Journal of Archaeological Science: Reports 26 (2019) 101884

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Archaeobotanical inference of intermittent settlement and agriculture at Middle Bronze Age Zahrat adh-Dhra'1, Jordan

Patricia L. Fall[a,*], Steven E. Falconer[b], Steven Porson[c]

[a] Department of Geography and Earth Sciences, University of North Carolina Charlotte, 9201 University City Blvd., Charlotte, NC 28223, USA
[b] Department of Anthropology, University of North Carolina Charlotte, 9201 University City Blvd., Charlotte, NC 28223, USA
[c] Department of Geography and Earth Sciences, University of North Carolina Charlotte, 9201 University City Blvd., Charlotte, NC 28223, USA

ARTICLE INFO

Keywords:
Accelerator Mass Spectrometry (AMS) ages
Archaeobotanical flotation analyses
Archaeological settlement patterns
Bronze Age
Dead Sea Plain
Jordan Rift Valley

ABSTRACT

Analysis of botanical evidence excavated from Zahrat adh-Dhra'1, Jordan elucidates intermittent settlement and agriculture on the geographical and social margins of Middle Bronze Age society in the Southern Levant. Zahrat adh-Dhra'1, lying just east of the Dead Sea, provides data from multiple discontinuous phases of occupation, particularly in comparison to evidence from the continuously occupied Middle Bronze Age village of Tell el-Hayyat in the agricultural heartland of the Jordan Valley. We focus our analysis on taxonomic frequencies and ubiquities for carbonized seeds recovered from 88 flotation samples from Zahrat adh-Dhra'1 and 152 samples from Tell el-Hayyat. Both settlements emphasized cereal cultivation, with a greater accompanying proliferation of wild and weedy taxa on the anthropogenic landscape around Tell el-Hayyat. In contrast, lower taxonomic ubiquities, many of which decline through time, reflect less consistent seed deposition and agricultural practices in accordance with episodic habitation at Zahrat adh-Dhra'1 on the more sparsely settled and impacted hinterland of the Dead Sea Plain. In concert, a suite of evidence, including dispersed architecture, Bayesian modeling of calibrated Accelerator Mass Spectrometry (AMS) ages and comparative analysis of archaeobotanical evidence, illuminates Zahrat adh-Dhra'1 as an unprecedented example of discontinuous agrarian settlement on the fringes of Levantine Middle Bronze Age urbanized society.

1. Introduction

The Bronze Age of the Southern Levant has inspired a substantial body of social interpretation focused largely on the rise and collapse of agrarian urbanism. Following this paradigm, the major component of the Levantine Early Bronze Age (Early Bronze II-III; about 3000–2500 cal BCE) is noteworthy for the advent of fortified towns atop the region's mounded tells, and the first coalescence of urbanized society and possible localized polities (e.g., Greenberg, 2002, 2014; de Miroschedji, 2009, 2014; Falconer and Savage, 2009). This initial urbanism was followed by its region-wide collapse, which was manifested by the pervasive abandonment of towns during Early Bronze IV (also known as the Intermediate Bronze Age; about 2500–2000 cal BCE), an economic reorientation that emphasized non-sedentary pastoralism, and a settlement shift from walled towns to seasonal encampments and small villages (Palumbo, 1991; Dever, 1995; Cohen, 2009; Prag, 2014; Falconer and Fall, 2019). The subsequent Middle Bronze Age (about 2000–1600 cal BCE) is portrayed as the apex of prehistoric Levantine urbanism, during which larger walled cities reappeared rapidly in Middle Bronze I (traditionally termed Middle Bronze IIA). These cities grew in size, number, and scale of fortification during Middle Bronze II and III (traditionally Middle Bronze IIB and IIC) (Greenberg, 2002; Bourke, 2014; Cohen, 2014).

Several facets of this Bronze Age narrative are undergoing significant revisions that carry fundamental implications for archaeological interpretation of Levantine Bronze Age settlement and society. Perhaps most basically, Bayesian modeling of calibrated Accelerator Mass Spectrometry (AMS) ages now expands Early Bronze IV from a relatively brief two-century interruption of Levantine urbanization to a half-millennium era of urban abandonment that rivals the duration of town emergence in Early Bronze II-III (Regev et al., 2012; Falconer and Fall, 2016) (Table 1). This chronological modeling also curtails the Middle Bronze Age from about five centuries to perhaps as few as 300 years (Höflmayer et al., 2016; Cohen, 2017; Falconer and Fall, 2017, 2019; Höflmayer, 2017). These temporal adjustments tend to redirect the Levantine Bronze Age narrative from an emphasis on progressive urbanization to a more balanced appreciation of both urbanized and non-urbanized social configurations and their constituent

* Corresponding author.
E-mail addresses: pfall@uncc.edu (P.L. Fall), sfalcon1@uncc.edu (S.E. Falconer), sporson@uncc.edu (S. Porson).

https://doi.org/10.1016/j.jasrep.2019.101884
Received 9 March 2019; Received in revised form 31 May 2019; Accepted 6 June 2019

Table 1
Traditional and revised Early and Middle Bronze Age chronologies for the Southern Levant. Traditional chronology based on Levy (1995: fig. 3); revised chronology based on Regev et al. (2012), Falconer and Fall (2016, 2017) and Höflmayer (2017).

Period	Traditional (B.C.)	Revised (cal B.C.)
MB III	1650–1500	1700–1600
MB II	1800–1650	1850/1800–1700
MB I	2000–1800	2000/1900–1850/1800
EB IV	2200–2000	2500–2000/1900
EB III	2700–2200	2900–2500
EB II	3000–2700	3000–2900
EBI	3500–3000	3500–3000

elements.

In this context, Early Bronze IV, formerly seen as a relatively brief interruption in an overarching trend of Levantine urbanization (hence its "Intermediate" alternative nomenclature), now elicits broadened social interpretations that recognize and accommodate a growing array of sedentary agrarian communities, creating more nuanced, less strictly pastoral appreciations of society during town abandonment (Cohen, 2009; Richard et al., 2010; Prag, 2014; Falconer and Fall, 2019). The subsequent Middle Bronze Age has long been characterized as "urban," based in part on long occupations of large fortified communities, whereas discontinuous settlement of smaller sites has been portrayed as a quintessential aspect of Early Bronze IV "pastoral" society (e.g., Haiman, 1996; Dever, 2014). Although the importance of smaller communities in Bronze Age society is recognized implicitly (e.g., Palumbo, 1991; Greenberg, 2002; Maeir et al., 2003; Falconer and Fall, 2006, 2019; Cohen, 2014), they rarely figure explicitly in models of Middle Bronze settlement and social systems. This study introduces the settlement of Zahrat adh-Dhra'1 (hereafter "ZAD 1") as it fits a niche not recognized previously in Levantine Bronze Age archaeology. Archaeobotanical evidence from ZAD 1 is contrasted with data from Tell el-Hayyat, a sedentary farming village in the northern Jordan Valley, which was inhabited continuously through the Middle Bronze Age. As elucidated through this comparative analysis, ZAD 1 illustrates a unique instance of a discontinuously occupied small agrarian settlement during the heyday of Middle Bronze urbanized society, and thereby exemplifies a geographically and socially distant element in the world of early Levantine towns and cities.

2. Study sites

2.1. Setting of Zahrat adh-Dhra'1

ZAD 1 represents an intermittent agrarian settlement in a geographically isolated, agriculturally marginal environmental setting east of the hypersaline Dead Sea (410 m below sea level), which lies at the lowest elevation on earth (Fig. 1). Situated on the Dead Sea Plain at about 180 m below sea level, ZAD 1 stretches over 6 ha along a narrow northwest-southeast trending ridge between Wadi Dhra'and Wadi Wa'ida, two tributaries of the Wadi al-Karak (Fig. 2), which descends from the Transjordanian Plateau to the Dead Sea. Long-term erosion has created a deeply dissected badland topography on this large alluvial plain of steep wadis and gently sloping plateaus. Today the region is characterized by high temperatures (often over 40° C in summer) and very low rainfall (annual mean < 50 mm) (Al-Eisawi, 1996). These extreme environmental conditions are moderated by a nearby perennial spring, 'Ayn adh-Dhra', which flows down the Wadi adh-Dhra' and today, as in the past, provides water for nearby farming communities. The Wadi adh-Dhra' runs along a narrow ravine about 25 m below the level of ZAD 1 (Fig. 3). In antiquity, however, water would have flowed nearer the plain level of Zahrat adh-Dhra', as evidenced by the remains of freshwater mollusks (*Melanopsis praemorsa*) recovered from the nearby Neolithic (PPNA) site of ZAD 2, also situated on the Plain of Dhra' (Edwards et al., 2001). Down cutting on the Plain of Dhra' either curtailed, or occurred after, the Middle Bronze Age occupation of ZAD 1. Eroded buildings on both the northern and southern banks of Wadi adh-Dhra' suggest an original settlement extending over at least 12 ha, which has been truncated by Bronze Age or post-Bronze Age down cutting (Edwards et al., 2001, 2002; Fall et al., 2007), as also seen at Early Bronze Age Bab edh-Dhra', just downstream on the Wadi al-Karak (Rast and Schaub, 2003). This erosion could have been accelerated by tectonic uplift, although no evidence for uplift has been demonstrated (Donahue, 1985), nor is the stratigraphy in this area tilted. Alternatively, pronounced wadi incision may be due to the lowering of the Dead Sea over the past 5000 years (Frumkin et al., 1994), as indicated by very large limestone boulders at the eastern and western ends of the ridge of ZAD 1 that may represent remnant alluvial deposition along the latest Pleistocene shoreline of ancient Lake Lisan.

The relative isolation of ZAD 1 is reflected by its distance from the nearest Middle Bronze Age settlements, which lie 50–55 km to the west at Tell Msas (Fritz and Kempinski, 1983) and Tell al-Milh (Kochavi, 1967), and 60 km to the north at Tell Nimrin (Flanagan and McCreery, 1990; Flanagan et al., 1994). The Middle Bronze Age is noteworthy for its dearth of settlements on the Transjordanian Plateau, especially in modern southern Jordan (Falconer, 2008; Bourke, 2014). As part of this relatively sparse cultural landscape, the Middle Bronze Age cemetery of Dayr 'Ayn 'Abata, is located about 25 km to the south of ZAD 1 (Politis, 1997). Additional mortuary sites lie closer at hand, including the Early Bronze Age cemetery of Bab edh-Dhra' (Schaub and Rast, 1989), just 3 km downslope from ZAD 1 toward the Dead Sea. Reconnaissance on the Plain of Dhra' in 1977 revealed a larger distribution of tombs over roughly 60 ha beyond the burials immediately associated with Bab adh-Dhra' (McCreery, 1977/78; Clark, 1979). In 2002, we examined the eastern-most extension of this mortuary landscape, which included a sprawling array at least 50 poorly preserved cairn tombs south of the Wadi edh-Dhra' (Fig. 4); we also mapped isolated cairn tombs north and northeast of ZAD 1. Sherds from some of these tombs, and some reported from the McCreery/Clark survey (McCreery, 1977/78; Clark, 1979), closely resemble the straight-sided, flat-based cooking pots that typify the ZAD 1 Middle Bronze Age ceramic assemblage (Edwards et al., 2002: fig. 24). Thus, much of the mortuary architecture on the Plain of Dhra' appears to date to the Middle Bronze Age, raising the possibly that the inhabitants of ZAD 1 periodically built, used and visited these tombs (see Falconer in Edwards et al., 2004). Accordingly, the seemingly isolated settlement of ZAD 1 emerges amid a larger social landscape on the Dead Sea Plain and as a remote element in the regional cultural fabric of the Middle Bronze Age Southern Levant.

2.2. Setting of Tell el-Hayyat

Tell el-Hayyat lies approximately 240 m below sea level in the *ghor*, the agricultural lowlands of the Jordan Valley (see Fig. 1). This low mound, consisting of about 4.5 m of stratified sediments, is surrounded by fertile alluvial soils on a broad terrace above the present floodplain of the Jordan River. Modern precipitation averages approximately 300 mm annually (e.g., Horowitz, 1979: fig. 2.31). The largest local spring lies at the foot of ancient Pella, 7 km to the NE, while other minor springs flow from wadis in the foothills of the Transjordanian Escarpment to the east. The Jordan River flows 2 km to the west, but at a substantially lower elevation (about 30m lower). Thus, the site's location relative to these perennial water sources suggests the possibility of localized irrigation, but more definitely affirms the importance of rainfall agriculture in the fields surrounding Tell el-Hayyat.

The Bronze Age settlement at Tell el-Hayyat was a small (0.5 ha) village situated between the ancient town of Pella and the Early Bronze IV village of Tell Abu en-Ni'aj, as well as a variety of other ancient communities in the northern Jordan Valley. Tell el-Hayyat provides an ideal community for comparison with ZAD 1, based on the overall

Fig. 1. Map of eastern Mediterranean showing study sites of Zahrat adh-Dhra'1 and Tell el-Hayyat, Jordan, as well as major sites contributing to new Bronze Age radiocarbon chronologies.
(Prepared by JoAnna Klinge and Patrick Jones)

contemporaneity of these settlements, their comparably modest populations, their common agricultural orientation, and the use of identical methods directed by the authors for the excavation and analysis of both sites. Excavated floral and faunal evidence suggests that the villagers of Tell el-Hayyat were dedicated farmers who cultivated annual cereals and legumes, and perennial orchard crops, and husbanded sheep, goat, cattle and pig amid a largely cultivated, anthropogenic landscape in the northern Jordan Valley (Falconer and Fall, 2006). Six stratigraphic phases document continuous occupation at Tell el-Hayyat from late Early Bronze IV (Phase 6) through Middle Bronze III (Phase 1).

2.3. Ecological contrasts

ZAD 1 and Tell el-Hayyat provide a noteworthy pair of comparably excavated and analyzed archaeological sites in which contrasts in paleobotanical evidence highlight fundamental distinctions in agrarian life at a sedentary village marked by long-term continuous occupation in the agricultural bread basket of the northern Jordan Valley vs. a discontinuously inhabited settlement on an arid alluvial fan east of the Dead Sea. The paleobotanical differences between these sites may be fueled by a number of ecological factors. Whereas both settlements could have utilized springs for localized irrigation, the spring 'Ayn adh-Dhra' would have been immediately available to the people of ZAD 1. However, the occupants of ZAD 1 would have faced greater challenges in maintaining productive agriculture on a more dynamic landscape subject to greater erosion, with less fertile soils and more arid climatic conditions. The location of ZAD 1, beyond immediate contact with contemporaneous communities, rendered this settlement marginal in social terms as well.

3. Materials and methods

3.1. Archaeological excavation

The settlement of ZAD 1 was excavated over four weeks between mid-December 1999 and mid-January 2000. The settlement's most prominent features are exposed stone remains of > 40 semi-subterranean rectilinear structures ranging from single walls to multi-room compounds. One- and two-room structures with attached courtyards are dispersed along the ridge of ZAD 1 (Fig. 5). After these structures were mapped and enumerated, 24 excavation units sampled archaeological sediments across the site (Falconer in Edwards et al., 2001; Fall

Fig. 2. View north across Plain of Dhra', Jordan, showing Structures 40–44 toward the western end of Zahrat adh-Dhra'1 in the foreground.

et al., 2007). These units were tailored in size and orientation according to visible architectural remains (Fig. 6), labeled A-Z (omitting U and W), and designed to explore interiors, exteriors and courtyard enclosures associated with nine structures (36–44), as well as more isolated potential midden locations (Units S and T) (Falconer in Edwards et al., 2001; Falconer in Edwards et al., 2002).

Tell el-Hayyat was excavated during three field seasons totaling 22 weeks in 1982, 1983 and 1985 (Falconer and Fall, 2006). A combination of 21 excavation units (17 measuring 4 × 4 m; 4 measuring 2 × 4 m; separated by one-meter balks) revealed six stratified phases of habitation through 4.5 m of deposition. A cumulative exposure of approx. 400m^2 provides an 8% excavated sample of the settlement. The initial and final occupations of the settlement are represented by limited remains at the center of the site in phases 6 and 1, dating to Early Bronze IV and Middle Bronze III, respectively. Tell el-Hayyat's most robust data, including abundant material culture, floral and faunal remains, document the course of Middle Bronze Age village life through Middle Bronze I-III in phases 5-2. Village architecture is centered on a stratified sequence of four mudbrick temples, each surrounded by an enclosure wall, in these four phases. Household activities are reflected in evidence from surrounding houses, courtyards and alleys.

3.2. Recovery of plant macrofossils

The excavations of ZAD 1 and Tell el-Hayyat incorporated identical methods of sediment sampling and macrobotanical recovery. All sediments excavated from ZAD 1 and Tell el-Hayyat were dry sieved through 5 mm mesh screens, enabling the recovery of animal bone remains. Sediments with apparent organic content were not dry sieved and were processed by water flotation to recover carbonized seeds and charcoal. As a routine excavation method, all archaeological sediments with visible burned organic content were sampled from a variety of contexts. We focused our collection on hearths, pits, floors, and other use surfaces where we expected minimal disturbance and the most abundant burned material. Nearly 500 l of sediment from the two sites, averaging about three liters per sample, were processed by non-mechanized water flotation methods (e.g., Pearsall, 2000) to recover plant macrofossils (Fall et al., 1998, 2002, 2015; Fall in Edwards et al., 2001; Falconer and Fall, 2006: 38–43; Klinge and Fall, 2010; Klinge, 2013). Once the floated organic fraction from each sample was dried, the remaining carbonized seeds and charcoal were poured through nested 4.75 mm, 2 mm, 1 mm and 0.5 mm mesh sieves. All material 0.5 mm or larger was sorted under a binocular microscope to separate charred seeds from charcoal fragments (see detailed methods in Klinge and Fall, 2010: 38–43).

Carbonized seeds recovered from 88 sediment samples provide the archaeobotanical data from ZAD 1, which are incorporated in this study and compared to data from 152 samples from Tell el-Hayyat (Falconer and Fall, 2006). Identifications of seeds, seed fragments, fruits and other floral parts are based on external morphology using Fall's personal reference collection and comparative literature (e.g., Helbaek, 1958; Martin and Barkley, 1961; Renfrew, 1973; Zohary and Hopf, 1973; Zohary and Spiegel-Roy, 1975; van Zeist, 1976; Hillman, 1978; van Zeist and Bakker-Heeres, 1982, 1984a, 1984b, 1985; Hubbard, 1992; Jacomet, 2006). Charcoal fragments from 39 ZAD 1 sediment samples and 60 Tell el-Hayyat samples were segregated from the seed remains and weighed collectively. Taxonomic identifications were based on scanning electron microscopy (JEOL JSM6300 at Arizona State University), which produced photos that were compared with published keys (Fahn et al., 1986; Schweingruber et al., 2011; Akkemik and Yaman, 2012). Scanning electron microscopy provides the best optical resolution for identifying specific features of wood anatomy, especially when charcoal fragments are too small to analyze with a dissecting microscope (see discussion in Fall et al., 2015).

Archaeobotanical studies commonly suggest food processing as a means by which plants intended for human consumption may become carbonized and enter the archaeological record (e.g., Chernoff and Paley, 1998; Dennell, 1974; Fuller and Harvey, 2006; Fuller and Stevens, 2009; Hastorf, 1988; Jones, 1987; Jones and Halstead, 1995; van der Veen, 2007). However, in regions characterized by animal husbandry and diminished sources of fuel wood, burning of dung fuel constitutes a particularly important mechanism for the carbonization of both cultivated crops and wild plants (Anderson and Ertuğ-Yaras, 1996; Bottema, 1984; Charles, 1998; Hastorf and Wright, 1998; Miller, 1984; Miller and Smart, 1984; Reddy, 1998; Shahack-Gross, 2011). In the Southern Levant, analysis of archaeological charcoal (Klinge and Fall,

Fig. 3. View downstream along the Wadi adh-Dhra', Jordan. Note crew member crossing wadi bed and surface of Zahrat adh-Dhra'1 illuminated at top of photo.

2010) and modeling of regional vegetation (Soto-Berelov et al., 2015; Fall et al., 2018) indicate Bronze Age landscapes that were substantially deforested, in contrast, for example, to contemporaneous persistently wooded uplands on Cyprus (Fall et al., 2015). Thus, the likelihood of regional deforestation, clear importance of sheep/goat husbandry, and incorporation of abundant wild, as well as cultivated plants in the archaeological records of ZAD 1 and Tell el-Hayyat, suggest the importance of dung burning as a cause for the carbonization and incorporation of plant remains in the archaeological contexts sampled at both sites (Klinge and Fall, 2010). Interpretation of these carbonized assemblages thus provides a means of inferring vegetation profiles indicative of both cultivation practices and local vegetation.

3.3. Quantification and analysis of plant macrofossils

The seeds from the ZAD 1 and Tell el-Hayyat flotation samples are quantified as NISP (numbers of identified specimens) in a manner analogous to the quantification of animal bones (O'Connor 2000;: 55). Data expressed as NISP do not quantify the number of individuals in a plant assemblage, but they do provide effective estimates of the relative proportions of taxa in a population (e.g., Banning 2000: 94). Data based on NISP are more robust than other comparative measures (e.g., MNI), and are well-suited for inferring changing relative frequencies of taxa across time or space (see zooarchaeological discussions in Grayson 1984: 94–96; Crabtree 1990: 159–160; Reitz and Wing 2008: 202–210). Relative frequencies are calculated as percentages of individual taxa or plant categories in the total seed assemblage for a site or habitation phase, whereas sample ubiquities are calculated as percentages of the number of flotation samples in which a taxon or category is present.

Relative frequencies provide a means of standardizing seed counts to permit comparisons between the abundances of individual taxa, plant categories or archaeological sites, especially when sample sizes vary (Miller, 1988; Kreuz et al., 2005; van der Veen, 2007). Ubiquity values provide a complementary standardized measure based on the presence or absence of a taxon or category across all samples from a site or chronological phase (Popper, 1988: 60–64; Pearsall, 2000: 212–216). Both measures are most informative when samples are drawn from similar depositional contexts using consistent sampling methods, as in this study. Ubiquity is a particularly valuable measure that accommodates data from samples that vary considerably in size, and for taxa that differ in frequencies due to variables such as fragmentation rate or the number of seeds produced per plant (e.g., Marston, 2014: 167). Thus, ubiquity provides an especially important measure for comparable assessments of relative abundance at both sites, especially in light of the greater sample-to-sample variability in seed counts and taxonomic frequencies at ZAD 1. Distinctions in

Fig. 4. Partially preserved circular cairn tomb south of Zahrat adh-Dhra'1 and Potash City, Jordan, facing east. Note stones in larger stone circular alignment in background.

relative frequencies and ubiquities are assessed for statistical significance using χ^2 tests of seed counts from ZAD 1 and Tell el-Hayyat when these counts meet the minimum values required for χ^2 analysis. The plant remains recovered from both sites include carbonized macrofossils from 61 identified taxa, which are categorized as cultivated cereals, cultivated legumes, cultivated fruits, woody shrubs, wild grasses, wild sedges, wild legumes, wild and weed taxa, and unidentified seeds. We use wild grasses, wild sedges, wild legumes, and other wild and weed taxa as mutually exclusive categories; other wild and weed taxa include largely crop-following weeds and/or shrubs.

As with carbonized seeds, charcoal remains are quantified according to taxonomic ubiquity (i.e., percentage of samples in which a taxon is present). Charcoal abundance also is expressed in terms of density ratios based on charcoal weight (g) per kiloliter of sediment floated (see discussions in Klinge and Fall, 2010 and Marston, 2014: 164–167). The identified charcoal data for both sites are organized in three vegetation

Fig. 5. View north across Zahrat adh-Dhra'1, Jordan, showing Structure 37 and boulder field around Structure 36 toward eastern end of Zahrat adh-Dhra'1.

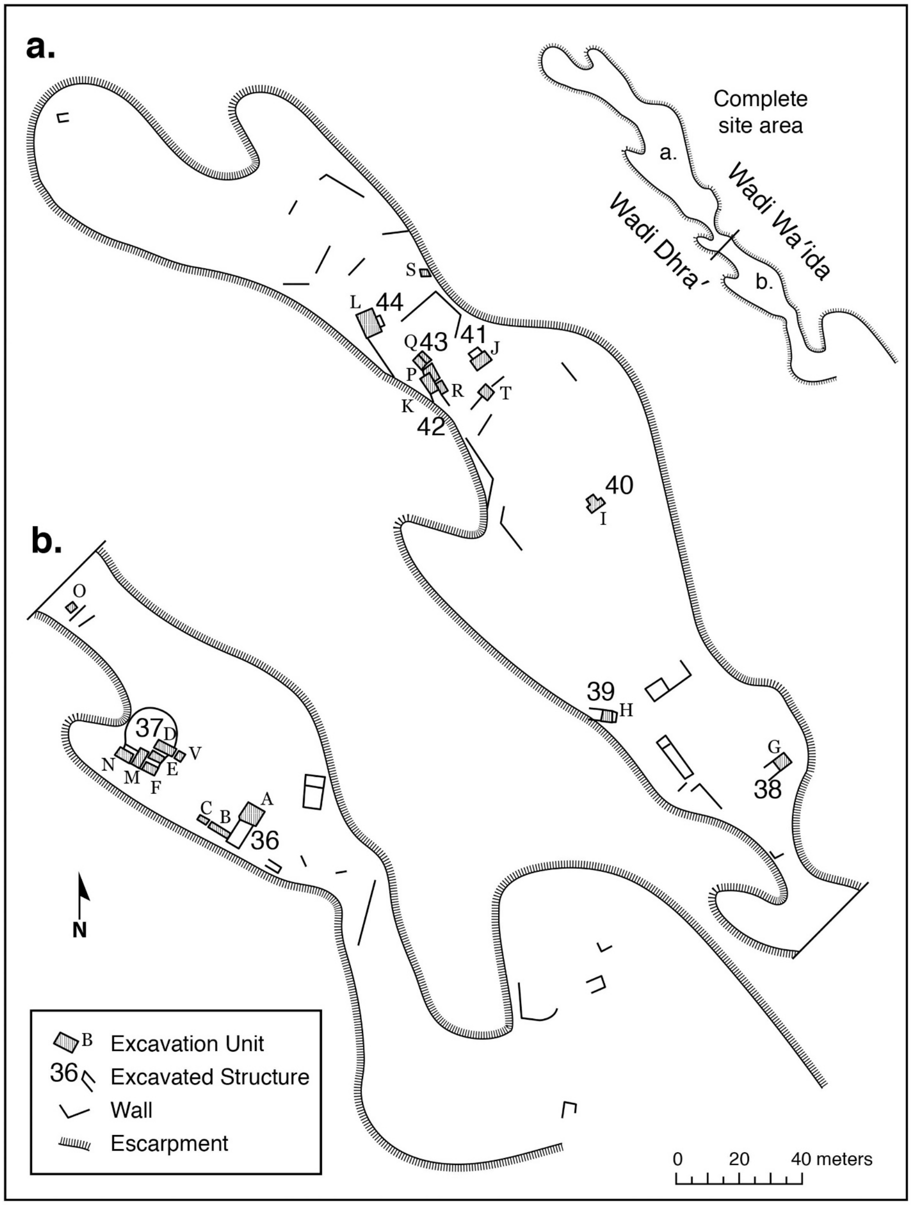


Fig. 6. Site plan for Zahrat adh-Dhra'1, Jordan, showing visible wall lines, enumerated structures and lettered excavation units. (Prepared by Wei Ming and Barbara Trapido-Lurie)

categories: trees, shrubs and orchard taxa.

3.4. Accelerator Mass Spectrometry (AMS) dating

We submitted seed samples representing short-lived cultigens (rather than charcoal) for AMS ^{14}C analysis to optimize chronological resolution. Eight seed samples were analyzed by the University of Arizona Accelerator Mass Spectrometry (AMS) Laboratory and six samples were sent to the Australian Institute of Nuclear Science in the Australian Nuclear Science and Technology Organisation (ANSTO). The AMS ^{14}C ages in this study were calibrated using OxCal 4.3.2 (Bronk Ramsey, 2017) and the IntCal13 calibration curve (Reimer et al., 2013). The modeling tools in OxCal 4.3.2 were used for Bayesian analysis of the ages. This analytical method permits coordinated probabilistic analysis of large suites of calibrated ^{14}C ages (Bronk Ramsey, 2009), accommodates the common non-normal distribution of these probabilities, and incorporates prior probabilities based on stratigraphic sequences. Bayesian analysis provides a means for building statistically robust, stratigraphically informed radiocarbon sequences for individual or multiple sites, or across geographic regions.

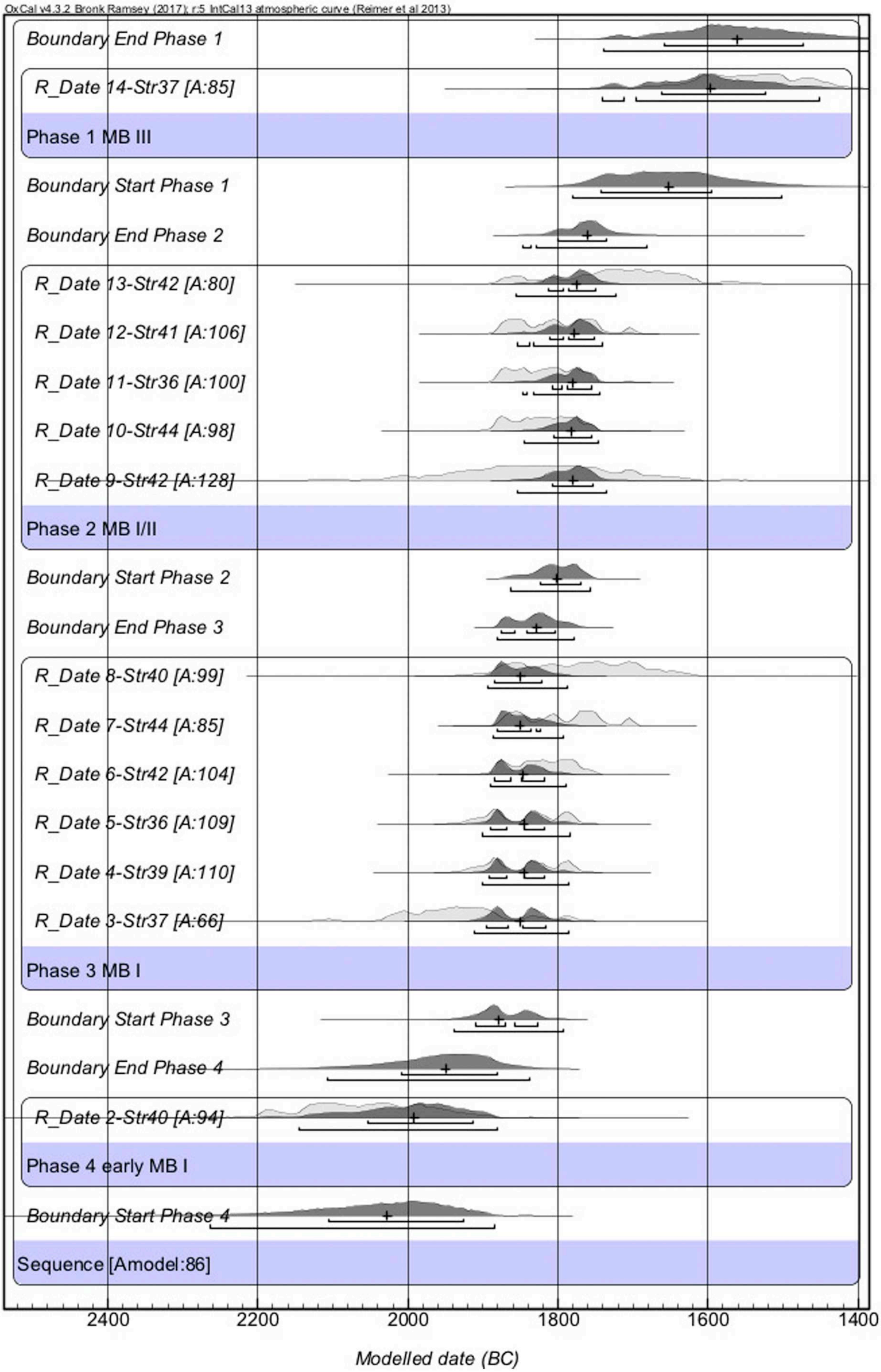
3.5. Faunal evidence

The faunal remains recovered from ZAD 1 suggest highly variable depositional patterns. A relatively sparse assemblage includes 323 bones and bone fragments, most of which were preserved poorly, probably due to their relatively shallow deposition in porous sediments. Bone fragments were recovered from just eight excavation units, three of which (Areas J, K, M, in Structures 37, 41 and 42) contributed 82% of these faunal remains. Among 31 identifiable elements, 30 represent domestic sheep (*Ovis aries*) or goat (*Capra hircus*); one bone comes from a domestic pig (*Sus scrofa*) (Metzger in Edwards et al., 2001). While the sheep/goat orientation of animal husbandry at ZAD 1 may be unsurprising, the discontinuous patterning that characterizes this bone evidence is amplified by the site's occupational history.

Table 2.
AMS radiocarbon results for seed samples from Zahrat adh-Dhra'1, Jordan. Ages listed in order used for Bayesian modeling (see Fig. 7). Calibration based on OxCal 4.3.2 (Bronk Ramsey, 2017) using the IntCal13 atmospheric curve (Reimer et al., 2013). Context is indicated according to Structure, Stratum, Excavation Unit, Locus and Bag (e.g., Str. 40, lower, I.012.72 = Unit I, Locus 012, Bag 72). $^{+}$OZH756 $\delta^{13}C$ ‰ value assumed.

Lab number	Str.	$\delta^{13}C$ ‰	Conventional ^{14}C age yr BP	Calibrated 1σ ranges yr BCE (probability)	Calibrated 2σ ranges yr BCE (probability)	Median Age cal yr BCE	Archaeological context	Material dated
1) AA109800[a]	41	−22.1	3982 ± 25	2562–2535 (36.4%) 2493–2471 (31.8%)	2571–2513 (54.7%) 2503–2465 (40.7%)	2525	Str. 41, lower, J.031.113	*Triticum* seeds
2) OZH756	40	−25.0^{+}	3670 ± 60	2137–1971 (68.2%)	2206–1890 (95.4%)	2055	Str. 40, lower, I.012.72	*Hordeum* seeds
3) OZH758	37	−22.8	3580 ± 50	2022–1990 (12.6%) 1985–1882 (55.6%)	2120–2095 (2.4%) 2041–1769 (93.0%)	1934	Str. 37, lower, F.015.98	Legume seeds
4) AA109798	39	−27.2	3528 ± 22	1904–1873 (27.1%) 1844–1815 (24.0%) 1800–1779 (17.2%)	1929–1771 (95.4%)	1840	Str. 39, lower, H.007.28	Cereal frags
5) AA110725	36	−23.4	3527 ± 21	1901–1873 (25.2%) 1844–1814 (24.9%) 1801–1778 (18.1%)	1926–1771 (95.4%)	1838	Str. 36, lower, A.012.72	Cereal frags
6) AA110726	42	−11.8	3503 ± 21	1882–1870 (10.0%) 1846–1775 (58.2%)	1890–1754 (95.4%)	1822	Str. 42, lower, K.020.126 and K.022.202	Cereal frags
7) AA110727	44	−22.8	3468 ± 21	1874–1843 (25.7%) 1816–1799 (11.6%) 1779–1744 (30.9%)	1880–1739 (89.6%) 1713–1698 (5.8%)	1800	Str. 44, lower, L.010.10	*Hordeum* seeds
8) OZH757	40	−27.1	3450 ± 60	1877–1841 (15.7%) 1821–1796 (10.2%) 1782–1690 (42.3%)	1916–1624 (95.4%)	1768	Str. 40, lower, I.014.98	*Vitis vinifera* seeds
9) OZI636	42	−21.8	3500 ± 80	1926–1739 (64.0%) 1713–1697 (4.2%)	2030–1628 (95.4%)	1826	Str. 42, upper, K.014.177	*Hordeum* seeds
10) AA109802	44	−24.2	3500 ± 24	1881–1867 (10.7%) 1848–1774 (57.5%)	1891–1749 (95.4%)	1821	Str. 44, upper, L.010.10	*Hordeum* seeds
11) AA110724	36	−22.6	3489 ± 21	1878–1840 (29.5%) 1826–1793 (27.2%) 1784–1770 (11.5%)	1884–1749 (95.4%)	1816	Str. 36, upper, A.010.41	*Triticum* frags
12) AA109799	41	−27.4	3475 ± 24	1876–1842 (26.3%) 1821–1797 (16.5%) 1782–1748 (25.4%)	1882–1741 (92.2%) 1711–1700 (3.2%)	1807	Str. 41, upper, J.014.30	*Vitis vinifera* seeds
13) OZI635	42	−22.5	3410 ± 60	1862–1851 (3.3%) 1772–1627 (64.9%)	1886–1606 (92.0%) 1584–1545 (3.4%)	1716	Str. 42, upper, K.019.117	*Hordeum* seeds
14) OZH759	37	−26.9	3260 ± 60	1614–1496 (62.3%) 1475–1461 (5.9%)	1682–1675 (0.6%) 1666–1421 (94.8%)	1542	Str. 37, upper, N.012.37	*Hordeum, V. vinifera, Pisum sativum* seeds

[a] Outlier in Bayesian modeling.



(caption on next page)

Fig. 7. Bayesian sequencing of calibrated ^{14}C ages for seed samples from Phases 4–1 at Zahrat adh-Dhra'1, Jordan. Light gray curves indicate single-sample calibration distributions; dark curves indicate modeled calibration distributions. Calibration and Bayesian modeling based on OxCal v 4.3.2 (Bronk Ramsey, 2017) using the IntCal13 atmospheric curve (Reimer et al., 2013).

Table 3
Hypothesized chronology for phases of occupation and unoccupied gaps at Zahrat adh-Dhra'1. AMS ages based on phase boundary medians produced by Bayesian modeling of 13 calibrated radiocarbon ages (AA109800 excluded as an outlier). Calibrations based on OxCal 4.3.2 (Bronk Ramsey, 2017) using the IntCal13 atmospheric curve (Reimer et al., 2013). Phases of occupation at Zahrat adh-Dhra'1 commence with Phase 4 (earliest) and conclude with Phase 1 (latest).

Period	Modeled AMS Ages (cal B.C.)	
	Occupied	Unoccupied
Phase 1 (MB III)	1653–1562	
		1761–1653
Phase 2 (MB II)	1802–1761	
		1829–1802
Phase 3 (MB I)	1879–1829	
		1950–1879
Phase 4 (early MB I)	2029–1950	

4. Results

4.1. Chronology at ZAD 1

Typological ceramic analysis and inference of abandonment patterns based on pottery breakage patterns previously suggested discontinuous occupation in late Middle Bronze I through early Middle Bronze II (Falconer in Edwards et al., 2002; Berelov, 2006a: 92; Berelov, 2006b; Fall et al., 2007). Bayesian modeling of calibrated AMS ages now reveals disjunct episodes of habitation and abandonment at ZAD 1 during Middle Bronze I, II and III, marked most clearly by two distinct tightly-defined clusters of AMS radiocarbon dates in Middle Bronze I and II. Fourteen AMS ages from seven structures provide the radiocarbon chronology for ZAD 1 (see Table 2). Excavation of these structures revealed stratified upper and lower occupational layers, sometimes separated by aeolian sediments suggesting periodic abandonment of individual buildings. Eight seed samples were recovered from lower stratified sediments and six samples came from upper stratified contexts. The earliest AMS age from ZAD 1 (AA-109800) derives from *Triticum* seeds from lower sediments in Structure 41 with a modeled two-sigma range of 2571–2465 cal BCE. This age lies at the Early Bronze III/IV transition in current Levantine radiocarbon chronologies (Regev et al., 2012; Höflmayer et al., 2014; Falconer and Fall, 2016, 2017). Since ZAD 1 reveals no evidence of Early Bronze III or IV material culture, we note this unexpectedly early date but exclude it from our Bayesian modeling of Middle Bronze Age occupation at ZAD 1.

By incorporating sample stratification and the prior probability of intermittent structural abandonment, Bayesian analysis of the remaining 13 AMS ages produces an optimal chronological model (Fig. 7; $A_{model} = 85.7$) in which four “sequential” phases of occupation are separated by gaps of varying lengths (Table 3). The beginning of Middle Bronze Age settlement is estimated by the Phase 4 start boundary median of 2029 cal BCE, which stems from a single age (OZH 756) from lower sediment in Structure 40 with a modeled two-sigma range of 2146–1882 cal BCE. The interval between the end boundary median for Phase 4 (1950 cal BCE) and the start boundary median for Phase 3 (1879 cal BCE) suggests a roughly 70-year hiatus in occupation of the site. Subsequent reoccupation in Phase 3 is modeled on a tightly-defined series of six ages from lower sediments in six different structures with two-sigma ranges between 1911 and 1785 cal BCE, and a very narrow range of median values between 1852 and 1846 cal BCE.

A second gap in occupation of only about 30 years is modeled between the Phase 3 end boundary median (1829 cal BCE) and the phase 2 start boundary median (1802 cal BCE). Phase 2 habitation is modeled on the basis of another closely-spaced series of five constituent ages from upper sediments in four structures with 2-sigma ranges between 1857 and 1723 cal BCE, and a correspondingly tight alignment of median values between 1783 and 1776 cal BCE. A roughly one-century occupational gap emerges between the Phase 2 end boundary median (1761 cal BCE) and the Phase 1 start boundary median (1653 cal BCE) preceding the latest habitation in Phase 1, which is reflected by a single age from upper sediment in Structure 37 with a modeled two-sigma range of 1742–1453 cal BCE. The final abandonment of the site is estimated by the Phase 1 end boundary median of 1562 cal BCE. In overview, this model portrays intermittent occupation of ZAD 1 in four phases of about 40–90 years each, separated by three gaps in occupation ranging from 30 to 100 years each. The most distinct chronological evidence for occupation of ZAD 1 stems from closely clustered AMS ages for Phases 3 and 2, dating to Middle Bronze I and II, respectively.

4.2. Chronology at Tell el-Hayyat and comparison with Zahrat adh-Dhra'1

The AMS ages from Zahrat adh-Dhra'1 describe a variety of

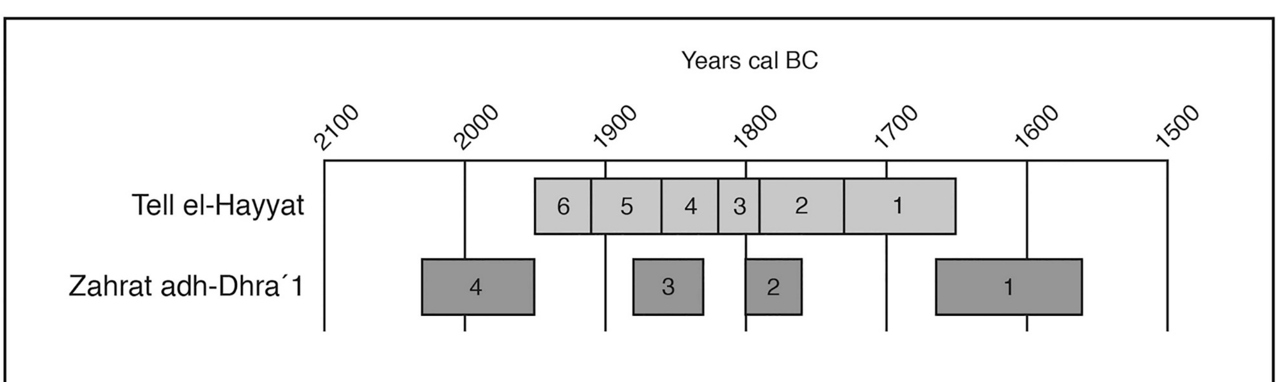


Fig. 8. Comparative chronologies of occupation in four sequential phases at Zahrat adh-Dhra'1 and six contiguous phases at Tell el-Hayyat, based on Bayesian modeling of calibrated AMS ^{14}C ages from Zahrat adh-Dhra'1 and Tell el-Hayyat. Calibration based on Oxcal 4.3.2 (Bronk Ramsey, 2017) using the IntCal 13 atmospheric curve (Reimer et al., 2013). Phase beginning and end dates are based on Bayesian boundary median ages.

Table 4
Comparison of numbers of analyzed flotation samples and identified seeds according to phases at ZAD 1 (179.6 l of sediment floated) and Tell el-Hayyat (318 l floated; data from Falconer and Fall, 2006).

Period	ZAD 1			Tell el-Hayyat		
	Phase	Samples	Seeds	Phase	Samples	Seeds
MB III	1	12	616	1	1	31
MB II/III	–	–	–	2	26	2626
MB II	2	31	1014	–	–	–
MB I/II	–	–	–	3	40	2036
MB I	3	39	1212	4	46	1868
Early MB I	4	1	22	5	36	1743
EB IV	–	–	–	6	3	89
	Pre-4	5	129	–	–	–
Total		88	2993		152	8393

noteworthy patterns, particularly in comparison to evidence from the Middle Bronze Age village of Tell el-Hayyat in the Jordan Valley (Falconer and Fall, 2006). Bayesian modeling of 14 AMS seed dates from Tell el-Hayyat suggests occupation between about 1950 and 1650 cal BCE (Falconer and Fall, 2017). A comparison of occupational histories (Fig. 8) suggests initial occupation and abandonment of ZAD 1, prior to the founding of Tell el-Hayyat, followed by partially contemporaneous Middle Bronze I habitation at ZAD 1 (Phase 3) and Tell el-Hayyat (Phases 5 and 4). Another settlement hiatus at ZAD 1 largely paralleled Phase 3 at Tell el-Hayyat, after which Phase 2 at both sites represents partially contemporaneous Middle Bronze II occupations. Middle Bronze III habitation at Tell el-Hayyat largely spans the third abandonment of ZAD 1, prior to a subsequent final occupation of ZAD 1.

The chronological modeling for these two sites documents continuous occupation at Tell el-Hayyat in keeping with an emerging, somewhat abbreviated ^{14}C Middle Bronze Age chronology for the Southern Levant. The clearest chronological signatures at ZAD 1 emerge from modeling of clustered AMS ages in two distinct roughly half-century episodes of occupation (Phases 3 and 2) separated by about 30 years of abandonment in the midst of the Middle Bronze Age. Additional ages suggest site use at the beginning and end of the Middle Bronze, in Phases 4 and 1 respectively. Bayesian modeling of the estimated lengths of Phases 4 and 1 may be somewhat exaggerated due to their single constituent dates. Thus, an alternative hypothesis would suggest that the occupation at ZAD 1 lay entirely within ZAD Phases 3 and 2, corresponding to Tell el-Hayyat's Phases 5-2. In sum, the modeled radiocarbon chronologies for Tell el-Hayyat and ZAD 1 present a striking contrast between uninterrupted Middle Bronze I-III habitation at Tell el-Hayyat and clearly discontinuous occupations and abandonments of ZAD 1 in Middle Bronze I and II, possibly bracketed by chronologically distinct, less clearly defined episodes of use at the onset and end of the Middle Bronze Age.

4.3. Carbonized seeds

Carbonized plant macrofossils were recovered from all excavated phases at ZAD 1 and Tell el-Hayyat (Table 4). Flotation samples and identified seeds are most abundant from Phases 3-1 at ZAD 1 and Phases 5-2 at Tell el-Hayyat. Seed remains were recovered from all excavation units at Tell el-Hayyat, and seven of the nine structures excavated at ZAD 1 (Structures 36, 37, 39–42, 44), one midden (Unit O). The arrays of crops cultivated by each community share many important taxa (Tables 5 and 6). Among cultivated cereals, wheat is represented by einkorn (*Triticum monococcum*), emmer (*T. dicoccum*) and bread wheat (*T. aestivum/durum*) at both settlements, while barley appears in both hulled (*Hordeum vulgare*) and naked (*H. vulgare* var. *nudum*) forms. Other cultivated grasses include rye (*Secale cereale)* and millet (*Panicum miliaceum*). Farmers in both communities cultivated

Table 5
Counts, relative frequencies (%) and ubiquity (% samples with taxon present) of seeds from 88 flotation samples collected at Zahrat adh-Dhra'1.

	Seeds	Freq.	Ubiquity
	NISP	%	%
Cultivated cereals			
Hordeum vulgare	62	2.1	20.5
Hordeum vulgare var. *nudum*	93	3.1	19.3
Undifferentiated *Hordeum*	36	1.2	12.5
Triticum aestivum/durum	35	1.2	14.8
Triticum monococcum	1	0.03	1.1
Triticum dicoccum	24	0.8	11.4
Undifferentiated *Triticum*	6	0.2	4.5
Panicum miliaceum	11	0.4	4.5
Secale cereale	2	0.06	1.1
Undifferentiated cereal	648	21.7	69.3
Cultivated cereal total	918	30.7	75.0
Cultivated legumes			
Lens culinaris	4	0.1	3.4
Pisum sativum	37	1.2	17.0
Vicia faba	9	0.3	4.5
Undifferentiated cultivated legume	60	2.0	6.8
Cultivated legume total	110	3.7	28.4
Cultivated fruits			
Ficus carica	250	8.4	46.6
Vitis vinifera	113	3.8	20.5
Cultivated fruit total	363	12.1	56.8
Other cultivated			
cf. *Linum usitatissimum*	2	0.06	2.3
Other cultivated total	2	0.06	2.3
Wild tree fruits			
Pistacia cf. *atlantica*	1	0.03	1.1
Wild tree fruit total	1	0.03	1.1
Wild woody shrubs			
cf. *Berberis* sp.	5	0.2	1.1
cf. *Crataegus* sp.	1	0.03	1.1
Wild shrub total	6	0.2	1.1
Wild grasses			
cf. *Bromus* sp.	3	0.1	3.4
Phalaris sp.	10	0.3	4.5
cf. *Phleum* sp.	1	0.03	1.1
Undifferentiated wild grass	45	1.5	13.6
Wild grass total	59	2.0	19.3
Wild sedges			
cf. *Carex* sp.	23	0.8	14.8
cf. *Elocharis* sp.	10	0.3	6.8
cf. *Fimbristylis* sp.	2	0.06	2.3
cf. *Scirpus martimus*	6	0.2	4.5
Wild sedge total	41	1.4	23.9
Wild legumes			
cf. *Astragalus* sp.	2	0.06	2.3
cf. *Lathyrus* sp.	1	0.03	1.1
cf. *Medicago* sp.	40	1.3	8.0
cf. *Melilotus* sp.	7	0.2	3.4
Undifferentiated wild legume	420	14.0	38.6
Wild legume total	470	15.7	43.2
Other wild & weed taxa			
cf. *Adonis* sp.	2	0.06	1.1
cf. *Aizoon* sp.	493	16.5	33.0
Amaranthus sp.	61	2.0	9.1
cf. *Androsace* sp.	1	0.03	1.1
cf. Asteraceae	1	0.03	1.1
cf. *Bellevalia* sp.	14	0.5	8.0
Chenopodium sp.	122	4.1	37.5
cf. *Croton* sp.	1	0.03	1.1
cf. *Euphorbia* sp.	43	1.4	2.3
cf. *Fumaria* sp.	5	0.2	3.4
cf. *Helianthemum* sp.	1	0.03	1.1
Malva sp.	57	1.9	19.3
Malvaceae	5	0.2	2.3
cf. *Ornithogalum* sp.	35	1.2	4.5
Plantago sp.	9	0.3	6.8

(*continued on next page*)

Table 5 (*continued*)

	Seeds	Freq.	Ubiquity
	NISP	%	%
cf. *Polanisia* sp.	14	0.5	3.4
cf. *Polygonum* sp.	11	0.4	2.3
cf. *Ranunculus* sp.	2	0.06	1.1
Rumex sp./*Polygonum* sp.	146	4.9	26.1
Other wild & weed taxa total	1023	34.2	70.5
Total	2993	99.99	

Table 6

Counts, relative frequencies (%) and ubiquity (% samples with taxon present) of seeds from 152 flotation samples collected at Tell el-Hayyat.

	Seeds	Freq.	Ubiquity
	NISP	%	%
Cultivated cereals			
Hordeum vulgare	636	7.7	57.9
Hordeum vulgare var. *nudum*	94	1.1	21.7
Undifferentiated *Hordeum*	408	4.9	57.2
Triticum aestivum/durum	192	2.3	38.2
Triticum monococcum	163	2.0	36.2
Triticum dicoccum	119	1.4	32.2
Undifferentiated *Triticum*	315	3.8	52.6
Panicum miliaceum	1	0.01	0.7
Secale cereale	356	4.3	36.2
Undifferentiated cereals	11	0.1	4.6
Cultivated cereal total	2295	27.8	84.9
Cultivated legumes			
Cicer arietinum	19	0.2	3.3
Lens culinaris	117	1.4	25.7
Pisum sativum	63	0.8	23.7
Vicia ervilia/Lathyrus	124	1.5	27.6
Vicia faba	12	0.1	4.6
Undifferentiated cultivated legume	18	0.2	4.6
Cultivated legume total	353	4.3	48.0
Cultivated fruits			
Ficus carica	1205	14.6	62.5
Olea europaea	121	1.5	21.1
Vitis vinifera	26	0.3	11.8
Cultivated fruit total	1352	16.4	68.4
Wild woody shrubs			
Prosopis sp.	172	2.1	20.4
Wild shrub total	172	2.1	20.4
Wild grasses			
Avena sp.	234	2.8	31.6
Phalaris sp.	333	4.0	44.1
Undifferentiated wild grass	121	1.5	22.4
Wild grass total	688	8.3	55.9
Wild legumes			
Undifferentiated wild legume	564	6.8	55.3
Wild legume total	564	6.8	55.3
Other wild & weed taxa			
cf. *Adonis* sp.	9	0.1	3.9
Amaranthus sp.	207	2.5	12.5
cf. Asteraceae	1	0.01	0.7
cf. *Beta* sp.	1	0.01	0.7
Chenopodium sp.	37	0.4	5.9
Galium sp.	155	1.9	38.2
Malva sp.	1943	23.5	52.0
cf. *Ochthodium* sp.	2	0.02	0.7
Plantago sp.	102	1.2	23.7
Rumex sp./*Polygonum* sp.	350	4.2	48.0
Other wild & weed taxa total	2807	34.0	80.3
Unknown	33	0.4	9.9
Total	8264	100.1	

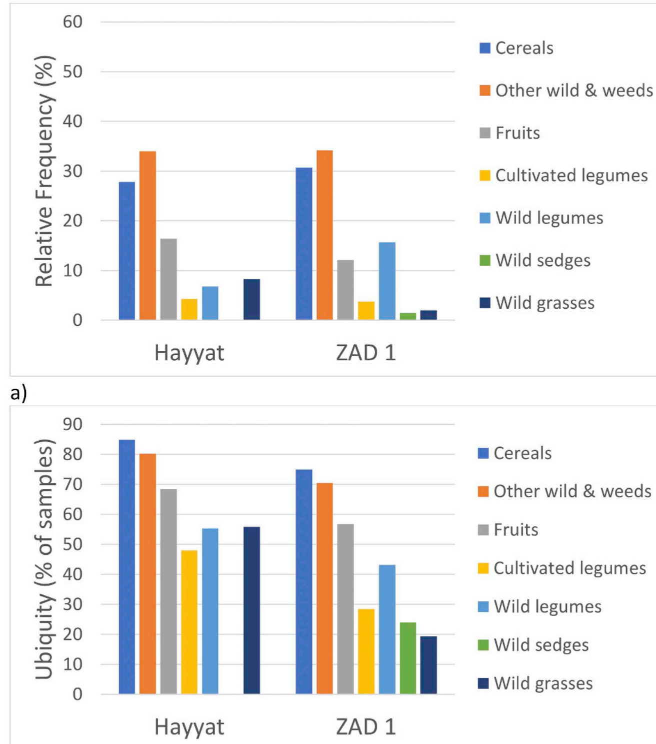


Fig. 9. Measures of the seven major taxonomic categories of carbonized plant remains recovered from Tell el-Hayyat and Zahrat adh-Dhra' 1': a) Relative frequencies (χ^2 [excluding wild sedges] = 355.0, df = 5, p < 0.001); b) Ubiquities (χ^2 [excluding wild sedges] = 12.6, df = 5, p = 0.027).

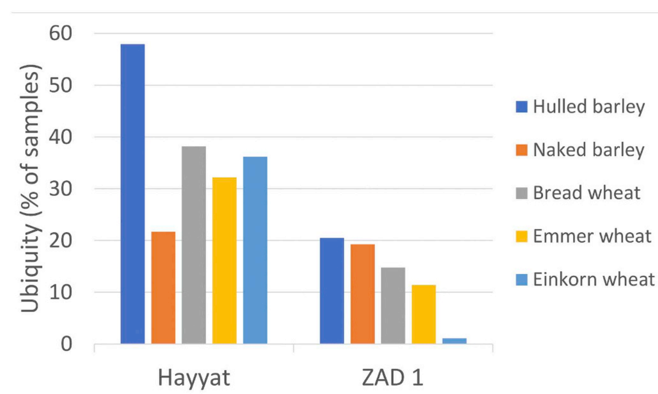


Fig. 10. Ubiquities of varieties of barley and wheat recovered from Tell el-Hayyat and Zahrat adh-Dhra'1 (χ^2 = 19.3, df = 4, p = 0.001).

legumes, including lentils (*Lens culinaris*), peas (*Pisum sativum*) and beans (*Vicia faba*; *V. ervilia/Lathyrus sativus*), as well as fruit crops such as figs (*Ficus carica*) and grapes (*Vitis vinifera*). A slightly broader range of cultigens at Tell el-Hayyat also included chickpeas (*Cicer arietinum*) and olive (*Olea europaea*), neither of which appear at ZAD 1. Notable wild grasses include *Phalaris* sp.; the Tell el-Hayyat evidence also includes oat (*Avena* sp.). Wild legumes, largely undifferentiated, were recovered at both sites, while wild sedges (e.g., cf. *Carex* sp., *Eleocharis* sp., *Fimbristylis* sp., *Scirpus maritimus*) appear only at ZAD 1. Other wild and weed taxa comprise a category of crop-following weeds and/or shrubs with many taxa common to both sites. This category is represented at both sites in very similar relative frequencies, but is more ubiquitous and constituted by nearly twice as many taxa at Tell el-Hayyat.

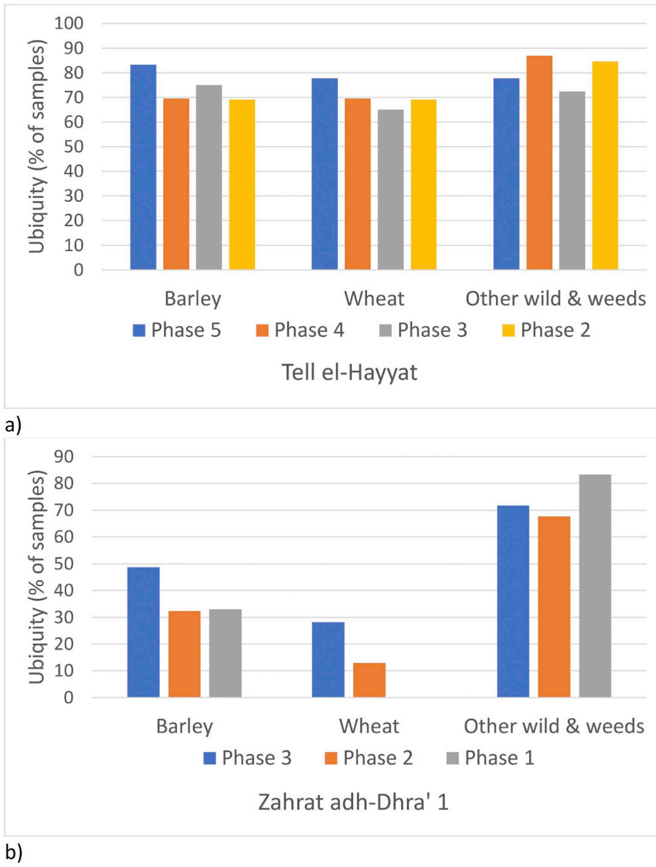


Fig. 11. Ubiquities of barley, wheat, and other wild and weed taxa: a) Tell el-Hayyat Phases 5–2; b) Zahrat adh-Dhra'1 Phases 3–1.

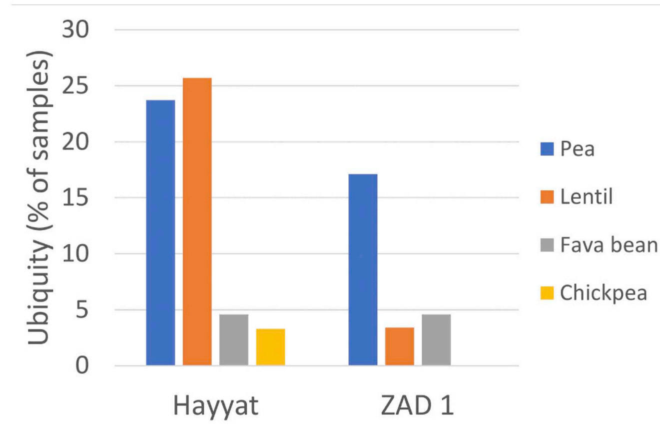


Fig. 12. Ubiquities of cultivated legume taxa at Tell el-Hayyat and Zahrat adh-Dhra'1.

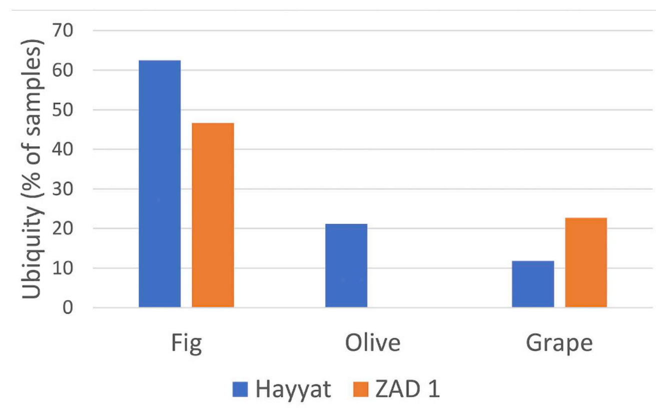


Fig. 13. Ubiquities of cultivated fruit taxa at Tell el-Hayyat and Zahrat adh-Dhra'1.

Relative seed frequencies reveal significantly different representations of the seven major taxonomic categories in the floral assemblages from ZAD 1 and Tell el-Hayyat (Fig. 9a). Among cultigens, cereals are most abundant at both sites, comprising about 30% of the plant remains. Cultivated fruits and legumes occur at decidedly lower frequencies at ZAD 1, both of which are more abundant at Tell el-Hayyat. Other wild and weed taxa comprise more than one-third of the Tell el-Hayyat assemblage and nearly that frequency at ZAD 1. The remaining categories of wild plants show greater differences between sites. The remains of wild grasses are substantially more frequent at Tell el-Hayyat, while ZAD 1 produced more abundant wild legumes, as well as evidence of wild sedges, which are absent at Tell el-Hayyat.

Relative taxonomic seed frequencies provide an expedient means of illustrating overall similarities and differences between the floral assemblages of ZAD 1 and Tell el-Hayyat. These patterns may be influenced, however, by seed deposition rates that tend to vary between plant taxa (e.g., much higher seed counts per fruit for fig than olive) or archaeological contexts (especially when individual samples vary considerably according to seed abundance or taxonomic composition). The use of taxonomic ubiquity, expressed as the frequency of samples in which a plant taxon or category appears, provides a complementary measure for illuminating more divergent patterns that illustrate fundamental differences in surrounding vegetation, settlement history and agrarian behavior at Tell el-Hayyat and ZAD 1. Tell el-Hayyat seed ubiquities reveal a relatively consistent pattern in which six of the seven plant categories are represented in 48% or more of the flotation samples (Fig. 9b). The leading categories, consisting of cultivated cereals, cultivated fruit, and other wild and weed taxa, are found in 64% or more of the samples. At ZAD 1 seed ubiquities are significantly different from those at Tell el-Hayyat. While the three most ubiquitous categories (i.e., ubiquities > 50%) coincide with those at Hayyat, the remaining categories descend dramatically, with values below 30% for cultivated legumes and wild grasses at ZAD 1. Cultivated cereals are most ubiquitous at ZAD 1 (75%), while at Tell el-Hayyat other wild and weed taxa are the most widespread (81%) and represent nearly twice as many taxa as at ZAD 1. Ubiquity values for legumes (both cultivated and wild), fruits, and especially for wild grasses, are noticeably higher for Tell el-Hayyat. The distinction between these sites based on wild sedges, which are absent at Tell el-Hayyat and modestly frequent at ZAD 1 (1.3%), is amplified by their considerable ubiquity (24%) at ZAD 1.

Among cultivated cereals, which form a major crop category at both sites, all five species of identified barley and wheat are significantly more ubiquitous at Tell el-Hayyat (> 50% for barley; > 30% for wheat) than at ZAD 1 (20% or less for both barley and wheat), with similar descending orders of species ubiquity from greater values for hulled barley to lower ubiquity for all three varieties of wheat (Fig. 10). The only cereal species occurring in similar ubiquities at the two sites is naked barley. The greater predominance of barley relative to wheat at ZAD 1 is underscored by its higher barley:wheat ratio of 2.89:1, which is twice the ratio of 1.44:1 for Tell el-Hayyat. The seed counts that generate these ratios differ significantly between ZAD 1 and Tell el-Hayyat ($\chi^2 = 22.2$, $df = 1$, $p < 0.001$). An additional noteworthy distinction among cereals shows einkorn wheat to be nearly absent at ZAD 1, and infrequent (2.0%) but disproportionately ubiquitous (36%) at Tell el-Hayyat.

Another facet of this patterning is revealed by differential trends in ubiquity through the phases with the most robust macrofossil assemblages at both sites. These assemblages stem from Phases 3-1 at ZAD 1

Table 7
Charcoal ubiquities (% samples with taxon present) anddensity ratios (g charcoal/kl sediment) for 39 samples (totaling 401 g of charcoal) from ZAD 1 and 60 samples (totaling 515 g of charcoal) from Tell el-Hayyat, Jordan (Density ratios from Fall et al., 2015).

	ZAD 1		Tell el-Hayyat	
	Ubiquity	Density	Ubiquity	Density
	(%)	(g/kl)	(%)	(g/kl)
Trees				
Acacia sp.	51.3	69.8	0	0
cf. *Ceratonia siliqua*	0	0	1.6	1.9
cf. *Crataegus*	2.6	7.5	0	0
Cupressus sp.	0	0	3.3	3.9
cf. *Pistacia* sp.	2.6	2.5	3.3	3.9
cf. *Populus* sp.	0	0	1.6	3.9
Quercus sp.	0	0	8.3	9.7
Salicaceae	7.7	10.0	3.3	3.9
Tamarix sp.	82.1	134.5	50.0	97.1
Ziziphus sp.	2.6	2.5	6.7	9.7
Tree subtotal	97.4	226.8	63.3	134.0
Shrubs				
Asteraceae	0	0	6.7	11.7
Capparis sp.	10.3	7.5	1.6	1.9
Chenopodiaceae	0	0	18.3	54.4
Cistus sp.	2.6	2.5	0	0
Ephedra sp.	0	0	1.6	3.9
Lamiaceae	7.7	7.5	0	0
Loranthaceae	2.6	5.0	0	0
Monocot	7.7	7.5	6.7	11.7
cf. *Myrtus* sp.	0	0	1.6	3.9
Nerium oleander	0	0	3.3	3.9
cf. *Rubia* sp.	0	0	1.6	1.9
Shrub subtotal	28.2	30.0	33.3	93.3
Orchard taxa				
cf. *Punica granatum*	7.7	10.0	0	0
Ficus carica	7.7	12.5	8.3	9.7
Olea europaea	0	0	16.7	31.1
Vitis vinifera	7.7	15.0	11.7	15.5
Orchard subtotal	12.8	37.5	33.3	56.3
Total		296.8		297.2

Wood identification based on Fahn et al., 1986; Schweingruber et al., 2011; Akkemik and Yaman, 2012.

(82 of 88 samples; 95% of macrofossils) and Phases 5-2 at Tell el-Hayyat (148 of 152 samples; 99% of macrofossils) (see Table 4), which encompass similar portions of the Middle Bronze Age. Barley, wheat, and other wild/weed taxa all maintain relatively consistent ubiquity values during Phases 5-2 at Tell el-Hayyat, with no significant temporal trends (Fig. 11a). The trends through Phases 3–1 at ZAD 1 incorporate substantially lower ubiquities for barley and wheat, and these values descend noticeably through time (Fig. 11b). By the end of habitation at ZAD 1, wheat disappears, while wild and weed taxa increase in ubiquity.

Another set of distinctions is apparent in the ubiquities of cultivated legumes, which are found in nearly half the samples from Tell el-Hayyat, but < 30% of samples from ZAD 1. Within this category, both sites reveal moderately ubiquitous peas and sparse remains of fava beans, while at ZAD 1 lentils are much less common and chickpeas are absent altogether (Fig. 12). Cultivated fruits, which appear in a majority of flotation samples from both sites, reveal marked distinctions in which fig is more ubiquitous at Tell el-Hayyat, grape is more common at ZAD 1, and olive occurs at > 20% ubiquity at Tell el-Hayyat, but is absent altogether at ZAD 1 (Fig. 13).

4.4. Charcoal

Carbonized seeds were recovered from every flotation sample considered in this study and charcoal remains approached the same levels of ubiquity (100% at ZAD 1 and 98% at Tell el-Hayyat). The charcoal assemblages at both sites reflect varying combinations of tree, shrub and orchard species (Table 7). Charcoal from tree taxa are is particularly abundant at ZAD 1, as indicated by 97% ubiquity for tree taxa vs. 63% at Tell el-Hayyat, and tree charcoal density nearly twice the value for Tell el-Hayyat. Among tree fuel sources, the inhabitants of both ZAD 1 and Tell el-Hayyat made abundant use of *Tamarix* sp., supplemented by *Acacia* sp. at ZAD 1. Shrub charcoal represents distinctly different patterns of fuel use in which nine of 11 taxa are found in modest quantities at one site but are absent at the other. For example, the most abundant taxon in this category, Chenopodiaceae, occurs at a substantial density in > 18% of samples from Tell el-Hayyat, but is absent altogether at ZAD 1. Similarly, burning of orchard wood included the classic Mediterranean triad of *Ficus*, *Olea* and *Vitis* at Tell el-Hayyat, while at ZAD 1 orchard fuel consumption included *Ficus*, *Vitis* and possibly *Punica*, but *Olea* charcoal is strikingly absent.

5. Discussion

Relative frequencies of cultivated cereals, legumes and fruits, as well as wild and weed taxa, provide a broad initial portrait of cultivation regimes and crop-following vegetation around ZAD 1 and Tell el-Hayyat. At both sites, cereals and other wild/weed taxa jointly are nearly twice as abundant as all other plant remains combined. Among cereals, barley:wheat ratios provide a general proxy measure of cultivation practices in response to environmental constraints. Since barley is more tolerant of limited water availability and saline soils (Zohary, 1982; Hopf, 1983; Zohary and Hopf, 1988), higher barley:wheat ratios tend to indicate less favorable conditions for cereal agriculture (e.g., Fall et al., 1998, 2002). Accordingly, the significantly higher barley:wheat ratio for ZAD 1 suggests an agricultural response to its more marginal agricultural setting in the Dead Sea Basin, in comparison to the northern Jordan Valley. Strikingly higher Early Bronze IV ratios for nearby Bab edh-Dhra' (6.2:1) (McCreery, 1980) and Tell Abu en-Ni'aj (3.3:1) (Fall et al., 2002), near Tell el-Hayyat in the northern Jordan Valley, suggest the even greater potential influence of environmental change (i.e., regional desiccation during the late third millennium BCE; Soto-Berelov et al., 2015; Fall et al., 2018) on cultivation practices.

While some distinctions between ZAD 1 and Tell el-Hayyat may have resulted from environmental differences along the Jordan Rift, many of them, particularly those reflected in ubiquity values, reflect fundamentally distinct patterns of continuous or discontinuous settlement and use of surrounding landscapes. Comparable ubiquities for the three major plant categories reiterate the importance of cereal cultivation and arboriculture at both settlements, where cereal remains are the most ubiquitous, followed in descending order by other wild and weed taxa, and by cultivated fruits. More detailed examination, however, reveals a number of basic distinctions in agrarian behavior between ZAD 1 and Tell el-Hayyat. Other wild and weedy vegetation remained consistently ubiquitous around ZAD 1, reaching a maximum in Phase 1. The diminishing ubiquities of barley and wheat suggest less continuous cultivation of cereals in keeping with perhaps increasingly intermittent settlement and utilization of local fields. At Tell el-Hayyat, in contrast, the ubiquities for barley, wheat and wild/weed taxa range consistently between 60 and 80%. These results illustrate further distinctions between these two landscapes, in which repeatedly high ubiquities of cultivated cereals at Tell el-Hayyat are accompanied by equally steady and somewhat higher ubiquities of other wild and weed taxa. These results provide clear measures of the importance of cereal agriculture, through the continuous occupation of Tell el-Hayyat and the discontinuous habitation of ZAD 1, and the greater pervasiveness of wild and weed taxa on the cultivated landscape around Tell el-Hayyat.

Among cereals, all five species of cultivated wheat and barley are much less ubiquitous at ZAD 1 (with the exception of naked barley, which is slightly less common), and the predominance of barley over wheat is significantly more pronounced. These distinctions become accentuated through the last three phases at ZAD 1, in which barley and wheat values diminish (wheat is absent in Phase 1), while other wild and weed taxa ubiquities remain high. Between barley varieties, comparative studies (e.g., Sturite et al., 2018) show that hulled barley can provide higher grain yields, while naked barley provides more protein and does not require processing to remove its protective hull, which is indigestible for humans (Dickin et al., 2011). Thus, cultivation of naked barley may be more suggestive of human consumption, while hulled barley would have been well-suited for more productive cultivation of animal food, especially in arid conditions. The more pronounced signature of hulled barley cultivation at Tell el-Hayyat, therefore, may reflect more intensified animal management than at ZAD 1. Among wheat varieties, einkorn prefers dry cultivation in cooler settings (Zohary and Hopf, 1988), while emmer and bread wheat are adapted better for irrigation (Helbaek, 1970; McCreery, 1980). Thus, in contrast to Tell e-Hayyat, the near absence of einkorn and the appreciable ubiquity of hydrophilic wild sedges at ZAD 1 combine to suggest the possiblity of spring-fed irrigation, apparently on an intermittent basis, on the Plain of Dhra'.

The evidence for cultivated legumes and fruits reinforces the distinctions between continuous vs. discontinuous settlement and cultivation. Cultivated legumes are uniformly less common at ZAD 1, with the most common (peas) having a ubiquity of only 17%. Among fruits, only grapes are more ubiquitous at ZAD 1, while olive is absent altogether. This suite of contrasts accords once again with a general preference for olive (and wheat) cultivation under more favorable environmental conditions, and grape (and barley) cultivation in more agriculturally marginal settings (Fall et al., 1998, 2002). In keeping with the data for other wild and weed taxa, the ubiquities of wild legumes and wild grasses accentuate the inter-site distinctions based on relative seed frequencies, and underscore the greater impact of cereal cultivation coupled with more common wild vegetation on the agricultural landscape around Tell el-Hayyat.

When viewed jointly, the seed and charcoal profiles for these communities suggest burning of dung fuel indicative of more grazing and cereal cultivation at Tell el-Hayyat in contrast to animal browsing on wild species around ZAD 1. Fuel wood consumption at both sites included substantial burning of *Tamarix* sp., accompanied by *Acacia* sp. at ZAD 1. Both the charcoal and seed evidence suggest the greater importance of *Olea europaea* than *Vitis vinifera* on the agrarian landscape around Tell el-Hayyat, while the remains from ZAD 1 suggest a contrasting pattern of more *Vitis vinifera* and a striking absence of *Olea europaea* along nearby wadis, reflecting more arid-adapted land use on the Dead Sea Plain. Thus, the occupants of ZAD 1 relied on fuel wood from desert trees, complemented with dung fuel from animals browsing on wild plants, whereas Tell el-Hayyat's villagers cultivated their surrounding fields and utilized a more diverse array of fuel sources, including greater burning of dung from grazing animals and wood from riparian trees.

While these patterns may, in part, be influenced by the greater numbers of samples and identified seeds from Tell el-Hayyat, they also reflect a number of characteristics that distinguish the unusual nature of settlement and agriculture at ZAD 1. While the higher and more consistent ubiquity values from Tell el-Hayyat indicate agricultural continuity across taxa and through time, the evidence from ZAD 1 reveals more sporadic seed deposition, greater distinctions in ubiquity between taxa, more discernible trends of declining barley and wheat ubiquity through time, and the absence or near absence of key cultigens (e.g., olive, chickpea and lentil). Another factor influencing these results is the much greater abundance and ubiquity of charcoal from tree species at ZAD 1 (especially desert/riparian species like *Tamarisk* sp. and *Acacia* sp.), in contrast with greater burning of shrubs, orchard wood and animal dung at Tell el-Hayyat (Fall et al., 2015). In overview, the plant evidence from Tell el-Hayyat conforms with consistent agrarian behavior during continuous occupation by a community practicing broad-based agriculture on a largely deforested anthropogenic landscape. In contrast, and in keeping with its unusual character, the more heterogeneous evidence from ZAD 1 attests to discontinuous habitation by smaller numbers of scattered households practicing more variable, shorter-term agriculture in a more isolated, desert environment where inhabitants exploited desert and riparian trees and sedges from local springs.

6. Conclusions

Zahrat adh-Dhra'1 represents a component of agrarian society generally not incorporated in current interpretations of ancient Levantine society, in which explicitly or implicitly the Middle Bronze Age is distinguished in many ways by virtue of its contrasts with settlement and society during the preceding Early Bronze IV, and its assumed perpetuation of a grand trajectory of urbanization initiated in Early Bronze II-III. Long-standing interpretations of Middle Bronze Age society are based on pervasive sedentary agriculture, while social reconstructions of Early Bronze IV highlight a much greater element of non-sedentary pastoralism due, in part, to the greater frequency of seasonal encampments and cemeteries, and relatively few studies of village life during this period. Recent interpretations of Early Bronze IV settlement patterns call growing attention to small agrarian villages in arable regions, but tend to emphasize the appearance of intermittent or short-term encampments in agriculturally marginal regions (e.g., the Negev and Sinai). In contrast, analyses of Middle Bronze Age settlement patterns rarely extend to agriculturally-marginal or socially-distant regions.

As a counterpoint to standard interpretations of Middle Bronze Age settlement and society, ZAD 1 exemplifies discontinuous agrarian settlement in a decidedly marginal environmental setting on the social and geographical outskirts of early urbanized society. Its record of dispersed semi-subterranean structures contrasts with the aggregated domestic and public architecture within often fortified Middle Bronze Age towns. Our inference of discontinuous occupation at ZAD 1 contrasts with numerous examples of long-term continuous settlement of Middle Bronze Age towns and villages alike, as exemplified by Tell el-Hayyat. Analysis of the floral assemblage from ZAD 1, especially as it contrasts with data from Tell el-Hayyat, highlights ZAD 1 as an unprecedented example of intermittent settlement in a marginal agricultural setting during an era known otherwise for the growth and proliferation of sedentary agrarian towns and cities, particularly in more favorable environmental settings. In this capacity, the evidence from Zahrat adh-Dhra'1 challenges us to accommodate peripheral or uncommon elements in our social reconstructions, and thereby expand our comprehension of rural as well as urban, and peripheral as well as central, communities that populated the social landscapes of the Levantine Bronze Age.

Declarations of Competing Interest

None.

Acknowledgements

The field research was conducted under permit from the Department of Antiquities, Jordan (Director-General Fawwaz Khraysheh), and in affiliation with the American Center of Oriental Research, Amman (Director Pierre Bikai). This research was funded by grants from the Australian Research Council (1999), the Wenner-Gren Foundation (2000), the National Geographic Society (2000), the Australian Institute of Nuclear Science and Engineering (2002), and the University of North Carolina at Charlotte (2016). Samples were processed initially by Cathryn Meegan in the field and at Arizona State University. All flotation samples were subsequently resorted and seed identifications were redone by PLF and SP at the University of North Carolina Charlotte. We thank all the students from Arizona State

University who worked with us in the field, Ilya Berelov who conducted ceramic analyses of the pottery assemblage, and Mary Metzger who analyzed the faunal remains. Radiocarbon dating was done at the University of Arizona Accelerator Mass Spectrometry Laboratory and the Australian Institute of Nuclear Science in the Australian Nuclear Science and Technology Organisation (ANSTO). We thank two anonymous reviewers for their constructive comments.

References

Akkemik, Ü., Yaman, B., 2012. Wood Anatomy of Eastern Mediterranean Species. Kessel Publishing House, Remagen, Germany.

Al-Eisawi, D., 1996. Vegetation of Jordan. UNESCO, Cairo.

Anderson, S., Ertuğ-Yaras, F., 1996. Fuel, fodder and faeces: an ethnographic and botanical study of dung fuel use in Central Anatolia. Environ. Archaeol. 1 (1), 99–109. https://doi.org/10.1179/env.1996.1.1.99.

Banning, E.B., 2000. The Archaeologist's Laboratory. The Analysis of Archaeological Data. Springer, New York.

Berelov, I., 2006a. Occupation and Abandonment of Middle Bronze Age Zharat adh-Dhra'1, Jordan. British Archaeological Reports, International Series, vol. 1493 Archaeopress, Oxford.

Berelov, I., 2006b. Signs of sedentism and mobility in an agro-pastoral community during the Levantine Middle Bronze Age: interpreting site function and occupation strategy at Zahrat adh-Dhra'1 in Jordan. J. Anthropol. Archaeol. 25 (1), 117–143.

Bottema, S. 1984. The composition of modern charred seed assemblages, in: van Zeist, W., Casparie, W.A. (Eds.), Plants and Ancient Man: Studies in Palaeoethnobotany. A.A. Balkema, Rotterdam, pp. 207–12.

Bourke, S.J., 2014. The southern Levant (Transjordan) during the middle bronze age. In: Steiner, M.L., Killebrew, A.E. (Eds.), The Archaeology of the Levant c. 8000–332 BCE. Oxford University Press, Oxford, pp. 465–481.

O'Connor, T., 2000. The Archaeology of Animal Bones. Radiocarbon. Texas A&M University Press; College Station, TX: Texas A&M University Press.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360.

Bronk Ramsey, C., 2017. Methods for summarizing radiocarbon datasets. Radiocarbon 59 (2), 1809–1833.

Charles, M., 1998. Fodder from dung: the recognition and interpretation of dung-derived plant material from archaeological sites. Environ. Archaeol. 1 (1), 111–122. https://doi.org/10.1179/env.1996.1.1.111.

Chernoff, M.C., Paley, S.M., 1998. Dynamics of cereal production at Tell El Ifshar, Israel during the Middle Bronze Age. J. Field Archaeol. 25 (4), 397–416. https://doi.org/10.1179/009346998792005289.

Clark, V.A., 1979. Investigations in a prehistoric necropolis near Bab edh-Dhra'. Annual of the Department of Antiquities, Jordan 23, 57–77.

Cohen, S.L., 2009. Continuities and discontinuities: a re-examination of the Intermediate Bronze Age-Middle Bronze Age transition in Canaan. Bull. Am. Sch. Orient. Res. 354, 1–13.

Cohen, S.L., 2014. The southern Levant (Cisjordan) during the Middle Bronze Age. In: Steiner, M.L., Killebrew, A.E. (Eds.), The Archaeology of the Levant c. 8000–332 BCE. Oxford University Press, Oxford, pp. 451–464.

Cohen, S.L., 2017. Reevaluation of connections between Egypt and the Southern Levant in the Middle Bronze Age in light of the new higher chronology. Journal of Ancient Egyptian Interconnections 13, 34–42.

Crabtree, P.J., 1990. Zooarchaeology and complex societies: some uses of faunal analysis for the study of trade, social status, and ethnicity. In: Schiffer, M.B. (Ed.), Archaeological Method and Theory. 2. University of Arizona Press, Tucson, pp. 155–205.

Dennell, R.W., 1974. Botanical evidence for prehistoric crop processing activities. J. Archaeol. Sci. 1 (3), 275–284. https://doi.org/10.1016/0305-4403(74)90027-2.

Dever, W.G., 1995. Social structure in the Early Bronze IV period in Palestine. In: Levy, T.E. (Ed.), The Archaeology of Society in the Holy Land. Facts on File, pp. 282–296 New York.

Dever, W.G., 2014. Excavations at the Early Bronze IV Sites of Jebel Qa'aqir and Be'er Resisim. Eisenbrauns, Winona Lake, IN.

Dickin, E., Steele, K., Edwards-Jones, G., Wright, D., 2011. Agronomic diversity of naked barley (Hordeum vulgare L.): a potential resource for breeding new food barley for Europe. Euphytica 184 (1). https://doi.org/10.1007/s10681-011-0567-y.

Donahue, J., 1985. Hydrologic and topographic change during and after Early Bronze occupation at Bab edh-Dhra'and Numeira. In: Hadidi, A. (Ed.), Studies in the History and Archaeology of Jordan. vol. 2. Routledge and Kegan Paul, London, pp. 131–140.

Edwards, P.C., Falconer, S.E., Fall, P.L., Berelov, I., Davies, C., Meadows, J., Meegan, C., Metzger, M.C., Sayej, G.J., 2001. Archaeology and environment of the Dead Sea Plain: preliminary results of the first season of investigations by the joint La Trobe University/Arizona State University Project. Annual of the Department of Antiquities, Jordan 45, 135–157.

Edwards, P.C., Falconer, S.E., Fall, P.L., Berelov, I., Czarzasty, J., Day, C., Meadows, J., Meegan, C., Sayej, G.J., Swoveland, T., Westaway, M., 2002. Archaeology and environment of the Dead Sea Plain: preliminary results of the second season of investigations by the joint La Trobe University/Arizona State University Project. Annual of the Department of Antiquities, Jordan 46, 51–92.

Edwards, P.C., Falconer, S.E., Fall, P.L., Ariotti, A., Swoveland, T., 2004. Archaeology and environment of the Dead Sea Plain: preliminary results of the third season of investigations by the joint La Trobe University/Arizona State University Project. Annual of the Department of Antiquities, Jordan 48, 1–21.

Fahn, A., Werker, E., Baas, P., 1986. Wood Anatomy and Identification of Trees and Shrubs from Israel and Adjacent Regents. Israel Academy of Sciences and Humanities, Jerusalem.

Falconer, S.E., 2008. The middle bronze age. In: Adams, R. (Ed.), Jordan: An Archaeological Reader. Equinox, London, pp. 263–280.

Falconer, S.E., Fall, P.L., 2006. Bronze Age Rural Ecology and Village Life at Tell el-Hayyat, Jordan. British Archaeological Reports, International Series 1586, Oxford (ISBN 1 84171 799 1).

Falconer, S.E., Fall, P.L., 2016. A radiocarbon sequence from Tell Abu en-Ni'aj, Jordan and its implications for Early Bronze IV chronology in the Southern Levant. Radiocarbon 58 (3), 615–647. https://doi.org/10.1017/RDC.2016.26.

Falconer, S.E., Fall, P.L., 2017. Radiocarbon evidence from Tell Abu en-Ni'aj and Tell el-Hayyat, Jordan and its implications for Bronze Age Levantine and Egyptian chronologies. Journal of Ancient Egyptian Interconnections 13, 7–19.

Falconer, S.E., Fall, P.L., 2019. Early Bronze IV village life in the Jordan Valley: excavations at Tell Abu en-Ni'aj and Dharet Umm el-Marar, Jordan. In: British Archaeological Reports, International Series. vol. 2922 BAR Publishing, Oxford (ISBN 978 4073 1692 5). Eight appendices are available to download from. www.barpublishing.com/additional-downloads.html.

Falconer, S.E., Savage, S.H., 2009. The Bronze Age political landscape of the Southern Levant. In: Falconer, S.E., Redman, C. (Eds.), Polities and Power: Archaeological Perspectives on the Landscapes of Early States. University of Arizona Press, Tucson, pp. 125–151.

Fall, P.L., Lines, L., Falconer, S.E., 1998. Seeds of civilization: Bronze Age rural economy and ecology in the Southern Levant. Ann. Assoc. Am. Geogr. 88, 107–125.

Fall, P.L., Falconer, S.E., Lines, L., 2002. Agricultural intensification and the secondary products revolution along the Jordan Rift. Hum. Ecol. 30, 445–482. https://doi.org/10.1023/A:1021193922860.

Fall, P.L., Falconer, S.E., Edwards, P.C., 2007. Living on the edge: settlement and abandonment on the Dead Sea Plain. In: Levy, T.E., Daviau, P.M.M., Younker, R.W., Shaer, M. (Eds.), Crossing Jordan: North American Contributions to the Archaeology of Jordan. Equinox Publishing, London, pp. 225–232.

Fall, P.L., Falconer, S.E., Klinge, J., 2015. Bronze Age fuel use and its implications for agrarian landscapes in the eastern Mediterranean. Journal of Archaeological Science Reports 4, 182–191. https://doi.org/10.1016/j.jasrep.2015.09.004.

Fall, P.L., Soto-Berelov, M., Ridder, E., Falconer, S.E., 2018. Toward a grand narrative of Bronze Age vegetation change and social dynamics in the southern Levant. In: Levy, T., Jones, I. (Eds.), Cyber-Archaeology and Grand Narratives: Digital Technology and Deep-Time Perspectives on Culture Change in the Middle East. One World Archaeology Series Springer Nature, Springer, Cham, pp. 91–110. https://doi.org/10.1007/978-3-319-65693-9_6.

Flanagan, J.W., McCreery, D.W., 1990. First preliminary report of the Tell Nimrin Project. In: Annual of the Department of Antiquities, Jordan. vol. 34. pp. 131–152.

Flanagan, J.W., McCreery, D.W., Yassine, K.N., 1994. Tell Nimrin: preliminary report on the 1993 season. Annual of the Department of Antiquities, Jordan 38, 205–244.

Fritz, V., Kempinski, A., 1983. Ergebnisse der Ausgrabungen auf der Hirbet el-Msas (Tel Masos) 1972–1975. Abhandlungen des Deutschen Palastinavereins, Wiesbaden, pp. 1–3.

Frumkin, A., Carmi, I., Zak, I., Margaritz, M., 1994. Middle Holocene environmental change determined from the salt caves of Mount Sedom, Israel. In: Bar-Yosef, O., Kra, R.S. (Eds.), Late Quaternary Chronology and Paleo-Climates of the Eastern Mediterranean. University of Arizona Press, Tucson, pp. 315–332.

Fuller, D.Q., Harvey, E.L., 2006. The archaeobotany of Indian pulses: identification, processing and evidence for cultivation. Environ. Archaeol. 11 (2), 219–246. https://doi.org/10.1179/174963106x123232.

Fuller, D.Q., Stevens, C.J., 2009. Agriculture and the development of complex societies: an archaeobotanical agenda. In: Fairbairn, A., Weiss, E. (Eds.), From Foragers to Farmers: Papers in Honour of Gordon C. Hillman. Oxbow Books, Oxford, pp. 37–57.

Grayson, D.K., 1984. Quantitative Zooarchaeology. Topics in the Analysis of Archaeological Faunas. Academic Press, New York.

Greenberg, R., 2002. Egypt, Beth Yerah and early Canaanite urbanization. In: Greenberg, R. (Ed.), Early Urbanizations in the Levant: A Regional Narrative. Leicester University Press, London, pp. 213–221.

Greenberg, R., 2014. Introduction to the Levant during the Early Bronze Age. In: Steiner, M.L., Killebrew, A.E. (Eds.), The Archaeology of the Levant c. 8000–332 BCE. Oxford University Press, Oxford, pp. 269–277.

Haiman, M., 1996. Early Bronze Age IV settlement pattern of the Negev and Sinai deserts: view from small marginal temporary sites. Bull. Am. Sch. Orient. Res. 303, 1–32.

Hastorf, C.A., 1988. The use of paleoethnobotanical data in prehistoric studies of crop production, processing, and consumption. In: Hastorf, C.A., Popper, V.S. (Eds.), Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains. University of Chicago Press, Chicago, pp. 119–144.

Hastorf, C.A., Wright, M.F., 1998. Interpreting wild seeds from archaeological sites: a dung charring experiment from the Andes. J. Ethnobiol. 18 (2), 221–227.

Helbaek, H., 1958. Appendix A. Plant economy in ancient Lachish. In: Tufnell, O. (Ed.), Lachish: Tell Ed Duweir 4, the Bronze Age. Oxford University Press, Oxford, pp. 309–317.

Helbaek, H., 1970. The plant husbandry of Hacilar. In: Mellaart, J. (Ed.), Excavations at Hacilar. Edinburgh University Press, Edinburgh, pp. 189–249.

Hillman, G., 1978. On the origins of domestic rye – *Secale cereale*: the finds from aceramic Can Hasan III in Turkey. Anatol. Stud. 28, 157–174.

Höflmayer, F., 2017. A radiocarbon chronology for the Middle Bronze Age Southern Levant. Journal of Ancient Egyptian Interconnections 13, 20–33.

Höflmayer, F., Dee, M.W., Genz, H., Riehl, S., 2014. Radiocarbon evidence for the Early Bronze Age Levant: the site of Tell Fadous-Kfarabida (Lebanon) and the end of the

Early Bronze III Period. Radiocarbon 56 (2), 529–542.
Höflmayer, F., Kamlah, J., Sader, H., Dee, M.W., Kutschera, W., Wild, A.M., Riehl, S., 2016. New evidence for Middle Bronze Age chronology and synchronisms in the Levant: radiocarbon dates from Tell el-Burak, Tell el-Dab'a, and Tel Ifshar compared. Bull. Am. Sch. Orient. Res. 375, 53–76.
Hopf, M., 1983. Jericho plant remains. In: Kenyon, K.M., Holland, T.A. (Eds.), Excavations at Jericho. British School of Archaeology at Jerusalem, London, pp. 576–621.
Horowitz, A., 1979. The Quaternary of Israel. Academic Press, New York.
Hubbard, R.N.L.B., 1992. Dichotomous keys for the identification of the major Old World crops. Rev. Palaeobot. Palynol. 73, 109–115.
Jacomet, S., 2006. Identification of Cereal Remains from Archaeological Sites, 2nd edition. Basel University Archaeobotany Lab, IPAS, Basel.
Jones, G.E.M., 1987. A statistical approach to the archaeological identification of crop processing. J. Archaeol. Sci. 14 (3), 311–323. https://doi.org/10.1016/0305-4403(87)90019-7.
Jones, G.E.M., Halstead, P., 1995. Maslins, mixtures and monocrops: on the interpretation of archaeobotanical crop samples of heterogeneous composition. J. Archaeol. Sci. 22 (1), 103–114. https://doi.org/10.1016/S0305-4403(95)80168-5.
Klinge, J., 2013. Assessment of Environmental Change in the Near Eastern Bronze Age. PhD Dissertation. Arizona State University. University Microfilms International, Ann Arbor.
Klinge, J., Fall, P.L., 2010. A paleoethnobotanical analysis of Bronze Age land use and land cover in the eastern Mediterranean. J. Archaeol. Sci. 37, 2622–2629. https://doi.org/10.1016/j.jas.2010.05.022.
Kochavi, M., 1967. Tel Malhata. Israel Exploration Journal 17, 272–273.
Kreuz, A., Marinova, E., Schäfer, E., Wiethold, J., 2005. A comparison of early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities. Veg. Hist. Archaeobotany 14 (4), 237–258. https://doi.org/10.1007/s00334-005-0080-0.
Levy, T.E., 1995. Preface. In: Levy, T. (Ed.), The Archaeology of Society in the Holy Land. Facts on File, Inc, New York, pp. x–xvi.
Maeir, A., Dar, S., Safrai, Z. (Eds.), 2003. The Rural Landscape of Ancient Israel. British Archaeological Reports, International Series, vol. 1121 Archaeopress, Oxford.
Marston, J., 2014. Ratios and simple statistics in paleoethnobotanical analysis. In: Marston, J., d'Alpoim Guedes, J., Warinner, C. (Eds.), Method and Theory in Paleoethnobotany. University of Colorado Press, Boulder, pp. 163–179.
Martin, A.C., Barkley, W.D., 1961. Seed Identification Manual. University of California Press, Berkeley.
McCreery, D.W., 1977/78. Preliminary report of the A.P.C. Township Archaeological Survey. Annual of the Department of Antiquities, Jordan 22, 150–162.
McCreery, D.W., 1980. The Nature and Cultural Implications of Early Bronze Age Agriculture in the Southern Ghor of Jordan: An Archaeological Reconstruction. PhD Dissertation. University Microfilms, University of Pittsburgh, Ann Arbor, MI.
Miller, N.F., 1984. The use of dung as fuel: an ethnographic example and an archaeological application. Paleorient 10 (2), 71–79. https://doi.org/10.3406/paleo.1984.941.
Miller, N.F., 1988. Ratios in paleoethnobotanical analysis. In: Hastorf, C., Popper, V. (Eds.), Current Paleoethnobotany. University of Chicago Press, Chicago, pp. 72–85.
Miller, N.F., Smart, T.L., 1984. Intentional burning of dung as fuel: a mechanism for the incorporation of charred seeds into the archeological record. J. Ethnobiol. 4, 15–28.
de Miroschedji, P., 2009. Rise and collapse in the southern Levant in the Early Bronze Age. In: Cardarelli, A., Cazzella, A., Frangipane, M., Peroni, R. (Eds.), Reasons for Change: Birth, Decline and Collapse of Societies from the End of the Fourth to the Beginning of the First Millennium B.C. Universita degli Studi di Roma 'La Sapienza', Rome, pp. 101–129.
de Miroschedji, P., 2014. The southern Levant (Cisjordan) during the Early Bronze Age. In: Steiner, M.L., Killebrew, A.E. (Eds.), The Archaeology of the Levant c. 8000–332 BCE. Oxford University Press, Oxford, pp. 307–329.
Palumbo, G., 1991. The Early Bronze Age IV in the Southern Levant: Settlement Patterns, Economy and Material Culture of a "Dark Age." Contributi Materiali di Archeologia Orientale III. Universita Degli Studi di Roma la Sapienza, Rome.
Pearsall, D.M., 2000. Paleoethnobotany: A Handbook of Procedures, 2nd edition. Academic Press, San Diego, CA.
Politis, K.D., 1997. Excavations and restorations at Dayr 'Ayn 'Abata. Annual of the Department of Antiquities, Jordan 41, 341–350.
Popper, V.S., 1988. Selecting quantitative measurements in paleoethnobotany. In: Hastorf, C.A., Popper, V.S. (Eds.), Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains. University of Chicago Press, Chicago, pp. 53–71.
Prag, K., 2014. The Southern Levant during the Intermediate Bronze Age. In: Steiner, M.L., Killebrew, A.E. (Eds.), The Archaeology of the Levant c. 8000–332 BCE. Oxford University Press, Oxford, pp. 388–400.
Rast, W.E., Schaub, R.T., 2003. Bâb Edh-Dhrâ: Excavations at the Town Site (1975–1981). (Eisenbrauns, Winona Lake, IN).
Reddy, S.N., 1998. Fueling the hearths in India: the role of dung in paleoethnobotanical interpretation. Paleorient 24 (2), 61–69. https://doi.org/10.3406/paleo.1998.4677.
Reitz, E.J., Wing, E.S., 2008. Zooarchaeology, 2nd edition. Cambridge University Press, Cambridge.
Regev, J., de Miroschedji, P., Greenberg, R., Braun, E., Greenhut, Z., Boaretto, E., 2012. Chronology of the Early Bronze Age in the Southern Levant: new analysis for a high chronology. Radiocarbon 54 (3–4), 525–566.
Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Höffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55 (4), 1869–1887.
Renfrew, J.M., 1973. Palaeoethnobotany: The Prehistoric Food Plants of the Near East and Europe. Columbia University Press, New York.
Richard, S., Long Jr.J.C., Holdorf, P.S., Peterman, G. (Eds.), 2010. Khirbat Iskandar. Final Report on the Early Bronze IV Area C "Gateway" and Cemeteries. American Schools of Oriental Research Archaeological Reports, No. 14. American Schools of Oriental Research, Boston.
Schaub, R.T., Rast, W.E., 1989. Bab Edh-Dhra': Excavations in the Cemetery Directed by Paul W. Lapp (1965–67). American Schools of Oriental Research, Eisenbrauns, Winona Lake, IN.
Schweingruber, F.H., Börner, A., Schulze, E.-D., 2011. Atlas of Stem Anatomy in Herbs, Shrubs and Trees. Springer, Berlin.
Shahack-Gross, R., 2011. Herbivorous livestock dung: formation, taphonomy, methods for identification and archaeological significance. J. Archaeol. Sci. 38 (2), 205–218. https://doi.org/10.1016/j.jas.2010.09.019.
Soto-Berelov, M., Fall, P.L., Falconer, S.E., Ridder, E., 2015. Modeling vegetation dynamics in the Southern Levant through the Bronze Age. J. Archaeol. Sci. 53, 94–109. https://doi.org/10.1016/j.jas.2014.09.015.
Sturite, I., Kronberga, A., Strazdiņa, V., Kokare, A., Aassveen, M., Bergjord Olsen, A., Sterna, V., Straumite, E., 2018. Adaptability of hull-less barley varieties to different cropping systems and climatic conditions. Acta Agriculturae Scandinavica, Section B - Soil & Plant Science 69, 1–11. https://doi.org/10.1080/09064710.2018.1481995.
van der Veen, M., 2007. Formation processes of desiccated and carbonized plant remains—the identification of routine practice. J. Archaeol. Sci. 34 (6), 968–990. https://doi.org/10.1016/j.jas.2006.09.007.
van Zeist, W. 1976. On macroscopic traces of food plants in southwestern Asia (with some reference to pollen data). Philosophical Transactions of the Royal Society London B. 275, 27–41.
van Zeist, W., Bakker-Heeres, J.A.H., 1982. Archaeobotanical studies in the Levant. 1. Neolithic sites in the Damascus basin: Aswad, Ghoraife, Ramad. Palaeohistoria 24, 165–256.
van Zeist, W., Bakker-Heeres, J.A.H., 1984a. Archaeobotanical studies in the Levant. 2. Neolithic and Halaf levels at Ras Shamra. Palaeohistoria 26, 151–170.
van Zeist, W., Bakker-Heeres, J.A.H., 1984b. Archaeobotanical studies in the Levant. 3. Late-Paleolithic Mureybit. Palaeohistoria 26, 171–190.
van Zeist, W., Bakker-Heeres, J.A.H., 1985. Archaeobotanical studies in the Levant. 4. Bronze Age sites on the north Syrian Euphrates. Palaeohistoria 27, 247–316.
Zohary, D., Hopf, M., 1973. Domestication of pulses in the Old World. Science 182, 887–894.
Zohary, D., Hopf, M., 1988. Domestication of Plants in the Old World. Clarendon Press, Oxford.
Zohary, D., Spiegel-Roy, P., 1975. Beginnings of fruit growing in the Old World. Science 187, 319–327.
Zohary, M., 1982. Plants of the Bible. Cambridge University Press, Cambridge.