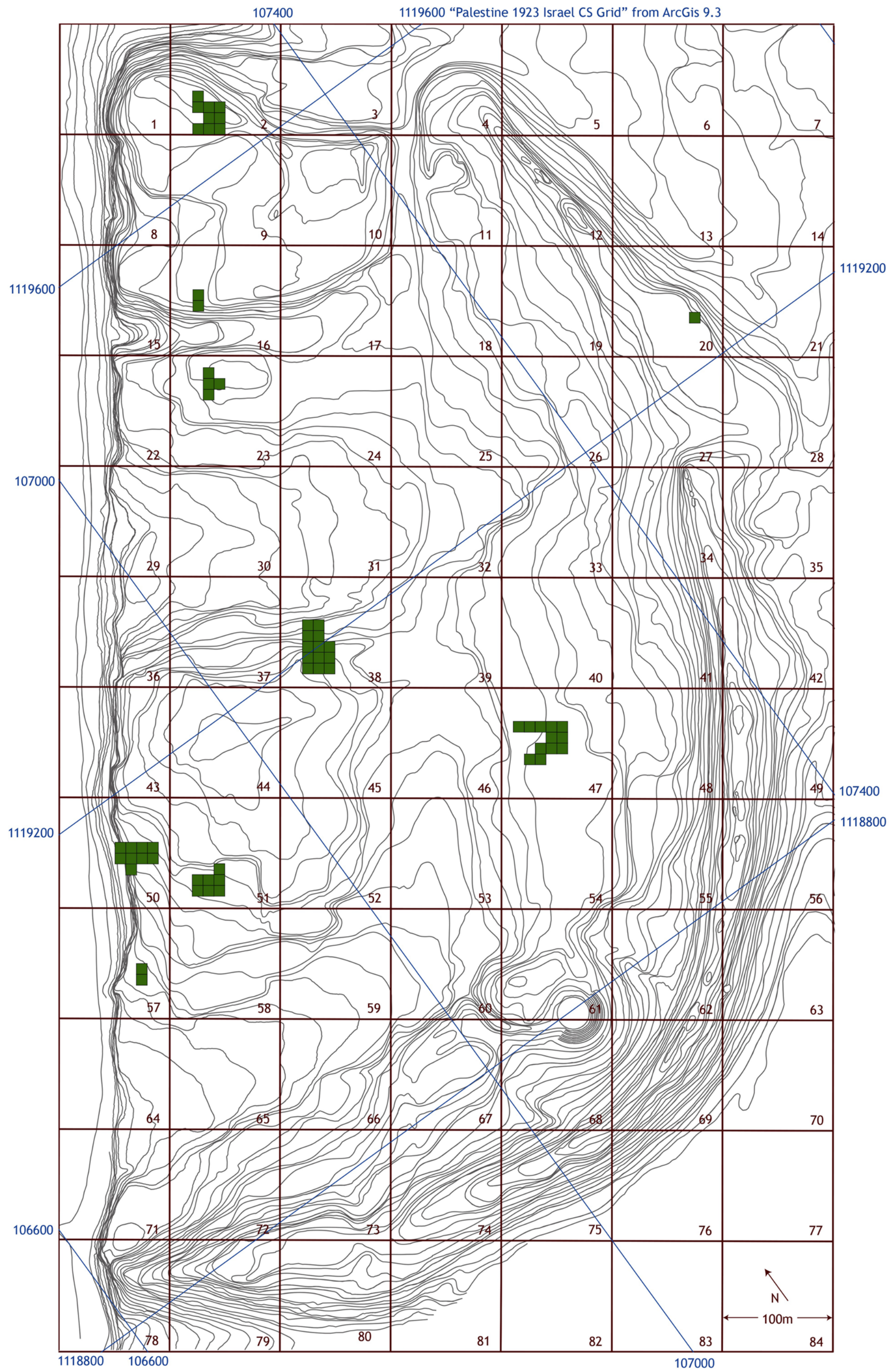

Fig. 2 Map of Ashkelon, showing excavation areas with evidence for Hellenistic occupation. Grids 51 and 57 are found along the south edge of the South Tell, near the coast, while Grid 38 lies on the north edge of the South Tell

Table 2 Dating of Hellenistic periods at Ashkelon

Period	Date
VIIA	125—late 1st cent. BCE
VIIB, Late	150—c. 125 BCE
VIIB, Early	271—c. 150 BCE
VIII	late 4th cent.—271 BCE

new construction in previously unoccupied areas in Grid 47 and on the North Tell, spaces which had never previously been part of Ashkelon's urban life. Period VIIA occupation continued until at least the later first century BCE. Ashkelon remained, however, free from Roman control, and occupation within residential areas continued without significant interruption from the Late Hellenistic into the Early Roman period.

Evidence for farming, cooking, and trade in agricultural products

As a major port city along the Levantine coast, Ashkelon had no shortage of access to imported delicacies and luxury items. During the Hellenistic period, however, imports were not limited to luxuries, but also included even basic items and staple foodstuffs. Ashkelon imported the majority of its common tablewares, some of which even arrived in standardized sets (Birney 2021). Nearly two-thirds of the city's fish supply may have been imported (Lernau 2021, p. 470), with imports not limited to Nilotic fish, but even species that could have been fished locally, such as porgies and sharks. The city was also a prominent importer of wine. These included wines from Cyprus, Knidos, Kos, and Chios, although Rhodian wine (or imitations thereof) was in particular a favoured brand; some may also have been provided by Phoenician suppliers.

The ceramic assemblage offers some insight into how foods were prepared. The cooking vessels of Period VIII, globular cooking pots and shallow casseroles derived from Greek culinary tradition, were already soundly established by the Persian period. The deep rounded shape and smaller mouths of globular pots precluded the addition of large morsels and, as such, these were best suited to simmering soups and porridges (Berlin 1997, p. 18). Heartier stews could have been prepared in the wide-mouthed shallower casseroles with rounded or flat bases, designed for braising (Bats 1988, pp. 45–48). Baking dishes and pans, originally Italian forms which were adopted in the East Mediterranean, arrived in Period VIIB. Heavy charring and soot on the bottoms of all such dishes suggest their placement directly into or close over a fire, perhaps connected with the preparation of quiches (*patinae)* or other foods with contents that required shaping or setting (Berlin 1997, p. 104). Further discussion and depiction of these cooking vessels can be found in Birney 2021 (Chapter 11).

Within the *insulae*, cooking and food storage practices changed over time. In the early Hellenistic levels, bread ovens and hearths were regular features of private households: for example, two were found in courtyard and courtyard-adjacent spaces in Grid 51, and four in Grid 38, with most in association with mortars and hammerstones suggestive of food processing. The widespread distribution of hearths and ovens demonstrates their regular use, whether shared among multiple families or the property of individual households. A striking change in the city's cooking spaces, however, occurred after Period VIII. Although insular plans remained largely the same, from this point onward (well into the Roman period) hearths and ovens became rare in insular spaces. This is in marked contrast with other insular-plan cities—particularly inland sites, such as Jebel Khalid—where ovens and hearths were installed in nearly every courtyard and often included more than one per domestic unit (Jackson 2014, pp. 37, 538). At Ashkelon, ovens instead appear to have been heavily concentrated in specialized spaces: one room in Grid 57 (Period VIIB) had seven ovens, with two or three active at a given time, which were continuously rebuilt and repaired throughout the first half of the second century (see Birney 2021, p. 523 for further discussion). Their concentration suggests a bakery or cookshop akin to a *thermopolia*. Storage facilities also appear to have been limited: only in Grid 51 was there evidence for bulk storage of grain, in the form of a nearly empty, cleaned-out grain storage area in a single room in Period VIIB Building 182, described in further detail later in this article.

The city's faunal assemblage reveals a complementary pattern. In a limited study of Grid 38 and (especially) Grid 51 material, Fulton and Hesse (2021) demonstrated that cattle, typically numerous in agricultural communities, made up less than 10% of animal bones at Ashkelon. The faunal data was instead characterized by a preponderance of uniform limb cuts from sheep and goat, and a corresponding absence of toes, vertebrae, and other remnants of primary butchering. Lernau (2021, p. 470), in a limited study, only identified patterns indicating dedicated spaces for fish preparation within *insulae* in Period VIII, but not thereafter. The decrease in private cooking facilities following Period VIII, coupled with these faunal patterns, may indicate that by the third century BCE Ashkelon had shifted away from a local agropastoral food economy towards a market model in which some staples were imported, processing occurred outside the home, and many residents purchased pre-prepared food from shops.

Samples and methods

Sampling and recovery

A variety of sampling strategies for macrobotanical remains have been employed at Ashkelon over 30 years of excavation at the site; samples included in this study were excavated between 1987 and 2014. Samples analysed here derive from two related sampling systems: (1) selective sampling of features deemed of particular interest by excavators, primarily hearths and structure fills; and (2) a blanket sampling strategy (d'Alpoim Guedes and Spengler 2014) that aimed to sample all deposits from floor surfaces, in which floors were divided into 1 m^2 grids and a flotation sample was taken from each, providing a "fine grid" context for each such sample (Lass 1994). Most samples (136 of the 145 presented here) were taken from fine-gridded m^2 floor contexts. The majority of samples were taken from Grid 51 (82 analysed samples), while Grid 38 produced 62 Hellenistic samples, and Grid 57 one sample. This total compares favourably to two other published archaeobotanical assemblages from Ashkelon: the recently analysed Islamic assemblage (132 samples; Forste and Marston 2019) and the Iron Age Philistine marketplace assemblage previously published by Weiss and Kislev (138 samples; Weiss and Kislev 2004; Weiss et al. 2011). Only samples from contexts stratigraphically certain to be Hellenistic in date are included in this study; mixed contexts or those containing ceramic or numismatic material of later date, even if thought to have been recovered from Hellenistic layers during excavation, are not reported here. Archaeological study of these areas indicates that these samples, with few exceptions, come from secondary or tertiary deposits of burned refuse that accumulated within and between buildings throughout their use and potentially during periods of abandonment prior to renovation, as discussed at length by Birney (2021). As such, these samples represent accumulated waste of daily activities (van der Veen 2007) and are appropriate for diachronic analysis and intersite comparison.

Sample sizes varied based on the size of deposits, although standard practice was to collect samples of "about two-thirds of a pottery bucket" (Weiss and Kislev 2004, p. 3), amounting to roughly 8–10 L, although sample volumes were not recorded prior to 2012. Fortunately, 69 samples analysed in this study were collected in 2012 and 2014, with volumes recorded for all of those samples. Among these samples, average volume was 5.78 L, with volumes ranging from 0.5 to 11 L, distributed with a mode in the 8–11 L range and a long tail of smaller sample sizes, due to occasional necessary sampling of small soil deposits (see ESM 1 for sample-by-sample data, including individual sample volumes).

From 1986 to 2010, flotation used the Tell el-Hesi system (Stewart and Robertson 1973), in which samples were poured into a 1.5 mm mesh-bottomed container, which was then placed within a larger tank of water and shaken manually, with the floating light fraction then skimmed off the water surface using a 0.5–0.6 mm mesh strainer (Lass 1994, p. 24; Weiss and Kislev 2004, p. 3), similar to the IDOT system better known in the United States (Pearsall 2015). In 2010 a Flote-Tech flotation device was introduced (Hunter and Gassner 1998), in which heavy residues were collected in a 1.5 mm mesh while light fractions flowed over and were collected in a very fine (< 0.1 mm) nylon mesh. Heavy and light fractions were air dried in shaded areas and stored onsite prior to analysis.

Analytical methods

Light fractions were analysed in the Boston University Environmental Archaeology Laboratory (BU EAL), following standard analytical protocols for sorting and identification (Fritz and Nesbitt 2014; Pearsall 2015). Samples were weighed and divided into four size fractions using geological screens (> 2 mm, > 1 mm, > 0.5 mm, < 0.5 mm) for sorting. Following practices employed at other sites in Southwest Asia (e.g. Miller and Marston 2012), all materials were sorted completely above 2 mm, whole and partial seeds and seed equivalents (i.e., caryopses for cereals) were retained above 1 mm, as were endocarp fragments (e.g. olive), but only entire seeds and other countable plant parts (e.g. cereal rachis fragments) were pulled below 1 mm. Seeds were counted using a minimum number of individuals (MNI) approach. Domesticated crop seeds were counted if whole, or by the half for pulses; cereals were counted when the embryo end of the caryopsis was present. All crop seeds were also weighed to provide a reliable quantification of seed fragments, except for fig seeds, which are only counted due to their minute size. Leica stereomicroscopes with a magnification range of 6–90 × were used to sort samples and identify specimens. Identifications relied on the modern comparative collections of the BU EAL, as well as published seed atlases and identification keys (e.g. Jacomet 2006; Nesbitt 2006). Uncertain identifications were noted with "cf." prior to the uncertain level in the identification except where only cf. identifications are present, in which case that level of uncertainty is preserved; these are differentiated in the attached raw data (ESM 1) but combined with definitely identified specimens by taxon in the summary data presented in the tables below.

Analytical metrics applied here include a variety of basic quantification measures (counts and weights) and simple statistics, namely ubiquity and several standardized and relative ratios (Miller 1988; Riehl 2010; Marston 2014). Given the limited number of seeds in most samples, this assemblage is not suitable for multivariate analysis (Valamoti and Jones 2003; Smith 2014). Ratios are effective tools for data reduction and normalization to facilitate comparison among samples, contexts, phases, and sites. The purpose of standardized ratios is to normalize data for comparison across contexts that are unlike in size or composition; for example, density is a standardized ratio that normalizes results to account for variable sample size (Marston 2014, pp. 166–167). Relative ratios allow the comparison of plants representing different ecological and/or depositional contexts; for example, as a measure of grazing pressure on a landscape (Marston 2012) or the relative contribution of fodder and forage plants in an animal's diet (Miller and Marston 2012). Ratios employed here include: (1) charred density (total charred material > 2 mm divided by soil volume) and find density (total count of seeds and plant parts divided by soil volume), relative measures of the density with which charred plant remains were deposited and preserved in a context; (2) the *T. dicoccum* grain to glume-base equivalent and the broader hulled *Triticum* grain to glume-base equivalent ratios, metrics that distinguish cleaned grain from entire spikelets/sheaves and final spikelet-processing residues (Stevens 2003); and (3) the wild seed to charcoal ratio, an indicator of the potential for dung fuel use (Miller 1997; Charles 1998; Miller and Marston 2012), which can be confirmed through multiproxy analyses (Shahack-Gross 2011; Filipović 2014; Smith et al. 2019; Fuks and Dunseth 2021).

Results

Crop plants

The majority of non-charcoal remains recovered from this assemblage are the remains of domesticated plants. Table 3 lists these crop plants by taxon, dividing cereals, pulses, and fruits, and gives the ubiquity for each (expressed as the percentage of samples within which those remains are found) both by grid and for the Hellenistic period overall. The ubiquity of all carbonized wild seeds and wood charcoal larger than 2 mm is also included. Key taxa are depicted in Fig. 3.

Cereal caryopses and grape seeds are the most ubiquitous crop remains, with at least one fragment of a cereal present in 75% of all samples, and grape seeds slightly more frequent. Other ubiquitous crops include *F. carica* (present in half of samples within Grid 38, and a third of samples overall), and *H. vulgare* (caryopses) and *T. dicoccum* (rachis fragments) also found in approximately a third of samples. At least one pulse fragment appeared in 40% of samples, with *L. culinaris* the most common identified taxon. The other common cereal is *T. aestivum/durum* (further identification is not possible; the only rachis fragment present is indeterminate), present in one quarter of all samples. Most taxa appear in similar ubiquities between the two grid areas, though *F. carica* is notably more ubiquitous in Grid 38, as is

Table 3 Ubiquity (expressed as percent of total samples, by grid) of crop plant remains, all wild plant seeds, and wood charcoal

Excavation grid (samples *n*)			Grid 38 (62)	Grid 51/57 (83)	Total (145)
Cereals					
Hordeum vulgare	Barley	Caryopsis	24.2	37.3	31.7
H. vulgare	Barley	Rachis fragment	1.6	6.0	4.1
cf. *Secale cereale*	Possible rye	Rachis fragment	3.2	4.8	4.1
Triticum aestivum/durum	Free-threshing wheat	Caryopsis	17.7	28.9	24.1
T. aestivum/durum	Free-threshing wheat	Rachis fragment	0.0	1.2	0.7
T. dicoccum	Emmer wheat	Caryopsis	9.7	14.5	12.4
T. dicoccum	Emmer wheat	Rachis fragment	24.2	34.9	30.3
T. cf. *monococcum*	Einkorn wheat	Caryopsis	1.6	1.2	1.4
T. monococcum	Einkorn wheat	Rachis fragment	0.0	2.4	1.4
T. monococcum/dicoccum	Emmer or einkorn wheat	Rachis fragment	29.0	16.9	22.1
All hulled wheats		Rachis fragment	43.5	37.3	40.0
All cereals			72.6	77.1	75.2
Pulses					
Cicer arietinum	Chickpea	Seed	3.2	2.4	2.8
Lens culinaris	Lentil	Seed	19.4	24.1	22.1
Pisum sativum	Pea	Seed	1.6	3.6	2.8
Vicia ervilia	Bitter vetch	Seed	4.8	6.0	5.5
All pulses			37.1	43.4	40.7
Fruits					
Ficus carica	Fig	Drupelet	51.6	20.5	33.8
Olea europaea	Olive	Endocarp	6.5	2.4	4.1
Pistacia	Pistachio (possibly wild)	Endocarp	8.1	2.4	4.8
Vitis vinifera	Grape	Seed	82.3	75.9	78.6
Vitis vinifera	Grape	Pedicel	19.4	9.6	13.8
Vitis vinifera	Grape	Fruit	1.6	2.4	2.1
cf. *Ziziphus*	Jujube	Endocarp	1.6	1.2	1.4
Wild and weed seeds			59.7	55.4	57.2
Wood charcoal > 2 mm			93.5	89.2	91.0

Taxon sums include probable (cf.) identifications except where only cf. identifications are present, in which case that level of uncertainty is preserved


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◂**Fig. 3** Representative images of key taxa from Ashkelon. Cereals: *Hordeum vulgare* (hulled barley), dorsal (1) and ventral (2); *Triticum dicoccum* (emmer), two specimens, dorsal (3) and ventral (4); *T. aestivum/durum* (free-threshing wheat), two specimens, dorsal (5) and ventral (6); *H. vulgare* rachis fragments, indeterminate and compact-eared types (7); *T. dicoccum* spikelet fork, one specimen from two sides (8). Field weed: *Lolium temulentum* (darnel grass), ventral (left) and dorsal (right, 9). Pulses: *Lens culinaris* (lentil), lateral (10); *Vicia ervilia* (bitter vetch), lateral (11); *Pisum sativum* (pea), lateral (left) and radicle (right, 12). Fruits: *Vitis vinifera* (grape), dorsal (left) and ventral (right, 13); *Ficus carica* (fig) drupelet (14); *Pistacia* sp. (pistachio) endocarp fragments, exterior (right) and cross-section (left, 15); *Olea europaea* (olive) endocarp (16); scale bars = 1 mm

V. vinifera (especially pedicel remains); conversely, cereals and lentils are more ubiquitous in Grid 51. Further exploration of this difference is given in the spatial analyses that follow.

Table 4 provides both count and weight data, again both by grid and site wide, for the same taxa, and additional summary statistics, including ratios. Here, we use ratios to compare samples from Grid 51 to those from Grid 38, although charred density cannot be used for Grid 38 since the sample volume is unknown for all Grid 38 samples. Charred density and wild seed to charcoal ratios were calculated on an individual sample basis and their median values are presented in Table 4, which allows exclusion of samples where the value cannot be calculated and is less biased by high outliers than an average.

These data indicate a similar pattern as the ubiquity figures above but lend additional perspective on differences between Grid 51 and Grid 38. The most ubiquitous and numerous cereals are *H. vulgare*, *T. aestivum/durum*, and *T. dicoccum,* in that order; the difference between Grids is much greater in absolute quantities than in ubiquity. Hulled wheat rachis fragments (both those of *T. dicoccum* and those indeterminate between *T. dicoccum* or *T. monococcum,* einkorn) are also much more numerous in Grid 51 than Grid 38. *Ficus carica* and *Vitis vinifera* seeds, in contrast, are even more numerous in Grid 38, compared to Grid 51, than their relatively ubiquity would imply. Results, however, are skewed by one sample with large counts of both *F. carica* (42) and *V. vinifera* (90, weighing 1.255 g) seeds; only two additional samples contain more than 10 *V. vinifera* seeds and three contain more than 10 *F. carica* seeds, all from Grid 38 (raw data in ESM 1). No sample contains more than two *V. vinifera* pedicels.

Three types of *H. vulgare* may have been grown during the Hellenistic period at Ashkelon: hulled types of both six- and two-row subspecies, and a naked type (which is almost always a six-row type; Nesbitt et al. 2017, p. 40). The naked can be distinguished from the hulled type by the lack of constriction imposed on the grain by tight enclosure in glumes and the slightly wrinkled surface of the caryopsis; two- and six-row types can be distinguished by the frequency of lateral grains, which grow asymmetrically and appear twisted (Zohary et al. 2012, p. 53). In pure six-row *H. vulgare*, there are two lateral grains present for each central (straight, symmetrical) grain, so we expect a ratio of 2:1 twisted:straight grains. In a purely two-row *H. vulgare* assemblage, all grains should be straight. Table 5 presents the counts of all identifiable grains from the Hellenistic assemblage, as well as three reconstructions of the ratio of two- to six-row *H. vulgare* ratio, depending on how complete, but indeterminate, grains are counted. At a minimum, six-row *H. vulgare* comprises half of the studied assemblage, but more likely it provides the majority of the specimens identified, and two-row barley may not be present in this assemblage at all. The two naked *H. vulgare* grains indicate the presence, but perhaps not the use as a crop, of this varietal.

Wild plants and weeds

Seeds of wild plants, including weedy species that are either ruderal (grow in areas of anthropogenic disturbance) or segetal (weeds of crop fields), are common among these samples. At least one carbonized wild plant seed is present in 57% of all samples. All carbonized wild seed taxa identified, including those identified only at the family level or tentatively to taxon, are listed below in Table 6, both by grid and site wide. The assemblage is diverse, with a handful of taxa represented by more than three specimens. These mainly include ruderal taxa (*Alopecurus*, *Chenopodium*, *Gypsophila*, and *Trifolium*) and an obligate segetal weed (*Lolium temulentum*); thus, this assemblage is primarily comprised of weedy taxa. *Beta vulgaris* may be evidence of a secondary cultigen (beet) or a native, edible wild plant (sea beet, *Beta vulgaris* ssp. *maritima*). The remaining taxa, present in low numbers, represent a diversity of vegetation communities in the Ashkelon area. *Echiochilon fruticosum*, which is also attested by 769 mineralized specimens in the assemblage, is incredibly common across the Hellenistic assemblage (ubiquity of mineralized seeds 42.8%), but only three samples contain carbonized specimens. Weiss and Kislev (2004, p. 8) interpret the nutlets of *E. fruticosum*, an obligate colonizer of bare sandy areas (such as dunes), as representing sand brought onto the site as construction fill; the seeds, which are high in silica and preserve in a mineralized state, are incidental components of that fill. The three samples with carbonized specimens are likely indications of burning that charred *E. fruticosum* nutlets in the surrounding sandy sediment. One sample (Ash no. 14426) that contains 54 charred *E. fruticosum* nutlets comes from a beaten earth floor in Grid 51, within a room (Room 184) covered by an ashy phytolith layer; the room is interpreted as a storage room for grain lined with matting, which at some point was burned (see further discussion of this space below).

The distribution of *L. temulentum* caryopses was further investigated to establish whether it is correlated with the distribution of specific crop seeds, which would support its attribution in this assemblage to a segetal weed co-harvested with crops. Every sample that contains more than one *L. temulentum* caryopsis also included at least one type of cereal, with *H. vulgare*, *T. aestivum/durum*, and hulled wheat (i.e. *T. dicoccum*) similarly associated with the presence of *L. temulentum*. A chi-square test of independence was conducted on the co-presence of *L. temulentum* with several types of cereal remains, yielding a p-value < 0.01, which indicates that these taxa co-occur in frequencies highly unlikely to be due to chance (Table 7). Thus, we conclude that *L. temulentum* appears in this assemblage as a weed of cereal fields, apparently affecting all cereals that were stored or consumed at Ashkelon.

Diachronic and spatial analysis

The samples from Grids 38, 51, and 57 differ in time as well as area of the site. As indicated in Table 8, the majority of phased samples from Grid 38 date to Period VIIA, while those in Grid 51 mainly date to VIIB and, especially, the earliest Hellenistic Period VIII; the single Grid 57 sample also dates to VIII. While a handful of Grid 38 samples date to VIIB and an equal number of Grid 51 samples date to VIIA, nearly all samples are temporally distinct between the two Grids. Moreover, the four Period VIIA samples from Grid 51 are nearly sterile with crop remains only in one sample (*T. aestivum/durum*, indeterminate cereal and pulse fragments, and a single *F. carica* seed); similarly, three of the four Grid 38 Period VIIB samples contain only charcoal, while the other sample contains two *V. vinifera* seeds and pedicels, and one probable *H. vulgare* grain. As a result, diachronic comparisons are spatial comparisons, and vice versa.

Spatial patterns noted earlier, such as the higher frequency of fruit seeds (*F. carica* and *V. vinifera*) in Grid 38, may be a product of differences in daily habits of fruit consumption and discard in different neighbourhoods. The difference may also, however, represent different patterns of trash disposal or changes in consumption patterns over time, as illustrated in Fig. 4. Further complicating this contrast is the different excavation history of these two areas, with most Grid 51 samples recovered in 2012 when soil volumes were recorded and sample integrity can be assured, while soil volumes were not recorded for Grid 38 and its samples suffered sporadic damage during years of storage, rendering some processed samples unavailable for this study.

As a result of the coincident spatial and temporal variability described above, detailed contextual analysis of groups of samples from specific spatial contexts is needed to offer more meaningful insights into the use and disposal of plants in the Hellenistic *insulae* of Ashkelon. Seven spatial contexts were selected for in-depth analysis based on the density of remains in those contexts; each includes the sum of at least five samples and as many as 25. Together, these total 34 of the 62 samples from Grid 38 and 50 of the 82 samples from Grid 51. Summary totals for these contexts are given in Table 9.

Selected contexts in Grid 38 all date to Period VIIA and represent parts of two *insulae*, the southern Building 134 containing Rooms 115 and 142 (which enclose Layers 119 and 149, respectively), and the northern Building 530 enclosing Room 530 (containing Layer 530); these buildings were separated by a street averaging 2 m in width (Fig. 5). Both buildings were rebuilt in the late Hellenistic period using more substantial ashlar construction to enable a second floor to these structures. The presence of numerous imported dining wares, signs of interior plastered decoration, and a cache of pan-Mediterranean coins (the so-called "Periplous" hoard; Gitler and Kahanov 2002) suggest that neighbourhood occupants were a networked elite.

Room 115 was significantly disturbed by Roman (Period VI) occupation, so the function of this space in the Late Hellenistic is difficult to reconstruct, although the ceramic and numismatic material confirms a date of deposition prior to the construction of Period VI floors. Layer 119 is a Late Hellenistic layer below the subsequent Period VI floor. The heterogeneity and density of botanical remains in this context are suggestive of redeposited long-term occupation debris. Notably, this context includes the greatest density of both *F. carica* and *V. vinifera* seeds of any Hellenistic context, as well as nearly all the probable jujube (cf. *Ziziphus*) remains in the entire assemblage. Fruit remains significantly outweigh cereals and pulses combined, as is the case among most Grid 38 samples from Period VIIA (Fig. 4). Room 530, in the other *insula*, contains a similar assemblage to that of Room 115, and is also a fill layer associated with a Period VIIA floor, though similarly disturbed by Roman construction. Remains are lower in density, with some taxa present in Layer 119 absent here (*Lens culinaris* is the only pulse, hulled *Triticum* and *Ziziphus* are absent), but a similar predominance of fruit (especially *V. vinifera*) remains over those of cereals and pulses is evident.

Room 142, in the same *insula* as Room 115, contains original occupation debris in the form of a roughly 10 cm-thick ashy deposit, which was preserved around the room edges. Over this floor lay the fill Layer 149. Both had been robbed and disturbed by later Roman pits. The room contained a mudbrick-based hearth in its north-western corner that contained fragments of heavily charred ceramic cooking vessels; fragments of cooking pots, casseroles, and baking trays were found throughout the room, as well as the hoard of 46 coins mentioned above. The botanical contents of this room include a diversity of cereals and fruits, though substantially less *V. vinifera* than in the other two Grid 38

Table 4 Summary statistics and crop plant remain counts and weights (all in g), by grid

Totals by excavation grid	Grid 38	Grid 51/57	Total
Summary statistics			
Samples (n)	62	83	145
Soil volume (L)[a]	nr	398.5	398.5
Charcoal > 2 mm (g)	52.22	19.05	71.27
Seed > 2 mm (g)	3.24	2.66	5.89
Wild and weed seeds (ct.)	123	229	352
Charred density (g/L) (median)	nc	0.03	0.03
Find density (count/L) (average)	nc	2.15	2.15
Wild seed:charcoal ratio (#/g) (median)	2.48	2.63	2.60
Cereals			
Hordeum vulgare (ct./wt.)	12/0.141	59/0.564	71/0.705
Triticum aestivum/durum (ct./wt.)	12/0.093	30/0.237	42/0.330
Triticum dicoccum (ct./wt.)	10/0.049	19/0.132	29/0.181
Triticum cf. *monococcum* (ct./wt.)	0.5/0.001	1/0.002	1/0.003
Cereal indet. (ct./wt.)	10/0.390	33/1.415	43/1.805
All cereals (ct./wt.)	44/0.648	142/2.376	186/3.024
Hordeum vulgare rachis total (ct.)	1	5	6
cf. *Secale cereale* rachis total (ct.)	3	4	7
Triticum aestivum/durum rachis total (ct.)		1	1
T. dicoccum rachis total (gb equivalents)[b]	51	233	284
T. monococcum rachis total (gb equivalents)[b]		2	2
T. monococcum/dicoccum rachis total (gb equivalents)[b]	43	109	152
T. dicoccum grain to glume base ratio	0.20	0.08	0.10
All hulled wheat grain to glume base ratio	0.11	0.06	0.07
Pulses			
Cicer arietinum (ct./wt.)	1/0.039	0.5/0.058	1.5/0.097
Lens culinaris (ct./wt.)	14.5/0.094	19/0.163	33.5/0.257
Pisum sativum (ct./wt.)	1/0.003	2/0.091	3/0.094
Vicia ervilia (ct./wt.)	1/0.009	2/0.024	3/0.033
Pulse indeterminate (ct./wt.)	2.5/0.106	2.5/0.104	5/0.210
All pulses (ct./wt.)	20/0.243	26/0.448	46/0.691
Fruits			
Ficus carica (ct.)	171	25	196
Olea europaea endocarp (wt.)	0.038	0.156	0.194
Pistacia endocarp (wt.)	0.121	0.014	0.135
Vitis vinifera seed (ct./wt.)	209/3.606	73/1.120	282/4.726
Vitis vinifera fruit (ct.)	1	3	4
Vitis vinifera pedicel	16	11	27
cf. *Ziziphus* endocarp (wt.)	0.042	0.004	0.046
All fruits (ct./wt.)	383/3.807	102/1.325	485/5.132

Taxon counts include probable (cf.) identifications. All values are for seeds, caryopses, or drupelets as botanically relevant (following Table 3), except where noted otherwise. Charred density includes wood charcoal; find density includes only countable seeds and other plant parts (i.e. rachis fragments)

nr not recorded, *nc* not calculable, *ct.* count, *wt.* weight in g, *gb* glume base

[a]This includes only samples where volumes were recorded, 69/83 samples from Grid 51/57

[b]Hulled wheat spikelet forks are counted as 2 glume bases to yield glume-base equivalents

Table 5 *Hordeum vulgare* metrics and modelled subspecies identifications

Hordeum vulgare	# twisted	# straight	# indet	# naked
	24	12	16	2
Model[a]	Basic	Maximum	Minimum	
% 6-row	100%	100%	43%	
% 2-row	0%	0%	57%	

[a]Basic model ignores indeterminate grains; maximum counts them as twisted; minimum counts them as straight

contexts. Pulses are few, with only *L. culinaris* and *V. ervilia* identified. The relatively large number of hulled *Triticum* rachis fragments (the large majority, if not all, *T. dicoccum*) in comparison to the number of *T. dicoccum* grains found, at a ratio of 0.06 grains to glume base equivalents (where a ratio of 1 is expected for charred whole spikelets), suggests the accumulation of dehusking remains occurred in this room.

The four Grid 51 contexts described here date to Period VIII (Units 68 and 161) and both early and late Period VIIB. All of these contexts represent sequential uses of a single *insula*, originally built in the Persian period, of fitted ashlars atop fieldstone foundations (Fig. 6).

Building 151 was divided into two houses in Period VIII (Fig. 6a); the southern of these is House 151, which included four excavated rooms and a central courtyard (Courtyard 65), within which Units 161 and 68 were deposited. Unit 68 is an abandonment layer atop Unit 161, a roughly 20 cm-thick ashy occupation debris layer, deepest in the northeast corner of the courtyard near a 60 cm-diameter, coil-built, mud-plastered oven. Fragmentary grinding stones, mortars, hammerstones, and flint and obsidian blades in the courtyard suggest that it was used for food preparation as well as cooking. A number of smashed, partial amphorae in the topmost layer of surface accumulation marks the cessation of use of the courtyard in Period VIII. The botanical finds from Unit 161 support the interpretation of this area as a food preparation and cooking area. Abundant wood charcoal attests to use and raking out of the *tabun* (clay-built oven); remains of all cereals and pulses recorded in the assemblage are present, especially *H. vulgare*, *T. aestivum/durum*, *L. culinaris*, and *Pisum sativum*. Although the density of fruit remains, especially *V. vinifera*, is substantially lower than in Grid 38, grape remains are more numerous in this context than others in Grid 51. The frequency of *Lolium temulentum* among these remains, as well as hulled *Triticum* rachis fragments (grain to glume base ratio is 0.19), suggest that dehusking and grain cleaning occurred in this courtyard. Unit 68, the overlying abandonment layer, is much less dense with remains and contains fewer crops than Unit 161. Notably absent from this context are hulled *Triticum* grains, *P.*

Table 6 All identified carbonized wild seeds (summed counts) by grid; "indet." indicates seeds of indeterminate taxon within a family

Taxon	Family	Grid 38	Grid 51/57	Total
Beta vulgaris	Amaranthaceae		4	4
Chenopodium	Amaranthaceae	3	3	6
cf. *Suaeda*	Amaranthaceae	1		1
Apiaceae indet	Apiaceae	2	2	4
cf. *Ambrosia maritima*	Asteraceae		3	3
cf. *Centaurea*	Asteraceae		1	1
Glebionis coronarium	Asteraceae	1		1
Asteraceae indet	Asteraceae	2	1	3
Echiochilon fruticosum	Boraginaceae		71	71
Rapistrum rugosum	Brassicaceae	2		2
Brassicaceae indet	Brassicaceae	2	3	5
cf. *Cephalaria*	Caprifoliaceae	1		1
cf. *Dianthus*	Caryophyllaceae		1	1
Gypsophila	Caryophyllaceae	1	5	6
Astragalus	Fabaceae	4		4
Trigonella	Fabaceae	1	4	5
Medicago	Fabaceae		1	1
Melilotus	Fabaceae	2	1	3
cf. *Pisum*	Fabaceae		1	1
Trifolium	Fabaceae	9	2	11
Fabaceae indet	Fabaceae		3	3
cf. *Erodium*	Geraniaceae		1	1
Teucrium	Lamiaceae		1	1
cf. *Ziziphora*	Lamiaceae	1		1
Malva	Malvaceae		3	3
Fumaria	Papaveraceae	1		1
cf. *Papaver*	Papaveraceae		1	1
Aegilops	Poaceae		2	2
cf. *Agrostis*	Poaceae	1		1
Alopecurus	Poaceae	25	15	40
Briza	Poaceae	1	1	2
cf. *Bromus*	Poaceae	1	1	2
Lolium temulentum	Poaceae	10	47	57
Phleum	Poaceae	3	2	5
Stipa	Poaceae		2	2
Poaceae indet	Poaceae	7	12	19
Polygonum	Polygonaceae	1		1
Adonis	Ranunculaceae		1	1
Ranunculus	Ranunculaceae	1		1
Hyoscyamus	Solanaceae		1	1
Solanum/Lycium	Solanaceae		1	1
Thymelaea	Thymelaeaceae		2	2
Unknown		40	30	70
Unidentifiable		3	3	6
Total		126	232	358

Table 7 Chi-square test of independence conducted on the co-presence of *L. temulentum* (darnel grass) with cereal remains identified at Ashkelon

	# Samples with *Lolium* present	
	Actual	Expected
Hordeum vulgare	15	7.93
Triticum aestivum/durum	9	6.03
Triticum dicoccum	6	3.10
All hulled *Triticum* rachis	15	10.00
Any cereal	24	18.79
Chi-square test *p*-value	0.0061	

Table 8 Count of samples by period and by grid

Period	Grid 38	Grid 51	Grid 57	Total
VIIA	58	4		62
VIIB	4	21		25
VIII		57	1	58
Total	62	82	1	145

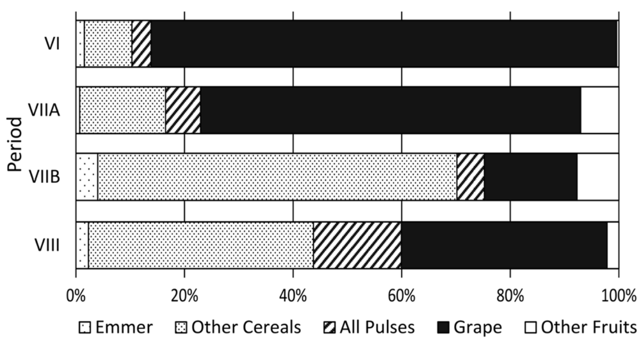


Fig. 4 Relative proportions by weight of crop seed types, by period

sativum, and all fruits other than *V. vinifera* and a single *F. carica* seed. The average charred density of samples in Unit 161 is more than twice that of Unit 68 (0.07 v. 0.03 g/L sediment); the charred density of Unit 68 is on par with the median value for all Hellenistic samples (Table 4).

Units 337 and 392 come from subsequent floor deposits within one room of the northern house, designated Building 184 (containing Room 184 and Unit 392) early in Period VIIB and Building 182 (containing Room 182 and Unit 337) later. In the earlier phase (Fig. 6b), plant remains come from a beaten earth floor that was covered in a 10 cm-thick layer of phytoliths, primarily cereal chaff remains, mixed with some straw, and an absence of dung spherulites; the excavators suggest that the room may have served for grain storage (Birney 2021, p. 483). This floor was covered with a levelling fill of silt and the subsequent late Period VIIB beaten earth floor (Fig. 6c) was similarly covered with a phytolith layer. This layer, however, includes more straw and grass leaf phytoliths, as well as dense burning and charcoal deposition along the eastern side of the room.

The macrobotanical remains from these two floors are similar: a diversity of cereal remains, especially *H. vulgare*, but also both free-threshing and hulled *Triticum*. Cereals comprise the large majority of crop remains in each context. *L. culinaris* and *V. ervilia* are found in both, and *P. sativum* only on the earlier floor, in small quantities. A few *V. vinifera* and *F. carica* seeds are present in both. Most notable, however, is the high density of hulled *Triticum* (mostly, if not entirely, *T. dicoccum*) rachis fragments on each floor, and the very low ratio of *T. dicoccum* grains to glume-base equivalents for these contexts. This pattern indicates the accumulation of burned dehusking remains, rather than whole spikelets, in this space.

Discussion

Cereal and pulse agriculture

The basic agricultural system inferred for Hellenistic Ashkelon based on these remains is one that heavily features cereals and legumes, as is typical for archaeobotanical assemblages from Southwest Asia (Miller 1991), including Hellenistic sites (Table 1). At Ashkelon, *L. culinaris* appears to have been the primary pulse crop, with three primary cereals grown: *H. vulgare* (predominantly a six-row hulled variety), *T. aestivum/durum*, and *T. dicoccum*.

The frequency of *T. dicoccum* at Ashkelon is surprising. *T. dicoccum* was the staple grain of Egypt prior to the Hellenistic period, but by the second century BCE *T. dicoccum* was increasingly replaced with *T. durum* (Samuel 1993; Mayerson 2002; Berlin et al. 2003; Monson 2012). *T. dicoccum* is not described as a major crop at any other Hellenistic site with published archaeobotanical data (Table 1). *T. dicoccum* is present in such small quantities at Gordion that it appears to be a weed (Marston 2017a). Similarly, although the Platania assemblage has not been published in full, *T. dicoccum* is described as occurring there "in very few samples" (Margaritis 2015, p. 341), and only 15 *T. dicoccum* grains were identified at Krania (against several hundred *H. vulgare* and *T. aestivum/durum* grains), where Margaritis (2014, p. 108) views it, alongside *T. spelta* (spelt), as a contaminant of *T. aestivum/durum* fields.

T. dicoccum has, however, now been identified at five sites in the Levant with published Hellenistic archaeobotanical assemblages of ten or more samples (Table 1). At Tel Kedesh, 23 *T. dicoccum* grains were found alongside 37 *T. aestivum/durum* and 26 *H. vulgare* grains, but *T. dicoccum* is not discussed as a crop at the site, despite the

Table 9 Summary totals from selected spatial contexts in Grids 38 and 51

	Grid 38			Grid 51			
Context	L119	L149	L530	U68	U161	U337	U392
Period	VIIA	VIIA	VIIA	VIII	VIII	VIIB late	VIIB early
Number of samples (n)	9	11	15	14	25	5	6
Wood charcoal (wt.)	2.819	33.560	6.347	1.156	9.376	0.891	1.210
Hordeum vulgare (wt.)	0.093	0.003	0.020	0.016	0.117	0.127	0.206
Triticum aestivum/durum (wt.)	0.014	0.009	0.039	0.047	0.071	0.022	0.009
Triticum dicoccum (wt.)	0.039	0.005			0.037	0.012	0.053
Triticum cf. *monococcum* (wt.)	0.001				+		0.002
Cereal total weight	0.305	0.083	0.109	0.165	0.528	0.487	0.823
Cicer arietinum (wt.)	0.039			0.040	0.018		
Lens culinaris (wt.)	0.084	+	0.003	0.005	0.106	0.002	0.019
Pisum sativum (wt.)	0.003				0.083		0.008
Vicia ervilia (wt.)	0.004	0.005		+	0.006	0.012	0.006
Pulse total weight	0.169	0.009	0.011	0.048	0.254	0.019	0.066
Ficus carica (ct.)	104	30	10	1	5	2	7
Olea europaea endocarp (wt.)	0.008	0.028	0.002		0.015		
Pistacia endocarp (wt.)		0.010	0.004		+		
cf. *Ziziphus* endocarp (wt.)	0.042				0.004		
Vitis vinifera (ct.)	140	3	28	6	28	3	8
Vitis vinifera pedicel (ct.)	7	1	3		6		
Vitis vinifera fruit (wt.)			0.003		0.006		
cf. *Ziziphus* endocarp (wt.)	0.042				0.004		
Lolium temulentum (ct.)	1	1	3	1	19	1	6
All hulled wheat rachis total (gb equivalents)*	35	32	18	20	32	151	128
All hulled wheat grain to glume-base equivalent ratio (by count)	0.20	0.06	0	0	0.19	0.01	0.07

All specimens are seeds or seed equivalents (i.e. caryopses for cereals, drupelets for fig) unless otherwise stated

+ Presence < 0.001 g

*Hulled wheat rachis fragments are counted as glume-base equivalents (spikelet forks as 2 glume bases)

relative equivalence in the number of finds among these cereals (Borojevic 2011). Tell el-Mazar includes only two *T. dicoccum* grains, but at Tell Iẓṭabba 35 grains were found alongside 161 hulled wheat chaff fragments, which are likely *T. dicoccum* given the lack of *T. monococcum* grains in the assemblage (Orendi et al. 2021). While less numerous than *H. vulgare* and *T. aestivum/durum*, *T. dicoccum* is numerous enough to consider it as a crop, especially given the numerous chaff fragments preserved. Quantitative results are not published for *T. dicoccum* at Tell el-Hesi, so quantities may have been significant, but Stewart (1978, p. 380) infers its presence as "probably a weed" due to the effort needed to prepare emmer for consumption. Our results, however, challenge this interpretation and suggest that *T. dicoccum* was a Hellenistic crop throughout the southern Levant; certainly the frequency and ubiquity of *T. dicoccum* at Ashkelon confirm that it was an agricultural product in its own right, based on its constant presence in both cooking and storage contexts from Period VIII to Period VIIA. This mirrors data from Tell Iẓṭabba and Tel Kedesh, which together suggest the widespread cultivation of *T. dicoccum* at both Ptolemaic (Tel Kedesh, Period VIII Ashkelon, possibly Tell el-Hesi) and Seleucid (Tell I·ṭabba, Period VIIA Ashkelon) sites.

Where this *T. dicoccum* was cultivated remains an open question. Ptolemaic control of Ashkelon, which lasted until ca. 201 BCE, could have included the import of *T. dicoccum* from Egypt or the local cultivation of *T. dicoccum* at Ashkelon. While *T. dicoccum* declines as a proportion of crop seeds following Period VIIB (Fig. 4), it does not disappear, and abundant *T. dicoccum* chaff is present in the storage assemblage in Grid 51 Room 182, dated to the latest part of Period VIIB, following Seleucid control over the site. Although *T. dicoccum* is present in the earlier Persian period assemblage, counts are very small in comparison to *T. aestivum/durum* and hulled *H. vulgare* (Weiss and Kislev 2004), suggesting it was an incidental weed of crop fields. The

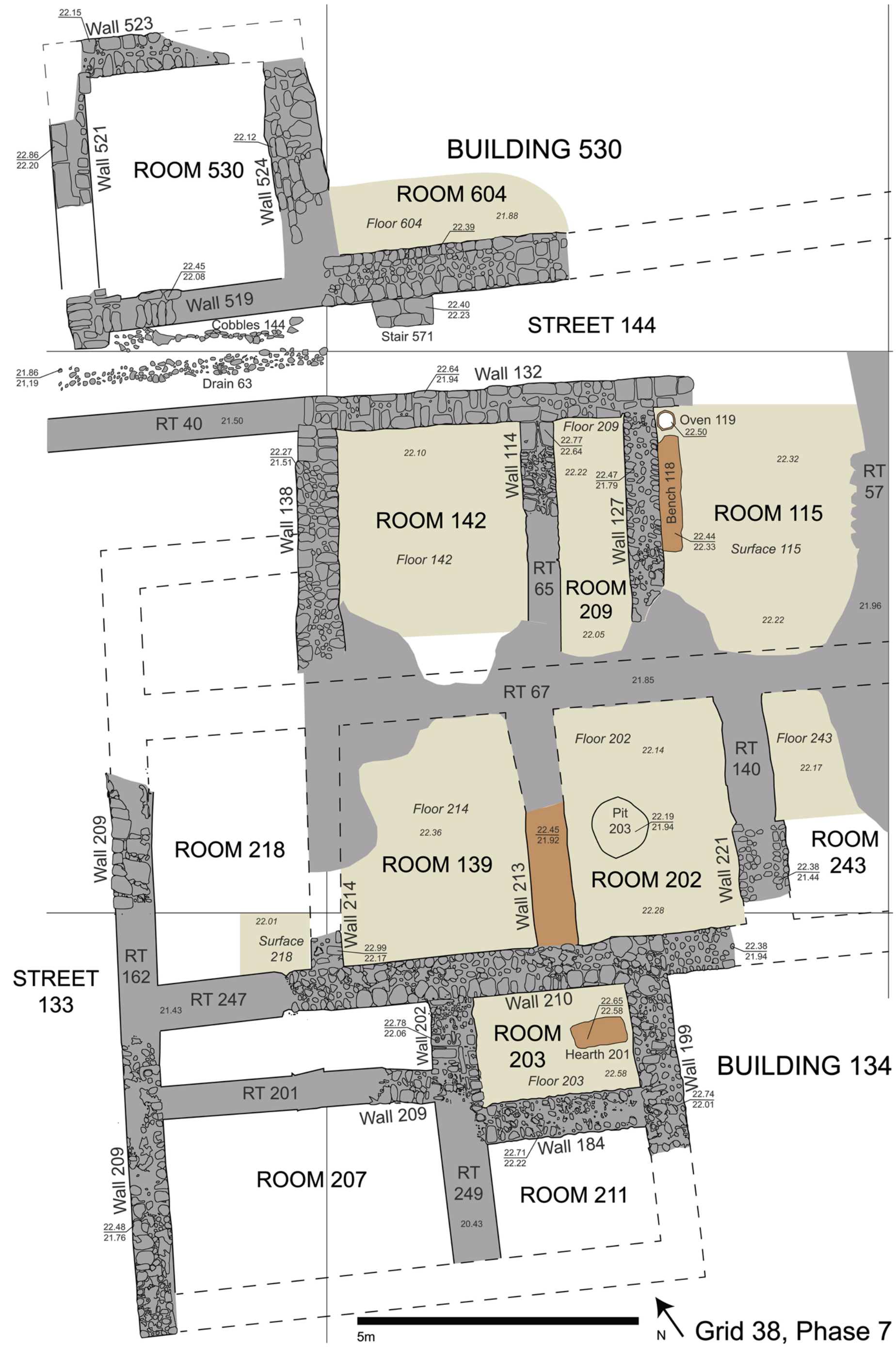
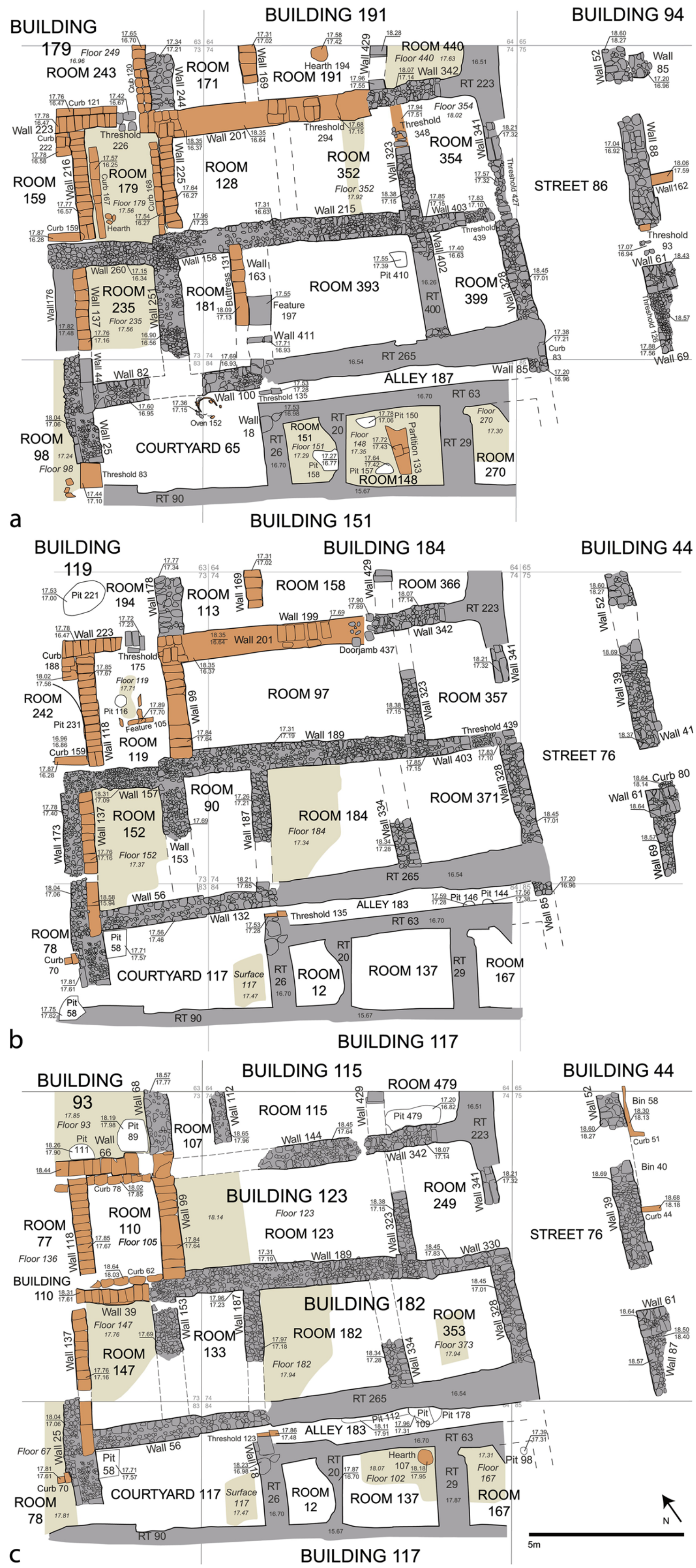


Fig. 5 Grid 38 during Period VIIA (tan = floors; grey = walls or robber trenches; orange-brown = mudbrick structures)

increased frequency and ubiquity of *T. dicoccum* at Ashkelon during the Hellenistic period suggests that patterns of grain cultivation (or possibly import) changed while the city was under Ptolemaic control. We suggest it is possible that such a change may have been widespread in the southern Levant, based on suggestive data from Tel Kedesh, Tell Iẓṭabba, and Tell el-Hesi. Whether another change occurred at the point of transfer from Ptolemaic to Seleucid control at Ashkelon cannot be determined based on current chronological evidence, but that is one possible explanation for the differences observed between Period VIIB and Period VIIA (Fig. 4). The ongoing frequency of *T. dicoccum* at the Seleucid site of Tell Iẓṭabba, however, suggests that *T. dicoccum* cultivation endured in the southern Levant following Seleucid conquest of the region.

Field weeds can provide clear ecological or geographic indications as to the locations of the fields in which crops were grown, as established with earlier, larger Ashkelon

Fig. 6 Grid 51 plan in Period VIII (**a**), VIIB early (**b**), and VIIB late (**c**) (tan = floors; grey = walls or robber trenches; orange-brown = mudbrick structures)



assemblages (Weiss and Kislev 2004). The Hellenistic wild seed assemblage, in contrast, gives only sparse information regarding the methods and location of cereal and pulse cultivation. The co-presence of *L. temulentum* with all cereals (Table 7) suggests that at Ashkelon, as well as other sites (especially Tell el-Hesi and Tell Iẓṭabba, as well as Tell el-Mazar), it was a common weed of cereal fields. *L. temulentum* is one of the most difficult weed seeds to remove from grain, given its similar size and weight to wheat and especially barley, and its presence is indicative of either grain storage or final crop processing/cleaning activities (Fuller and Stevens 2017, p. 114). The markedly higher number of grains of *L. temulentum* in Unit 161, the kitchen courtyard, suggest that this was a place for final grain processing prior to grinding or cooking; the weed seeds, alongside the *T. dicoccum* rachis fragments and other unwanted waste, may have been periodically swept into the *tabun* for disposal, resulting in their occasional carbonization. Other wild seeds that are common across the assemblage are also often weeds of cereal fields, e.g. *Alopecurus*. The absence of greater numbers of field weed seeds and certain common taxa often discarded in early stages of crop processing (e.g. *Galium*; Fuller et al. 2014) align with the near absence of *H. vulgare* and *T. aestivum/durum* rachis fragments, leading to the conclusion that primary threshing of these grains took place outside of the *insulae* sampled, with cleaned grain delivered to the *insulae*.

Fuel use and cooking practices

The fuel used for cooking fires can also be identified through archaeobotanical and microarchaeological analyses. Dung from ruminant animals (sheep, goats, cattle) is a common fuel across Southwest and Central Asia (Miller 1984; Charles 1998; Miller and Marston 2012; Fall et al. 2015; Spengler 2019) and can be identified through multiple avenues: the presence of charred dung pellets; finding spherulites in microscopic sediment analysis; ratios of ash-derived pseudomorphs to dung spherulites; phytolith densities and ratios of grass-derived to wood-derived phytoliths; and the identification of wild seeds typical of animal graze or fodder in high densities in charred archaeobotanical assemblages (Miller and Smart 1984; Charles 1998; Valamoti and Charles 2005; Shahack-Gross 2011; Filipović 2014; Gur-Arieh et al. 2014; Dunseth et al. 2019; Smith et al. 2019; Fuks and Dunseth 2021). No burned dung fragments, or seeds embedded in dung, were identified among the Hellenistic samples analysed here; additionally, spherulites were absent in key deposits from which archaeobotanical remains were recovered (e.g. Room 182/184; Birney 2021, p. 125). Phytoliths have yet to be studied from these contexts. An archaeobotanical statistic suggesting the potential presence of dung used as fuel is the ratio of wild seeds to charcoal; low values indicate a predominance of wood as fuel remains, while a high value suggests dung fuel inputs (Miller 1997; Klinge and Fall 2010; Miller and Marston 2012). The median ratio of wild seeds to charcoal site wide at Ashkelon is 2.6 (Table 4), which is lower than the lowest values of this ratio observed in a survey of five sites in the Eastern Mediterranean (Cyprus [15.5], Southern Levant [19.8 and 376.4], and Upper Euphrates River [717.4 and 1277.1]; Klinge and Fall 2010), as well as Hellenistic samples from a central Anatolia site with good access to local woodlands (Gordion [18.0]; Marston 2017a, p. 109). The low number of wild seeds relative to the standardizing variable of charcoal, together with limited numbers of seeds of taxa preferentially preserved in animal dung (e.g. *Chenopodium*; Spengler 2019), indicates minimal, if any, use of ruminant animal dung as fuel. The absence of multiple markers for dung fuel, together with the consistent presence of wood charcoal, suggests that wood was the primary fuel in the excavated areas and that dung was not used in these areas, or at least was not a significant fuel source. The Ashkelon samples are relatively sparse in botanical material in general, however, indicating that the contexts excavated were cleaned regularly and that burned trash was typically deposited elsewhere.

It also appears that cooking did not occur regularly within the *insulae*, especially in the later Hellenistic, as indicated by both architectural and faunal data that point to a concentration of cooking spaces in specialized shops alongside limited domestic food preparation. The restrictions on home cooking may, as in later Roman and Byzantine cities (including Jerusalem), have been externally imposed in order to reduce the risk of fire in densely populated cities (Fulton and Hesse 2021). The use of wood, or potentially prepared wood charcoal, as fuel rather than dung suggests the potential for higher density heat content of fuels and the capacity for attaining higher cooking temperatures. The literature on the benefits of wood versus dung-derived fuels is equivocal, however, about the relative utility of these options when both are available (see Fuks and Dunseth 2021 for an extended discussion of this literature).

Viticulture, wine production, and wine consumption

Grapes were unquestionably a significant component of the diet at Hellenistic Ashkelon. These grapes may have been grown locally for fruit, grown locally for wine production, or represent imported wine. Margaritis and Jones (2006) lay out archaeobotanical signatures that differentiate wine production, wine storage and consumption, and grape consumption; they note that *V. vinifera* seeds and a few pedicels found together "may represent the by-product of red/white wine or white must… they are kept as fuel or fertilizer" (Margaritis and Jones 2006, p. 799). At Ashkelon, several contexts may include wine residues: Grid 38 Layer 119 includes 140 entire

V. vinifera seeds alongside 7 pedicels, Layer 530 includes 28 seeds and 3 pedicels, Grid 51 Unit 161 28 seeds and 6 pedicels (Table 9). The substantially greater number and ubiquity of *V. vinifera* remains in Grid 38 (Tables 3, 4) suggests greater wine consumption in Grid 38, supportive of other archaeological evidence that indicates that Grid 38 was a wealthier neighbourhood than Grid 51. Indeed, the deposit of two complete imported Koan and Brindisian amphora—the only complete amphora to come from non-destruction contexts—in the foundational fills for the VIIA building in Grid 38 showcases the consumption preferences of the neighbourhood's residents.

In contrast, the *V. vinifera* seeds from Grid 51 are more scattered than in Grid 38 and most appear in samples without pedicels. The Grid 51 pattern is instead more consistent with the consumption of *V. vinifera* as fresh fruit or raisins than either wine production or consumption (Margaritis and Jones 2006). Notably, charred *V. vinifera* fruit is only found in the Grid 51 kitchen courtyard (Unit 161) and a fill (Layer 530) in Grid 38. The fruits found in the kitchen courtyard are underdeveloped, small, and wrinkled, with underdeveloped seeds also present in those samples. In Margaritis and Jones' (2006) model, the co-presence of wrinkled fruit and underdeveloped seeds indicates fresh grapes or raisins, rather than wine. Thus, we suggest that these grapes are residues of food storage or preparation, perhaps immature grapes selectively discarded into the fire.

The botanical results from Grid 38 are consistent with either frequent importation of wine and/or local production of wine, based on the co-occurrence of seeds and pedicels. Throughout most of the Hellenistic period Ashkelon was a heavy importer of wine, most especially from Rhodes, based on transport vessel stamps (Birney 2015). Ashkelon was famous for its own wine during the Late Roman period, with the Ashkelon brand shipped in a distinctive local jar called the *askaloniton*. Wine production installations have been found within the city dating to the Roman, Byzantine, and Islamic periods (Forste and Marston 2019). Although there is no direct evidence for Hellenistic wine production on site, Rhodian imports tapered markedly in the later second century BCE at a time when there was no hiatus in occupation and during a period when other coastal sites experienced a spike in Rhodian imports (Finkielsztejn 1999, p. 27; Birney 2015). The ebb in Rhodian imports, which continued into the first century BCE, coincided with a gradual increase in locally made wine jars (the "Proto-" and "Near-Gazan" amphorae of the early Roman and Roman periods), morphological precursors to the later *askaloniton.* These ceramic patterns may suggest that local wine production stretched back into the Late Hellenistic.

Conclusions

The agricultural system that supplied Hellenistic Ashkelon provided the urban *insulae* with several types of cereals (*T. aestivum/durum*, *H. vulgare*, *T. dicoccum*) that were initially processed elsewhere, likely close to the fields outside the city where they were grown. The frequency of *T. dicoccum* at Ashkelon, and its underreported ubiquity at both other Hellenistic sites in the Levant, begins during the period of Ptolemaic control of the region and suggests cultural affiliations with Egypt. This offers a counterpoint both to suggestions that *T. aestivum/durum* and *H. vulgare* were the most important cereals in the Hellenistic southern Levant and that environmental factors were the primary basis for determining cereal preferences (cf. Orendi et al. 2021). Perhaps surprisingly, the importance of *T. dicoccum* endured following Seleucid conquest of Ashkelon, demonstrating the lasting impact of political change on the agricultural landscape even beyond the influence of a particular regime. In contrast, the pulse and fruit assemblages at Ashkelon closely resemble those of other Hellenistic sites in the eastern Mediterranean. *V. vinifera* appears to have been consumed as both fresh or dried fruit and wine, which was imported through the Hellenistic period and may have been produced locally in increasing quantities during the later Hellenistic. Cooking relied on wood, rather than dung, as fuel, although relatively little charcoal is preserved in most samples, indicating that most refuse was disposed of outside the excavated areas. The scarcity of cooking fuel waste supports the model that cooking became increasingly commercialized, moving outside of *insula* units into large-scale bakeshops and *thermopolia* during the later Hellenistic.

Spatial analysis further illuminates daily life at Hellenistic Ashkelon, providing evidence for both grain storage and cooking in different rooms of the *insulae*. The differences between the relatively wealthy late Hellenistic neighbourhood excavated in Grid 38 and the earlier Hellenistic neighbourhood excavated in Grid 51 include diet, with the wealthier neighbourhood discarding more fruit remains and wine residues in comparison with the cereal-rich diet of Grid 51. While these data appear to reaffirm the picture provided by archaeological and ceramic evidence, the chronological distinction of these assemblages makes it impossible to state definitively whether observed differences in diet are due to wealth or changing agricultural patterns over time.

In comparison with other sites across the Hellenistic world, Ashkelon mostly fits expectations for crops grown in the Mediterranean climate of the coastal southern Levant. The absence or minimal presence of some typical cultivars, such as *O. europaea*, *P. dactylifera*, and *V. ervilia*, is unusual, as is the substantial presence of *T. dicoccum* in contexts demonstrating its role as a locally significant crop. Its early Hellenistic history as a Ptolemaic possession may have determined some of these agricultural decisions, especially the use of *T. dicoccum*, and agricultural changes evident in late Period VIIB and VIIA, after the city came under Seleucid control, suggest the significance of political transitions in changing local agricultural practices and consumption patterns. Further quantitative study and full reporting of archaeobotanical assemblages from Hellenistic sites in areas that transitioned between Ptolemaic and Seleucid control, namely Syria and the Levant, as well as sites in their power centres of Egypt and Mesopotamia, will help to illuminate the role of political economy in agricultural practices in the region. Likewise, such a comparison will provide additional evidence with which to interpret differences between the two kingdoms in systems of land tenure, agrarian taxation, and agricultural calendars that have been reconstructed based on textual records (e.g. Aperghis 2004; Monson 2012, 2015). In such context, we will better be able to determine the cause for agricultural changes observed at Ashkelon.

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References

Aperghis GG (2004) The Seleukid royal economy: the finances and financial administration of the Seleukid empire. Cambridge University Press, Cambridge

Ariel DT (2021) Coins. In: Birney KJ Ashkelon 9: the Hellenistic period. Eisenbrauns, University Park

Ayalon E, Frankel R, Kloner A (2009) Oil and wine presses in Israel from the Hellenistic, Roman and Byzantine periods. Archaeopress, Oxford

Badura M, Rzeźnicka E, Wicenciak U, Waliszewski T (2016) Plant remains from Jiyeh/Porphyreon, Lebanon (seasons 2009–2014): preliminary results of archeobotanical analysis and implications for future research. Pol Archaeol Mediter 25:487–510

Bagnall RS, Derow P (2008) The Hellenistic period: historical sources in translation. Blackwell, Malden

Bats M (1988) Vaiselle et alimentation à Olbia de Provence (v. 350-v.50 av. J.C.): Modèles culturels et catégories céramiques. Revue Archéologique de Narbonnaise Supplément 18. Éditions du Centre National de la Recherche Scientifique, Paris, pp 5–72

Berlin AM (1997) The plain wares. In: Herbert SC (ed) Excavations at Tel Anafa, Vol II, i. The Hellenistic and Roman pottery: the plain wares. Journal of Roman Archaeology Supplementary Series 10.2.1. Kelsey Museum, Ann Arbor, pp 1–244

Berlin AM, Ball T, Thompson R, Herbert SC (2003) Ptolemaic agriculture, "Syrian wheat", and *Triticum aestivum*. J Archaeol Sci 30:115–121

Birney KJ (2015) To the dregs: drawing meaning from the Rhodian handles of Hellenistic Ashkelon. Center for Hellenic Studies Research Bulletin 3(2)

Birney KJ (2017) Phoenician bathing in the Hellenistic East: Ashkelon and beyond. Bull Am Schools Orient Res 378:203–222

Birney KJ (2021) Ashkelon 9: the Hellenistic period. Eisenbrauns, University Park

Blakely JA, Horton FL Jr (2001) On site identifications old and new: the example of Tell el-Hesi. Near East Archaeol 64:24–36

Borojevic K (2011) Interpreting, dating, and reevaluating the botanical assemblage from Tell Kedesh: a case study of historical contamination. J Archaeol Sci 38:829–842

Braadbaart F, Marinova E, Sarpaki A (2016) Charred olive stones: experimental and archaeological evidence for recognizing olive processing residues used as fuel. Veget Hist Archaeobot 25:415–430

Bugh GR (2006) The Cambridge companion to the Hellenistic world. Cambridge University Press, Cambridge

Charles M (1998) Fodder from dung: the recognition and interpretation of dung-derived plant material from archaeological sites. Environ Archaeol 1:111–122

Cleymans S, Daems D, De Cupere B, Marinova E, Poblome J (2017) A taste of time. Foodways and cultural practices in late Achaemenid-early Hellenistic Düzen Tepe (SW Anatolia). HEROM 6:63–96

Crawford DJ (1979) Food: tradition and change in Hellenistic Egypt. World Archaeol 11:136–146

D'Alpoim Guedes J, Spengler RN (2014) Sampling strategies in paleoethnobotanical analysis. In: Marston JM, d'Alpoim Guedes J, Warinner C (eds) Method and theory in paleoethnobotany. University Press of Colorado, Boulder, pp 77–94

Dunseth ZC, Fuks D, Langgut D et al (2019) Archaeobotanical proxies and archaeological interpretation: a comparative study of phytoliths, pollen and seeds in dung pellets and refuse deposits at Early Islamic Shivta, Negev, Israel. Quat Sci Rev 211:166–185

Eig A (1939) The vegetation of the light soils belt of the coastal plain of Palestine. Palest J Bot Jerus Ser 1:255–308

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

Filipović D (2014) Early farming in Central Anatolia: an archaeobotanical study of crop husbandry, animal diet and land use at Neolithic Çatalhöyük. Archaeopress, Oxford

Finkielsztejn G (1999) Hellenistic Jerusalem: the evidence of the Rhodian amphora stamps. In: Faust A, Baruch E (eds) New studies on Jerusalem: proceeding of the fifth conference December 23rd 1999. Ingeborg Rennert Center for Jerusalem Studies, Jerusalem, pp 21–36

Forste KM, Marston JM (2019) Islamic and Crusader era agriculture at Ashkelon. In: Hoffman T (ed) Ashkelon 8: the Islamic and Crusader periods. Eisenbrauns, University Park, pp 649–669

Foxhall L (2007) Olive cultivation in ancient Greece: seeking the ancient economy. Oxford University Press, Oxford

Fritz GJ, Nesbitt M (2014) Laboratory analysis and identication of plant macroremains. In: Marston JM, d'Alpoim Guedes J, Warinner C (eds) Method and theory in paleoethnobotany. University Press of Colorado, Boulder, pp 115–145

Fuks D, Dunseth ZC (2021) Dung in the dumps: what we can learn from multi-proxy studies of archaeological dung pellets. Veget Hist Archaeobot 30:137–153

Fuller BT, De Cupere B, Marinova E, Van Neer W, Waelkens M, Richards MP (2012) Isotopic reconstruction of human diet and animal husbandry practices during the Classical-Hellenistic, Imperial,

and Byzantine periods at Sagalassos, Turkey. Am J Physical Anthropol 149:157–171
Fuller DQ, Stevens CJ (2017) Open for competition: domesticates, parasitic domesticoids and the agricultural niche. Archaeol Int 20:110–121
Fuller DQ, Stevens C, McClatchie M (2014) Routine activities, tertiary refuse and labor organization: social inferences from everyday archaeobotany. In: Madella M, Lancelotti C, Savard M (eds) Ancient plants and people: contemporary trends in archaeobotany. University of Arizona Press, Tucson, pp 174–217
Fulton DN, Hesse P (2021) The Hellenistic fauna. In: Birney KJ Ashkelon 9: the Hellenistic period. Eisenbrauns, University Park
Gitler H, Kahanov Y (2002) The Ascalon 1988 hoard (CH 9.548): a periplus to Ascalon in the late Hellenistic period? In: Meadows A, Wartenberg U (eds) Coin hoards 9: Greek hoards. Royal Numismatic Society, London, pp 259–268
Grainger JD (1999) Prices in Hellenistic Babylonia. J Econ Soc Hist Orient 42:303–325
Gur-Arieh S, Shahack-Gross R, Maeir AM, Lehmann G, Hitchcock LA, Boaretto E (2014) The taphonomy and preservation of wood and dung ashes found in archaeological cooking installations: case studies from Iron Age Israel. J Archaeol Sci 46:50–67
Hunter AA, Gassner BR (1998) Evaluation of the Flote-Tech machine-assisted flotation system. Am Antiquity 63:143–156
Isager S, Skydsgaard JE (1992) Ancient Greek agriculture: an introduction. Routledge, London
Jackson H (2014) Jebel Khalid on the Euphrates, vol 4. The housing insula. Meditarch, Sydney
Jacomet S (2006) Identification of cereal remains from archaeological sites, 2nd edn. Archaeobotany Lab, IPAS, Basel University, Basel
Klinge J, Fall P (2010) Archaeobotanical inference of Bronze Age land use and land cover in the eastern Mediterranean. J Archaeol Sci 37:2,622–2,629
Koucky FL (2008) Physical environment. In: Stager LE, Schloen JD, Master DM (eds) Ashkelon 1: introduction and overview (1985–2006). Eisenbrauns, Winona Lake, Indiana, pp 11–15
Lass EHE (1994) Quantitative studies in flotation at Ashkelon, 1986 to 1988. Bull Am Schools Orient Res 294:23–38
Lentz DL, Dunning NP, Scarborough VL, Grazioso L (2018) Imperial resource management at the ancient Maya city of Tikal: a resilience model of sustainability and collapse. J Anthropol Archaeol 52:113–122
Lernau O (2021) Fish bones dated to the Hellenistic period in Ashkelon. In: Birney KJ Ashkelon 9: the Hellenistic period. Eisenbrauns, University Park
Lev-Tov J (2003) 'Upon what meat doth this our Caesar feed…?' A dietary perspective on Hellenistic and Roman influence in Palestine. In: Alkier S, Zangenberg J (eds) Zeichen aus Text und Stein. Studien auf dem Weg zu einer Archäologie des Neuen Testaments. Francke, Tübingen, pp 420–446
Margaritis E (2014) The kapeleio at Hellenistic Krania: food consumption, disposal, and the use of space. Hesperia 83:103–121
Margaritis E (2015) Cultivating Classical archaeology: agricultural activities, use of space, and occupation patterns in Hellenistic Greece. In: Haggis DC, Antonaccio CM (eds) Classical archaeology in context: theory and practice in excavation in the Greek world. De Gruyter, Berlin, pp 333–354
Margaritis E (2016) Agricultural production and domestic activities in rural Hellenistic Greece. In: Harris EM, Lewis DM, Woolmer M (eds) The ancient Greek economy: markets, households and city-states. Cambridge University Press, Cambridge, pp 187–204
Margaritis E, Jones M (2006) Beyond cereals: crop processing and *Vitis vinifera* L. Ethnography, experiment and charred grape remains from Hellenistic Greece. J Archaeol Sci 33:784–805
Margaritis E, Jones M (2008) Olive oil production in Hellenistic Greece: the interpretation of charred olive remains from the site of Tria Platania, Macedonia, Greece (fourth–second century B.C.). Veg Hist Archaeobot 17:393–401
Marinova E, Riehl S (2009) *Carthamus* species in the ancient Near East and south-eastern Europe: archaeobotanical evidence for their distribution and use as a source of oil. Veg Hist Archaeobot 18:341–349
Marston JM (2011) Archaeological markers of agricultural risk management. J Anthropol Archaeol 30:190–205
Marston JM (2012) Agricultural strategies and political economy in ancient Anatolia. Am J Archaeol 116:377–403
Marston JM (2014) Ratios and simple statistics in paleoethnobotanical analysis: data exploration and hypothesis testing. In: Marston JM, d'Alpoim Guedes J, Warinner C (eds) Method and theory in paleoethnobotany. University Press of Colorado, Boulder, pp 163–179
Marston JM (2017) Agricultural sustainability and environmental change at ancient Gordion. University of Pennsylvania Museum Press, Philadelphia
Marston JM (2017) Consequences of agriculture in Mesopotamia, Anatolia, and the Levant. In: Bogucki P (ed) Oxford research encyclopedia of environmental science: agriculture and the environment. Oxford University Press, Oxford
Marston JM (in press) Archaeological approaches to agricultural economies. J Archaeol Res. https://doi.org/10.1007/s10814-020-09150-0
Mayerson P (2002) Three pharaonic crops in Ptolemaic Egypt: *ólyra* (emmer wheat) and maslins of *krithópyron* and *olyrókrithon*. Z Papyrol Epigr 141:210–213
Miller NF (1984) The use of dung as fuel: an ethnographic model and an archaeological example. Paléorient 10:71–79
Miller NF (1988) Ratios in paleoethnobotanical analysis. In: Hastorf CA, Popper VS (eds) Current paleoethnobotany: analytical methods and cultural interpretations of archaeological plant remains. University of Chicago Press, Chicago, pp 72–96
Miller NF (1991) The Near East. In: van Zeist W, Wasylikowa K, Behre K-E (eds) Progress in old world palaeoethnobotany. Balkema, Rotterdam, pp 133–160
Miller NF (1997) Farming and herding along the Euphrates: environmental constraint and cultural choice (fourth to second millennia B.C.). MASCA Res Pap Sci Archaeol 14:123–132
Miller NF (2010) Botanical aspects of environment and economy at Gordion. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, Turkey
Miller NF, Enneking D (2014) Bitter vetch (*Vicia ervilia*): ancient medicinal crop and farmers' favorite for feeding livestock. In: Minnis PE (ed) New lives for ancient and extinct crops. The University of Arizona Press, Tucson, pp 254–268
Miller NF, Marston JM (2012) Archaeological fuel remains as indicators of ancient West Asian agropastoral and land-use systems. J Arid Environ 86:97–103
Miller NF, Smart TL (1984) Intentional burning of dung as fuel: a mechanism for the incorporation of charred seeds into the archeological record. J Ethnobiol 4:15–28
Monson A (2012) From the Ptolemies to the Romans: political and economic change in Egypt. Cambridge University Press, Cambridge
Monson A (2015) Hellenistic empires. In: Monson A, Scheidel W (eds) Fiscal regimes and the political economy of premodern states. Cambridge University Press, Cambridge, pp 169–207
Morehart CT (2018) Inherited legacies of ecological imperialism in central Mexico. J Anthropol Archaeol 52:103–112
Nesbitt M (2006) Identification guide for Near Eastern grass seeds. Institute of Archaeology, University College London, London
Nesbitt M, Bates J, Hillman G, Mitchell S (2017) The Archaeobotany of Aşvan: environment and cultivation in eastern Anatolia

from the Chalcolithic to the Medieval period. British Institute at Ankara, London
Nir Ya (2008) The wells of Ashkelon. In: Stager LE, Schloen JD, Master DM (eds) Ashkelon 1: introduction and overview (1985–2006). Eisenbrauns, Winona Lake, Indiana, pp 105–106
Orendi A, Lichtenberger A, Tal O (2021) Food in a colonial setting: the flora assemblage of a short-lived Seleucid-founded site in the Near East. Veg Hist Archaeobot. https://doi.org/10.1007/s00334-020-00820-z
Pearsall DM (2015) Paleoethnobotany: a handbook of procedures, 3rd edn. Left Coast Press, Walnut Creek
Ramsay JH, Mueller N (2016) Telling seeds: archaeobotanical investigations at Tall al-‘Umayri, Jordan. Ann Am Schools Orient Res 69:1–16
Riehl S (2010) Flourishing agriculture in times of political instability – the archaeobotanical and isotopic evidence from Tell Atchana. In: Yener A (ed) Tell Atchana, ancient Alalakh. The 2003–2004 excavation seasons. Koç Üniversitesi Yayınları, Istanbul, pp 123–136
Riehl S, Pustovoytov KE, Weippert H, Klett S, Hole F (2014) Drought stress variability in ancient Near Eastern agricultural systems evidenced by $\delta^{13}C$ in barley grain. Proc Natl Acad Sci USA 111:12,348–12,353
Rosen AM (2008) Site formation. In: Stager LE, Schloen JD, Master DM (eds) Ashkelon 1: introduction and overview (1985–2006). Eisenbrauns, Winona Lake, pp 101–104
Rosenzweig MS, Marston JM (2018) Archaeologies of empire and environment. J Anthropol Archaeol 52:87–102
Rostovtzeff MI (1941) The social and economic history of the Hellenistic world. Clarendon Press, Oxford
Rowan E (2015) Olive oil pressing waste as a fuel source in antiquity. Am J Archaeol 119:465–482
Samuel D (1993) Ancient Egyptian cereal processing: beyond the artistic record. Camb Archaeol J 3:276–283
Shahack-Gross R (2011) Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance. J Archaeol Sci 38:205–218
Smith A (2014) The use of multivariate statistics within archaeobotany. In: Marston JM, d'Alpoim Guedes J, Warinner C (eds) Method and theory in paleoethnobotany. University Press of Colorado, Boulder, pp 181–204
Smith A, Proctor L, Hart TC, Stein GJ (2019) The burning issue of dung in archaeobotanical samples: a case-study integrating macro-botanical remains, dung spherulites, and phytoliths to assess sample origin and fuel use at Tell Zeidan, Syria. Veg Hist Archaeobot 28:229–246
Spaer A (1984) Ascalon: from royal mint to autonomy. In: Houghton A (eds) Studies in honor of Leo Mildenberg: numismatics, art history, archeology. Editions NR, Wetteren, Belgium, pp 229–239
Spengler RN III (2019) Dung burning in the archaeobotanical record of West Asia: where are we now? Veget Hist Archaeobot 28:215–227
Stager LE (1971) Climatic conditions and grain storage in the Persian period. Biblic Archaeol 34:86–88
Stevens CJ (2003) An investigation of agricultural consumption and production models for prehistoric and Roman Britain. Environ Archaeol 8:61–76
Stewart RB (1978) Archeobotanic studies at Tell-el-Hesi. Econ Bot 32:379–386
Stewart RB, Robertson W (1973) Application of the flotation technique in arid areas. Econ Bot 27:114–116
Thompson DJ (1999) New and old in the Ptolemaic Fayyum. In: Bowman AK, Rogan E (eds) Agriculture in Egypt: from Pharaonic to modern times. Proceedings of the British Academy 96. Oxford University Press, Oxford, pp 123–138
Valamoti SM, Charles M (2005) Distinguishing food from fodder through the study of charred plant remains: an experimental approach to dung-derived chaff. Veg Hist Archaeobot 14:528–533
Valamoti SM, Jones G (2003) Plant diversity and storage at Mandalo, Macedonia, Greece: archaeobotanical evidence from the Final Neolithic and Early Bronze Age. Ann Br School Athens 98:1–35
Van der Spek RJ (2007) The Hellenistic Near East. In: Scheidel W, Morris I, Saller RP (eds) The Cambridge economic history of the Greco-Roman world. Cambridge University Press, Cambridge, pp 409–433
Van der Veen M (2007) Formation processes of desiccated and carbonized plant remains - the identification of routine practice. J Archaeol Sci 34:968–990
Vermoere M (2004) Holocene vegetation history in the territory of Sagalassos (Southwest Turkey): a palynological approach. Brepols, Turnhout, Belgium
Weiss E, Kislev ME (2004) Plant remains as indicators for economic activity: a case study from Iron Age Ashkelon. J Archaeol Sci 31:1–13
Weiss E, Kislev ME, Mahler-Slasky Y (2011) Plant remains. In: Stager LE, Master DM, Schloen JD (eds) Ashkelon 3: the seventh century BC. Eisenbrauns, Winona Lake, Indiana, pp 591–613
Willcox G (1990) The plant remains from Hellenistic and Bronze Age levels at Failaka, Kuwait: a preliminary report. Travaux De La Maison De L'orient 18:43–50
Yassine K, van der Steen EJ (2012) Tell el-Mazar II: excavations on the mound 1977–1981: Field I. Archaeopress, Oxford
Zohary D, Hopf M, Weiss E (2012) Domestication of plants in the old world: the origin and spread of cultivated plants in West Asia, Europe, and the Nile Valley, 4th edn. Oxford University Press, New York
Zohary M (1950) The segetal plant communities of Palestine. Plant Ecol 2:387–411
Zohary M (1962) The plant life of Palestine: Israel and Jordan. The Ronald Press Company, New York
Zohary M (1973) Geobotanical foundations of the Middle East. Fischer, Stuttgart