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ORIGINAL PAPER

Plant cultivation under climatic fluctuations during the sixth and fifth millennia BC at Tell Tawila (northern Syria)

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Abstract

This paper presents the macrobotanical record, supported by stable isotope data, from the Halaf (5850–5500 BC) and Late Chalcolithic (c. 4000 BC) occupation of the village Tell Tawila, northern Syria. Drawing on this new data and prior studies of the site, we show that subsistence at Tell Tawila combined agriculture, pastoralism, and foraging, adding it to a growing list of Halaf sites which do not conform to previous established subsistence norms. Furthermore, we argue for an aridification event taking place in the Late Chalcolithic and show how the population at Tell Tawila adapted to this changing climate through increasing exploitations of wild resources.

Keywords Halaf · Late Neolithic · Late Chalcolithic · Northern Mesopotamia · Archeobotany · Charcoal · Stable isotopes · Climate change

Introduction

Historical background and research aims

Between 5950 and 5300 cal BC (Table 1), the Halaf culture, named after the site of Tell Halaf at the Syro-Turkish border near modern Ra's el'Ain, developed from older roots of the Pottery Neolithic and is representing the Late Pottery Neolithic period of Upper Mesopotamia. Its main distribution area covers the northern "Fertile Crescent" and spans from the foothills of the Zagros mountains in the east to almost the Mediterranean coast, thus representing the first wide-ranging, ceramic horizon of the ancient Near East.

Settlement patterns of the Halaf culture are characterized by mostly small settlements, in a dense network of sites. A three-tiered settlement hierarchy has been observed with some larger villages (< 2 ha), occupied for several centuries, a lot of short-lived small hamlets (< 0.5 ha), and seasonal stations. In contrast to settlements of the Early Neolithic, there are no special buildings in the Pottery Neolithic cultures of Upper Mesopotamia that point to cultic functions. This coupled with the relatively homogenous size of buildings, furnishings, and burial goods across the Halaf period suggests a rather egalitarian social structure (Akkermans 1993; Frangipane 2007).

Although a subsistence based primarily on agriculture and domesticated livestock, partly supplemented by hunting, is largely the established model for the Halaf (Akkermans 1993; Matthews 2000; Akkermans and Schwartz 2003; Becker 2011), there is still much which is unknown. Our understanding of localized adaptations to environmental, social, and technological parameters is particularly lacking at the time being. Halafian sites such as Shams ed-Din (Uerpmann 1982), Tell Zeidan (Grossman and Hinman 2013), Umm Qseir (Hole et al. 1986), and Yarim Tepe II (Merpert and Munchaev 1981) deviate significantly from earlier models on account of what appears as highly mixed subsistence strategy, where foraging makes up a significant portion of food production.

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Table 1 Chronology of time periods mentioned in the text, adapted after Becker and Helms (2013) and Becker (2015)

Period	Cal BC	Phase
Late Chalcolithic	4000	II
Ubaid	4500	III
Halaf IIa	5700–5500	IV
Halaf Ib/IIa	5850–5550	IV
Halaf Ib	5850–5700	IV

Comparatively little is known of the earliest stages of the Late Chalcolithic period. The earlier Ubaid period and its expansion had established some degree of social hierarchies and patterns of subsistence and settlement (Stein 2012). The early Late Chalcolithic of northern Syria seems to have continued these traditions, where larger villages were centered on a temple and then surrounded by a swathe of smaller settlements (Akkermans and Schwartz 2003; Stein 2012; Wilkinson et al. 2012). Population mobility appears to have lowered compared to the late Halaf and early Ubaid, and people occupied the same location for longer periods of time. The Late Chalcolithic is primarily known for the Uruk expansion, where the complex urban societies of southern Mesopotamia extended their influence throughout the region (Akkermans and Schwartz 2003, p. 190). The exact nature of this expansion, whether some form of colonialism, imperialism, or simply an exchange of goods and ideas, is debated. Subsistence during this period often focused on sheep and goat pastoralism, considered a hallmark of Uruk colonial sites (Akkermans and Schwartz 2003, pp. 205–206), though possibly a practice seen in northern Mesopotamia prior to the Uruk expansion (Weber 1999). However, in addition to domesticated animals, faunal evidence from northern Syria points to hunted game as a staple, which contrasts strongly both with earlier periods and subsistence in southern Mesopotamia (Zeder 1998).

Covering the area of the rain-fed zone of Upper Mesopotamia (> 200 mm annual precipitation), arable farming is an option for human subsistence, but at the same time with a variation coefficient of the annual amount of precipitation of up to 50% (TAVO map A IV 4), this region is prone to climatic and environmental fluctuations (Wilkinson 2003). Such general uncertainty of regional climatic conditions entered also some influential models of the living mode during the time considered here. Hole (1997) suggests that the majority of Halafian tholoi (small round houses) may have served as seasonal shelter to a primarily herding society, despite falling into the time of the so-called Holocene climatic optimum. Devoid of local paleoclimate proxy archives, climate reconstruction is either based on the lakes to the north in Turkey or to the speleothems in Israel delivering partially contradictive results, surely related to regionally diverse climatic effects. And while, e.g., at around 4000 BC, the lake proxies at the latitude of ca. 37° N show relatively humid, the speleothems at 31° N show more arid conditions.

Against this background, our research questions are as follows:

- Can we see any regional effects of global climate fluctuations in our materials during the Halaf and the Late Chalcolithic periods?
- Are there any differences in plant cultivation and diet during these two time sequences, and if so can they be related to environmental dynamics?

Although this study is the first to present archeobotanical data on Tell Tawila, early finds suggested to the excavators a subsistence based on emmer wheat (*Triticum diccocum*) and animal husbandry in the form of sheep and goat, supplemented by pig and cattle breeding. It was clear that wild game, especially onagers and gazelles, constituted a significant portion of faunal remains. This reliance on wild game throughout the Halaf places Tell Tawila to the numerous Halaf sites which do not conform to the earlier subsistence models (Becker et al. 2007; Becker and Helms 2013; Becker 2015).

Tell Tawila

Tell Tawila is located in the north-eastern Syrian Jezirah between Balikh and Khabur, about 12 km south of Tell Chuera and immediately west of Wadi Chuera (Fig. 1). The region of Wadi Hamar is part of the north-eastern Syrian steppe area with altitudes between 350 and 430 m above sea level. The Wadi Hamar, which runs through the ENE–WSW, and the side valleys, which are mostly fed from the north, drain the area westwards into the Balikh. The Wadi Chuera forms the largest of these dry valleys in the Wadi Hamar region, which are often only slightly cut into the landscape (Becker et al. 2007; Becker and Helms 2013; cf. the final report Becker 2015).

Surveys for the Wadi Hamar Survey project were carried out between 1997 and 2000. Of the more than 100 settlement sites found in the region, 20 were settled during the Halaf period. Together with Tell Chuera itself and 'Ajila-South, Tell Tawila represents a village of the Halaf period, which was continuously inhabited over several centuries, while most other Halaf sites in the region represent smaller, often only briefly populated hamlets.

In 2005 and 2006, excavations were carried out at Tawila, under direction of Dr. Jörg Becker (University of Halle-Wittenberg), as part of the joint German-Syrian Tell Chuera Regional Project. The excavations concentrated on the two oldest settlement periods of the site, namely the Halaf and Ubaid periods, in various areas (A–D) of the gently sloping tell (Fig. 2). While Halaf layers could be recorded in all excavation areas, Ubaid layers were not found in the eastern part of

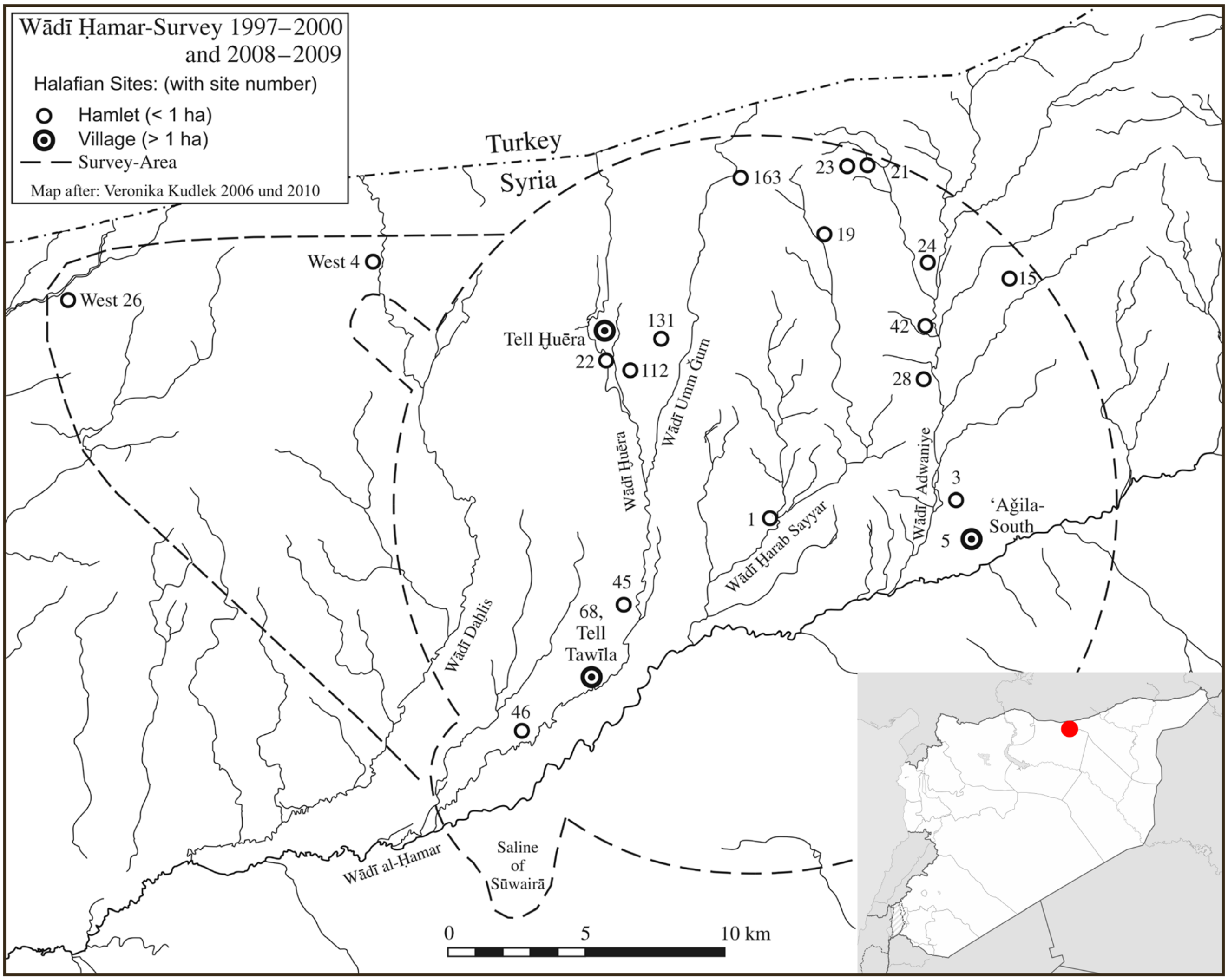

Fig. 1 Wadi Al-Hamar regional survey and its location in northern Syria. Image was modified from Becker and Helms (2013), and the inset map of Syria was modified from NordNordWest CC BY-SA 3.0

the excavation. Poorly preserved foundations and pits of the regional Late Chalcolithic (LC) were uncovered in area C and archeobotanically sampled (see Becker 2015). Similar Late Chalcolithic pottery was also uncovered in the surface area of Sondage D and comprised several completely preserved Coba bowls, typologically dating these layers to the period around 4000 BC (LC 1/2; Becker et al. 2007, p. 235, Abb. 16; cf. Fig. 2 for the location). For a discussion and complete presentation of the stratigraphy, see Becker (2007, 2015). A summary of the stratigraphy is seen in Table 2.

The stratigraphic evaluation (Table 2) of the building layers and finds from the Halaf period made clear that Tell Tawila was a village of max. 2 ha in size. With its typical round houses, the site was continuously inhabited, likely by 50–100 individuals, from around 5850 cal BC to around 5550 cal BC (Becker 2015). Repopulation occurred in the form of a small hamlet around 4500 cal BC (Ubaid stage 4), characterized by chaff-tempered pottery. Finally, the Late Chalcolithic is only represented in samples from area C, which are assigned to layer C 3, dating to approx. 4000 cal BC (= LC 1/2).

The chronology of the Halaf settlement in Tell Tawila is confirmed by a total of four calibrated radiocarbon dates (Becker 2015, pp. 84–86, figures 40–44), but there are so far no dates for the Ubaid period and the Late Chalcolithic (Fig. 3).

Modern environment and paleoclimatic records

Today, a semiarid steppe covers about one third of Syria, notably large parts of the north. The Wadi Al-Hamar is characterized by a semiarid steppe climate, with modern annual precipitation around or just above 250 mm. Most of this precipitation is seen during the winter months (Christiansen et al. 2015). The vegetation in northern Syria is dominated by among others *Salsola vermiculata*, *Atriplex leucoclada*,

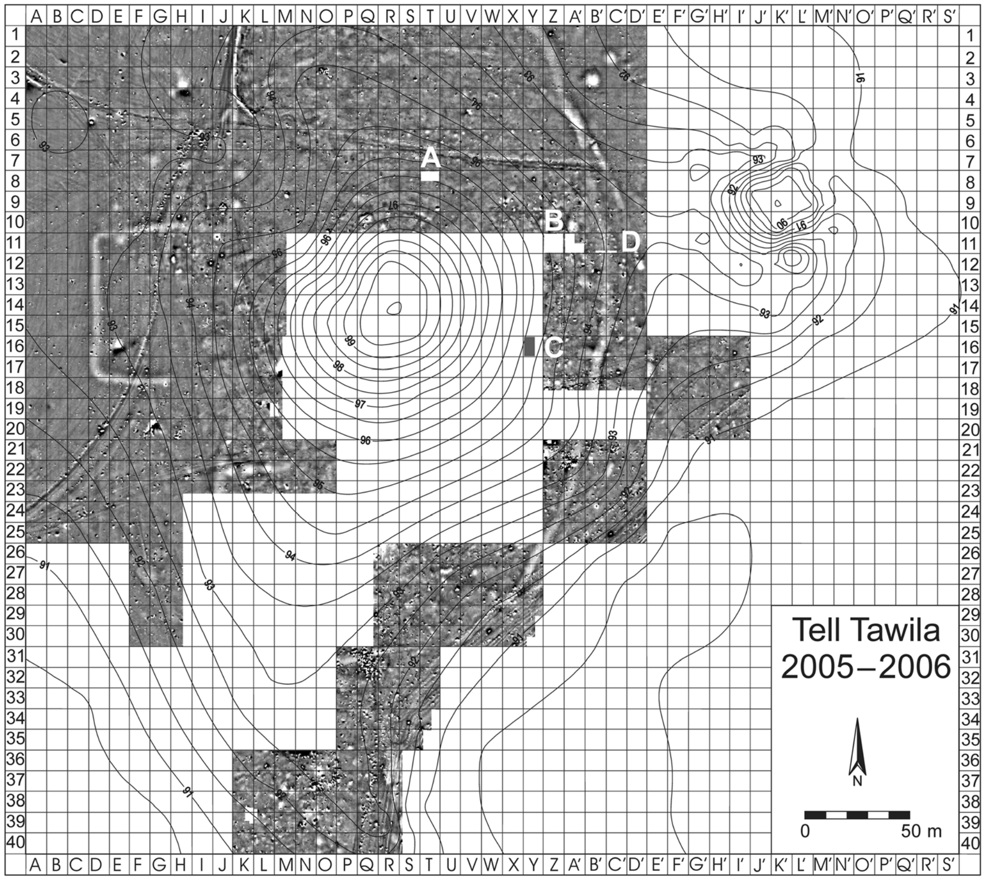

Fig. 2 Tell Tawila topographical map, from Becker and Helms (2013)

Atriplex halimus, *Vicia* sp., *Trigonella* sp., and in some areas by *Pistacia atlantica* (Zohary 1973).

It is important to note that while general climatic trends throughout the Holocene in the Eastern Mediterranean, have long been known (Kutzbach 1981; Kutzbach and Guetter 1986), these GCM-based models generally lack regional resolution. The perhaps most cited climatic models for studying environmental shift in the Northern Hemisphere are the so-called Bond events, where major climatic events in the Holocene have been linked to North Atlantic ice-rafting events. The Bond events show cyclical climatic activity every ~ 1500 years. While there is some dispute as to these cycles, an aridification event is noted at ~ 5900 ka (Bond et al. 1997), which would overlap with the LC 2, and the increased activity at Tell Tawila around LC 1/2 (~ 4000 cal BC). Due to a lack of paleoclimate proxy archives in northern Mesopotamia, researchers often refer to proxies from other regions, e.g., the southern Levant, such as Soreq Cave, and eastern Anatolia, such as Lake Van or more eastern lakes in Turkey. Isotope analysis of speleothems from Soreq Cave, Israel, shows a

Table 2 Tell Tawila. Comparative stratigraphy of the areas A–D (slightly revised version after Becker 2015, Abb. 44)

Period	Phase	Area A	Area B	Area C	Area D
Islam./ Iron Age/ EBA	I	A 1	B 1	C 1 C 2	D 1
LC	II	A 2		C 3	
Ubaid	III	Strawfinds	Strawfinds	Strawfinds	Strawfinds
HUT	e	Strawfinds		Strawfinds	
IIb	d	Strawfinds	Strawfinds	Strawfinds	
Halaf IIa	IV c	A 3	B 3 – B 2	C 4	D 3 – D 2
Ib	b	A 4 A 6 –A5	B 4 B 6 – B 5	C 5	D 4
Ia	a				
Pre- and Proto-Halaf	not proved				

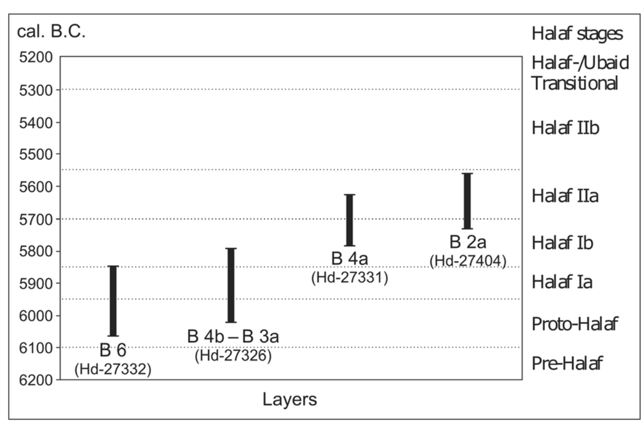

Fig. 3 Radiocarbon dates in cal BC, from Becker et al. (2007). For a more exhaustive discussion and details on the radiocarbon dates, refer to Becker et al. (2007, pp. 84–87)

wetter episode around 6550–6450 BP (Bar-Matthews and Ayalon 2011) in agreement with the reconstructed Dead Sea level curve by Migowski et al. (2006). However, the latter indicates strong fluctuations between levels above and below the modern sea level, particularly for the sequence between 7000 and 6000 BP, indicating highly unstable conditions for the post-Halafian periods. Roberts et al. (2011) studied oxygen isotopes from six lakes in Greece, Iran, and Turkey, and noted in contrast a shorter dry period around 4500 BC, with a subsequent wetter period around 4000 BC. Mayewski et al. (2004), compiling multiple paleoclimatic proxies, suggested a major arid event between 6000 and 5000 BP, which contrasts the reconstructed Dead Sea level curve by Migowski et al. (2006) that shows an overall trend of higher sea levels than today, but again with fluctuations. Bar-Matthews and Ayalon (2011) argue that the peak of this event would have occurred around 5700 BP, indicating that the climate would have gradually dried between 6450 BP and 5700 BP, coinciding with the LC occupation of Tell Tawila, but which is only weakly reflected in the reconstructed Dead Sea level curve. This would also suggest that the wetter period noted by Roberts et al. (2011) may have occurred later as the Soreq Cave data which is of remarkably high resolution (Bar-Matthews and Ayalon 2011). Studies of macrobotanical remains and charcoal at Tell Brak, north-eastern Syria, led Charles et al. (2010) to suggest an arid event around 5200 cal BP, which is in line with many archeological and paleoclimatological studies in the region (Staubwasser and Weiss 2006).

Although paleoclimatic proxies in general suggest a strong fluctuation of wet and dry periods with some indication of shorter-term dry and wet episodes and an overall trend toward drier conditions, their distance to the Khabur region and issues of synchronizing the diverse chronologies indicate the desiderate of generating high-resolution climatic data on a local level, which we are contributing to with our methods.

Methods

A total of 53 flotation samples were gathered by the excavators throughout the 2005–2006 field seasons at Tell Tawila. Samples were retrieved by the excavators, and sediment sample sizes were not recorded, but were generally about 10 L. Judgmental sampling was utilized, i.e., whenever ashy layers were noted, several liters of sediment per sample were taken. All samples were run through bucket flotation and left to dry. Sorting of seeds and charcoal was done by a research assistant in the archeobotanical laboratory of the University of Tübingen in 2007–2008. The seeds and fruits were evaluated by the first author as part of his master thesis in 2015.

Out of the 53 samples collected, 5 samples had to be excluded and a total of 48 were analyzed for seed and chaff remains. Of the 48 samples, 24 date to the Halaf Ib/IIa, 17 to the Halaf IIa, and 7 to the LC. With regard to the seed and chaff remains, it should be noted that from the oldest layer B 6 (beginning of Halaf Ib stage), there is only a singular sample. No samples can be assigned to the layers A 5, B 5, and C 5. Area B, especially layer B 4, is particularly rich in acheobotanical material from the Halaf Ib/IIa transition. Also well represented are samples from the subsequent layers B 3 and B 2, which already belong to the stage Halaf IIa, supplemented by a few samples from layer C 4.

Seeds, fruits, and chaff remains were identified using the modern reference collection at the University of Tübingen and seed identification literature (Berggren 1969, 1981; Anderberg 1994; Cappers et al. 2006, 2009; Jacomet 2006; Nesbitt 2006; Neef et al. 2012). A Euromex stereoscope, up to × 30 magnification, was used for all identifications, and a Zeiss Discovery V. 8 stereomicroscope with an Axiocam 105 color camera for taking images with the software Zen 2 Lite. Percentages and ubiquity of taxa were calculated for all samples.

Charcoal identifications were undertaken by Deckers with a Leitz Laborlux 12ME incident light microscope in combination with a Euromex stereoscope. The magnifications used included × 60, × 100, × 200, or × 500. For the identifications, a reference collection and identification literature have been used (e.g., Crivellaro and Schweingruber 2013; Fahn et al. 1986; Gale and Cutler 2000; Schweingruber 1990). One thousand nine hundred fifty-six charcoal fragments have been investigated.

For generating a local high-resolution record of moisture availability for crop production throughout the considered time sequence, 122 cereal grains (87 barley grains, 35 emmer grains) were analyzed by Riehl for their stable carbon isotope ratios. Due to variable availability of cereal grains in the different settlement phases at Tell Tawila, the number of cereal grains is relatively uneven, with 38 barley and 20 emmer grains from Halaf Ib/IIa, 31 barley and 15 emmer grains from Halaf IIa, and 16 barley grains from Late Chalcolithic contexts.

Measurements of $\delta^{13}C$ were carried out at the Institute of Geosciences of the University of Tubingen, Germany, on a FinniganMAT252 gas source mass spectrometer with a Thermo Finnigan Gas Bench II/CTC Combi-Pal autosampler. Before mass spectrometric measurements, the barley grains were reacted with 5% HCl to eliminate sedimentary carbonate.

Changes in atmospheric CO_2 concentration ($\delta^{13}C$ air) over time were taken into account, applying past $\delta^{13}C$ air values from ice-core projects to the discrimination formula (Ferrio et al. 2014)

Results

Seeds and chaff remains

The complete results of the seed and chaff identification are presented in the supplementary information (SI). A summary with proportions of the assemblage for each period can be found in Table 3. Sample F.699 is the sole sample which could be firmly attributed to the Halaf Ib. As this sample is unusually large, it has an impact on the overall numbers of the seed and chaff assemblage. Proportionally, however, it is very similar to the transitional period Halaf Ib/IIa. Taking into account the temporal difference between layers B6 and B4b (Figs. 3 and 4), sample F. 699 represents continuity between an earlier part of the Halaf Ib and the later part which makes up the transitional Halaf Ib/IIa period. As sample F.699 is a single sample, it cannot be considered to be representative for the Halaf Ib contexts at Tell Tawila, and given its transitional character outlined above, it has been included in the Halaf Ib/IIa assemblage.

Noteworthy is the high proportion of *Triticum* chaff remains (combined glume bases and spikelet base/fork) in both Halaf phases, representing 63% of the assemblage in Halaf Ib/IIa and ~ 50% in Halaf IIa alongside high ubiquities between 81 and 88%. The proportions drop dramatically in the LC where chaff remains make up about 12% of the assemblage, but the ubiquities remain very high. *Triticum dicoccum* grain (emmer) proportions are ~ 6% in both Halaf periods, before dropping to < 1% in the LC. The ubiquities are around 60% in the Halaf phases and then drop to 14% in the LC. Based on the ubiquity and overall proportions of seeds, it would appear that the chaff remains came primarily from *T. dicoccum* processing as opposed to from *Triticum monococcum* (*einkorn*), at least in the Halaf period (see Table 3). The virtual absence of *Triticum* grains in the LC samples is likely in part the result of sampling biases, i.e., the comparatively small number of LC samples, as the excavations were primarily focused on the Halaf phases (some *Triticum* chaff was found, but only 2 grains from the genus). Considering the ubiquities of emmer and einkorn throughout the Halaf, it is nonetheless probable that emmer saw a decline in the LC, as supported by low emmer grain ubiquities during the LC, whereas for einkorn, this is surely the case. Both *Triticum monococcum* and *Triticum aestivum/durum* (naked wheats) are present for all three time periods. Einkorn appears in low proportions (< 1%) throughout all three time periods and comparatively low ubiquities (with a maximum of 33% for einkorn grains in Halaf Ib/IIa [Table 3]). *Triticum aestivum/durum* (naked wheat) is present as ~ 1% of the total assemblage throughout time and with a similar ubiquity to einkorn.

Hordeum vulgare (barley) is the most prominent cereal at Tell Tawila. Its grains represent high proportions with 16% (Halaf Ib/IIa), 18% (Halaf IIa), and 13% (LC). Being present in 96% of the samples, barley has the highest ubiquity of all the taxa at Tell Tawila and seems to increase in ubiquity over time, which is particularly well visible in the barley rachis remains.

Other economic plants include species of the genera *Vicia/Lathyrus* (vetch/vetchling) and *Lens culinaris* (lentil). Distinction could not always be made between vetches and vetchlings. Although present, none of these economic crops appeared in great numbers.

Three species of wild grass taxa appear in noteworthy proportions. *Aegilops* sp. (goatgrass) constitutes a larger proportion of the assemblage over time at 3% (Halaf Ib/IIa), 5% (Halaf IIa), and 7% (LC). The ubiquity of its grains and chaff remains peaks at 86% and 71% respectively in the LC. *Eremopyrum* sp. (wheatgrass) appears in low proportions throughout the Halaf before accounting for more than ~ 15% of the assemblage in the LC and occurs here with a ubiquity of 29%. High proportions of *Eremopyrum* are rare in the archeological record. The only two notable sites found in the literature are those of Ohalo II, Israel, dated to about 22,000–25,000 BC (Nadel et al. 2004; Weiss et al. 2004), and Çatalhöyük (eastern area), Turkey, dated to around 6500–7000 cal BC (Fairbairn et al. 2007; Marciniak et al. 2015). Another interesting taxon is *Hordeum* cf. *marinum* (sea barley). Sea barley represents < 1% of the total assemblage in the Halaf Ib/IIa, 1.5% in the Halaf IIa, then ~ 45% in the LC, with ubiquities between 29 and 43%. Exact species identification has not yet been established. However, morphological comparisons with published reference material show close similarities with *Hordeum marinum* (Fig. 4). Morphologically, the wild barley from Tell Tawila has a relatively narrow embryo and a more rounded apex alongside a very distinct ventral furrow, providing the most characteristic morphological features of sea barley grains. Additionally, it has a rounded ventral shape and flat dorsal side when viewed from a lateral point. In cross-section, the seed is gently rounded as opposed to flat. When comparing the Tell Tawila remains with modern examples of sea barley, the view is almost identical from a lateral point, but the ends are more pointed. Its well-rounded shape alongside the length of the seed and very clear convexly shaped ventral side differentiates it from *H. murinum* and *H. spontaneum*. It appears that *H. marinum* has not been encountered at any Halafian site. There is no doubt that sea barley exists in Syria today as it has been recorded throughout the Near East, including Iran, Jordan, Israel, Turkey, Syria, Afghanistan, and Iraq (Sahebi 2004; Albert et al. 2008; Oran 2010; Naghavi et al. 2011). There is also little doubt that it was collected by humans (Kubiak-Martens et al. 2015), some as early as 23,000 cal BC at Ohalo II, Israel, which is also the only instance of large numbers encountered in the literature (Weiss et al. 2004, 2008). It is important to note that Weiss et al. refer to *H. marinum/hysterix* and are also wary of exact

Table 3 Summary of ubiquity per time period/phase, total ubiquity across time, and percentages as total percentages per taxon for period/phase

	Halaf Ib/IIa ($N = 24$)		Halaf IIa ($N = 17$)		LC ($N = 7$)		Total ubiquity
	Percent of phase total	Ubiquity	Percent of phase total	Ubiquity	Percent of phase total	Ubiquity	
Cereal grains							
Hordeum vulgare	15.6	85	18.2	94	13.1	100	96
Triticum dicoccum	6.2	59	5.9	65	< 0.1	14	58
Triticum aestivum/durum	1.0	33	1.1	35	1.2	14	33
Triticum cf. *dicoccum*	1.2	26	0.1	6			17
Triticum monococcum, cf. 1-grain	0.8	33	0.7	29	< 0.1	14	31
Triticum monococcum, cf. 2-grain	0.1	19	< 0.1	6			13
Glumes and chaff remains							
Triticum sp., glume base	32.7	85	30.1	88	6.9	86	92
Aegilops sp., spikelet	1.2	48	2.8	47	2.3	71	54
Free-threshing wheat rachis	< 0.1	4	< 0.1	6	0.1	14	6
Hordeum sp., rachis	0.1	15	0.3	6	1.8	57	19
T. dicoccum, glume base	0.3	22	1.7	24	0.3	14	23
T. dicoccum, spikelet	0.1	11	0.3	12	< 0.1	14	13
T. dicoccum, terminal spikelet	1.0	41	0.5	29	0.2	14	35
T. monococcum, glume base	0.1	11					6
T. monococcum, spikelet	0.1	19	< 0.1	6			13
Triticum sp., rachis					< 0.1	14	2
Triticum sp., spikelet base	30.9	81	19.9	88	5.3	57	85
Pulses							
Lens culinaris	0.2	30	0.5	29	0.3	29	31
Vicia sativa	0.6	37	0.8	35			33
Vicia/Lathyrus	0.1	19	0.7	12			15
Wild plants							
Hordeum cf. *marinum*	0.9	41	1.4	29	45.1	43	40
Adonis sp.			< 0.1	6			2
Aegilops sp.	3.1	70	5.3	65	7.1	86	75
Astragalus sp.	0.1	19	0.2	12	0.2	57	23
Atriplex sp.	< 0.1	7	0.7	18			10
Bellevalia sp.	0.2	26	1.0	29	< 0.1	14	27
Carthamus sp.					< 0.1	14	2
Eremopyrum sp.	0.6	48	1.3	29	15.5	29	42
Fumaria sp.	< 0.1	7	0.5	24			13
Galium sp.	0.2	19	0.4	29			21
Heliotropium sp.	0.1	7	1.1	18			10
Liliaceae	1.9	48	2.5	59			48
Malva sp.	< 0.1	4	0.1	12			6
cf. *Ornithogalum* sp.	0.2	22	0.8	29			23
Ornithogalum sp.	0.1	15	0.2	6			10
Teucrium sp.	< 0.1	4	0.5	18	< 0.1	14	10
Valerianella sp.					0.2	14	2

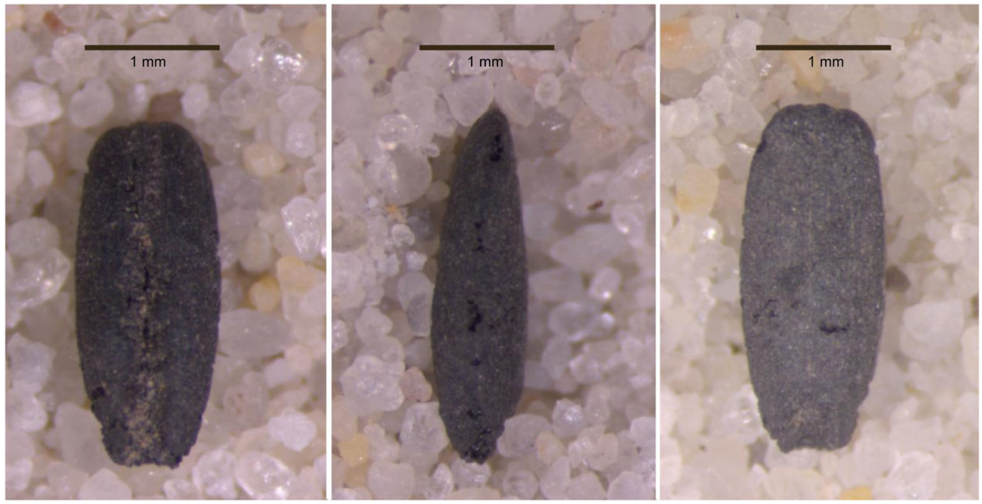

Fig. 4 *Hordeum* cf. *marinum*

species determination. There are also signs of *H. marinum* in the phytolith record at Tel Dor, Israel, a late Bronze Age/early Iron Age site (Albert et al. 2008). Beyond this, it appears to be a rare type to be present in such large numbers. Further studies are required to confirm the species with greater confidence. The presence of these wild taxa at pre-Neolithic sites are often interpreted as having been exploited by humans (Weide et al. 2018), whereas in later periods with arising animal husbandry, ruminant dung is considered a likely reason for the deposition of the plants on the site (Miller and Smart 1984). Another explanation would be that they grew together with the cereal crops and were deposited as crop-processing by-products.

Wood charcoal

Of the 1956 fragments investigated, an exceptionally high proportion of ca. 93% of the wood charcoal could not be identified because the fragments had an extremely small diameter (less than 0.5 cm [Table 4]): they represent shrub-like plants. The remaining pieces represent twelve other taxa in low percentages. About 1.3% of the charcoal remains were *Quercus* sp. (of which some could be identified as deciduous oak), ca. 1% were *Tamarix* sp. and *Fraxinus* sp., while about 0.7% were *Populus/Salix* sp. and 0.5% were *Prosopis* sp. From all other taxa, e.g., Chenopodiaceae, Maloideae, *Phragmites* sp., *Pinus brutia/halepensis*, *Pistacia* sp., and *Ulmus* sp., only a few fragments were observed (Table 3).

Despite the few identifiable remains, the samples were also checked for diachronic changes. A summary of charcoal proportions for each period can be seen in Table 4: in all periods, shrub-mini-diameter taxa dominate strongly, being between 96 and ca. 87%.

The proportion of typical riverine taxa (*Fraxinus* sp., *Phragmites* sp., *Populus/Salix*, *Tamarix* sp., *Ulmus* sp.) is between 2.6 and 4.2%. It is of note that in the Late Chalcolithic samples, oak percentages amount 5.2% of the fragments, while oak percentages were maximally 0.1% in earlier layers. Highest percentages of *Prosopis* sp. (3.6%) were found in samples from layers IIa, where also Chenopodiaceae percentages were highest (1.2%).

Stable isotope measurements

Most of the 122 measurements fall into the Halaf Ib/IIa phase, but with generally analyzing more than 6 single grains per sample, the number of measurements is sufficient for generating data sets representative of individual archeobotanical samples and for producing results of drought stress signals for the different phases (Riehl et al. 2014).

The relationship between carbon isotope composition from barley grains and total water inputs (TWI) during grain filling follows an exponential curve, relating values below 50 mm TWI during the grain-filling period to a range of $\delta^{13}C$ between − 24 and − 20‰ (cf. Araus et al. 1997). For barley, the grain-filling period is roughly 40 days or less, and a TWI of about 40 mm equals the monthly precipitation of the spring season in the coastal and hilly regions of upper Mesopotamia and the Levant. For modern barley, 40 mm TWI equals a $\delta^{13}C$ value of roughly − 23‰, corresponding to a $\Delta^{13}C$ of roughly 16‰. This value serves as a boundary below which increased drought stress has to be assumed, whereas calibrated values above 17‰ can be considered to characterize plants that formed grains devoid of particular drought stress (Riehl et al. 2008). This model is used to interpret the measurements from Tell Tawila; however, the reference lines of 16‰ and 17‰ have to be considered as relative borders, rather than exact indicators.

Despite considerable variation, the data mean values from Tell Tawila show an interesting pattern of drought stress during all the phases except for Halaf IIa, when water availability appears to have been mostly sufficient for both species, barley

Table 4 Charcoal results of individual samples from Tell Tawila, as well as total count for the different phases and fragment percentages considering all the samples

	TAW06-B.140-Z.11-F.699	TAW06-B.74-A'11-F.626	TAW06-B.112-Z.11-F.621	TAW06-B.165-Z.11-F.688	TAW06-B.165-Z.11-F.688	TAW06-B.63-A'11-F.631	TAW06-B.101-Z.11-F.548	TAW06-B.101-Z.11-F.548	TAW06-B.64-A'11-F.583	TAW06-B.109-Z.11-F.568	TAW06-B.97-Z.11/A'11-F.531	TAW06-B.59-A'11-F.486	TAW06-B.59-A'11-F.486
	Halaf Ib	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa
Layer	B 6	B 4b	B 4b	B 4b	B 4b	B 4b	B 4a	B 4a	B 4a	B 4a	B 4a	B 4a	B 4a
Chenopodiaceae													
Fraxinus sp.							1		5				
Maloideae								1					
Phragmites sp.													
Pinus brutia/halepensis								1					
Pistacia sp. (3–4 seriate, ringporous)													
Populus/Salix sp.								2					
Prosopis						3							
Quercus sp., deciduous													
Quercus sp.											1		
Tamarix sp.	5												1
Ulmus sp.													
Shrub - mini-diameter	35	12	17	69	51	5	1	139	6	23	220	68	56
Indet.				2	2		1						

	TAW06-B.50-A'11-F.505	TAW06-B.50-A'11-F.505	TAW06-B.64-A'11-F.713	TAW06-B.64-A'11-F.713	TAW06-B.59-A'11-F.500	TAW06-B.55-A'11-F.494	TAW06-B.55-A'11-F.501	TAW06-B.51-A'11-F.473		TAW06-B.8-Z.11-F.560	TAW06-B.8-Z.11-F.567	TAW06-B.8-Z.11-F.669	TAW06-B.28-Z.11-F.449
	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Halaf Ib/IIa	Total	Halaf IIa	Halaf IIa	Halaf IIa	Halaf IIa
Layer	B 4a	B 4a	B 4a	B 4a	B 4a	B 4a	B 4a	B 4a		B 2a	B 2a	B 2a	B 2a
Chenopodiaceae							1		1				2
Fraxinus sp.	4					4	3		17				
Maloideae									1				
Phragmites sp.									0				
Pinus brutia/halepensis									1				
Pistacia sp. (3–4 seriate, ringporous)									0			1	
Populus/Salix sp.						1		1	4				
Prosopis								1	4	4			
Quercus sp., deciduous									0				

Table 4 (continued)

Quercus sp.									1				
Tamarix sp.	2	1						4	13				
Ulmus sp.			1						1				
Shrub - mini-diameter	80	35	25	26	94	27	34	247	1270	9	8	34	9
Indet.								7	12				
									1325				

	TAW06-B.28-Z.11-F.449	TAW06-B.26-Z.11-F.456	TAW06-C.73-Y.16-F.194			TAW06-C.26-Y.16-F.150	TAW06-C.48-Y.16-F.121	TAW06-C.48-Y.16-F.121	TAW06-C.61-Y.16-F.155	TAW06-C.61-Y.16-F.199	TAW06-C.71-Y.16-F.200	Fragments in all samples	Fragment percentages
	Halaf IIa	Halaf IIa	Halaf IIa	Total	Late Chalcolithic	Late Chalcolithic	Late Chalcolithic	Late Chalcolithic	Late Chalcolithic	Late Chalcolithic	Late Chalcolithic		
Layer	B 2a	B 2a	C 4a		C 3c	C 3b	C 3b	C 3b	C 3b	C 3b			
Chenopodiaceae				2					1		1	4	0.20
Fraxinus sp.		1		1	2						2	20	1.02
Maloideae				0							0	1	0.05
Phragmites sp.				0	1						1	1	0.05
Pinus brutia/-halepensis				0							0	1	0.05
Pistacia sp. (3–4 seriate, ringporous)				1							0	1	0.05
Populus/Salix sp.	1		5	6	2				2		4	14	0.72
Prosopis		2		6							0	10	0.51
Quercus sp., deciduous				0	13			9			22	22	1.12
Quercus sp.				0				2			2	4	0.20
Tamarix sp.				0			1			6	7	20	1.02
Ulmus sp.				0							0	1	0.05
Shrub - mini-diameter	2	15	72	149	338	5	6		34	17	400	1820	93.05
Indet.		1	1	2	11			10			21	37	1.89
				167							460	1956	100.00

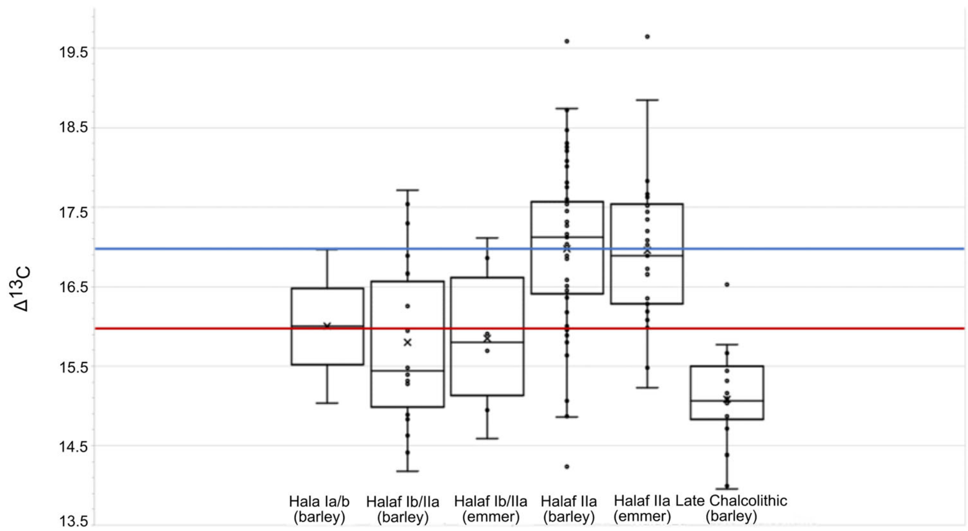

Fig. 5 Stable carbon isotope values of barley and emmer grains from different settlement phases at Tell Tawila. Single measurements are shown as dots. The reference lines of 16‰ and 17‰ indicate relative borders marking the area of transition between non-existing drought stress (above 17‰) and considerable drought stress (below 16‰)

and emmer wheat. Particularly during the Late Chalcolithic, drought stress seems to have been considerable (Fig. 5).

Discussion

Plant subsistence and vegetation patterns in the Halaf period

Zeder (1994) in her study of Umm Qseir and several other Mesopotamian sites convincingly showed variability and flexibility in post-Neolithic subsistence strategies throughout the region, in response to localized factors. Instead of accepting an agricultural and pastoral baseline subsistence strategy, and any deviation from it constituting an exception, Zeder (1994) argues that variability is the baseline. This would mean that what has been historically argued to be exceptions should be treated as part of a larger pattern of adaptation to local conditions (see Akkermans 1993 for further review, as well as Becker and von Wickede 2018, p. 267, figure. 75, for further references). McCorriston (1992) highlights further problems which build on our changing perceptions of Halaf subsistence, highlighting the need to understand change and how people responded to it. As demonstrated by these earlier studies, high-resolution data is the best way to further our understanding of local conditions, change, and the response to it. Unfortunately, such data is not always available for the Halaf period. Akkermans (1993) presents an overview of several subsistence studies done throughout the Balikh River valley. The macrobotanical record at many of the sites presented by Akkermans is spotty, but where the archeobotanical data is present there is a clear and overwhelming usage of domesticated plants. Wild plants are primarily interpreted as arable weeds or minor complements to the diet (see Akkermans 1993, pp. 250–268). The most complete of the early archeobotanical studies are Van Zeist (1979) and Van Zeist and Bakker-Heeres (1984) that contributed to our basic understanding of human subsistence, with a focus on plant use, during the Halaf. Three later studies (McCorriston 1992; Van Zeist 1999; McCorriston and Weisberg 2002) focused on placing the Halaf period in a greater chronological context and raising further questions.

Evident in the published archeobotanical record for the Halaf are several patterns. Notable are a reliance on barley (*Hordeum vulgare* L.) and emmer (*Triticum dicoccum*), alongside very low proportions of einkorn (*Triticum monococcum*) and the free-threshing wheats (*Triticum aestivum/durum*). This appears true also for Tell Tawila where emmer and einkorn proportions remain more or less stable throughout the Halaf period, only to become all but absent in the Late Chalcolithic. *Triticum* chaff appear to support this pattern. This is possibly explained by emmer being better suited to arid environments than einkorn (McCorriston 1992; Riehl 2012); thus, the same discrepancy holds true at other Halaf sites (Van Zeist and Bakker-Heeres 1984; Van Zeist and Waterbolk-Van Rooijen 1992; Van Zeist 1999; McCorriston and Weisberg 2002). At Tell Tawila, the majority of archeobotanical samples come from midden contexts, associated with the purposeful destruction of buildings (Becker et al. 2007 [see SI table 6 for context summary]). Barley is the most prolific cereal in both Halaf phases, not only in terms of proportions but also in ubiquity (Table 3). This too fits the patterns described at Halaf sites. Van Zeist and Bakker-Heres (1984) notes wild olive (*Olea oleaster*) at Ras Shamra and an absence of pistachio (*Pistacia* spp.) and wild almond (*Prunus* spp.). At the Halafian levels of Sabi Abyad, few wild species for human consumption are noted as well (Van Zeist 1999). Overall, the prevalence of wild plants as part of subsistence appears low throughout the Halaf, a similar pattern to that found at other Halaf sites (e.g., McCorriston and Weisberg 2002; Van Zeist and Bakker-Heeres 1984). The only wild grass taxon which occurs at higher proportions in the Halaf phases at Tell Tawila is *Aegilops* sp., and this is still in proportions significantly lower than for those of *H. vulgare* or *T. dicoccum*. It is possible that *Aegilops* was used for human consumption, similar as suggested for some early Neolithic sites such as M'Lefaat, Iraq (Savard et al. 2003), or Choga Golan, Iran (Riehl et al. 2015). If we can expect ancient humans desire for highly cleaned products to have been similar as today, it is also possible that *Aegilops* was difficult to remove during the processing of the harvest as the grains are of a comparable size and shape to *T. dicoccum* and *H. vulgare*, and therefore were not disposed of until just before the grain was to be used (e.g., see Hillman 1984 for ethnographic examples of traditional crop processing). Since most of the samples from the Halaf come from purposefully destroyed middens of rubbish, it is possible that with such a small proportion of *Aegilops*, it represents the latter (see the supplementary data for the raw counts as well as a brief description of the contexts). Alternatively, it may have been processed with higher difficulties, because the glumes are more resistant than those of barley and wheat. However, while the dominant presence of crop species places Tell Tawila neatly into the earlier ideas that subsistence during the Halaf was agriculturally based, the zooarcheological record, investigated by Emmanuelle Vila (Fig. 6), shows a heavy reliance on wild game (Becker et al. 2007). This combination of high amounts of hunted game and domesticated animals and plants highlights the importance of flexibility and adaptation at the site. When placed into a larger context, the Halaf sequence of Tell Tawila can be added to the now numerous sites (see "Introduction") which do not fully conform to the earlier ideas of a subsistence based almost exclusively on agriculture. This is also reflected in the strong increase of large-seeded wild grasses during the LC (see Fig. 7 for major taxon).

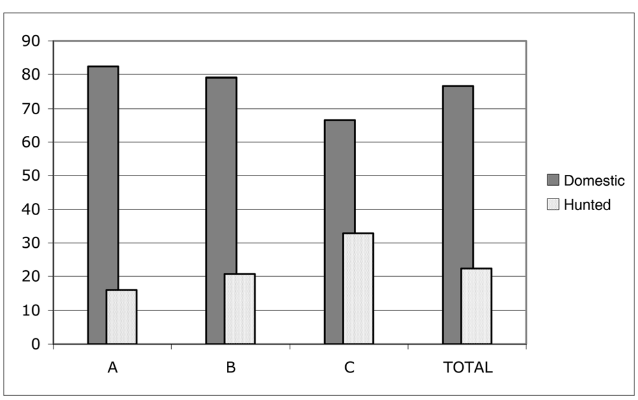

Fig. 6 Proportions of domesticated and hunted game at Tell Tawila. Table by Emmanuelle Vila in Becker et al. (2007, pp. 248). A—Halaf Ia/b; B—Halaf IIa; C—Late Chalcolithic

While much of our discussion on the archeobotanical record focuses on human consumption, there are other possible reasons for why and how plant materials have accumulated at a site. The most commonly cited alternative to human consumption is animal feed and the subsequent use of their dung as fuel (Miller 1982, 1984; Hillman et al. 1989; Valamoti and Charles 2005). As most of the Halafian samples represent infills or layers of debris, intentionally deposited and burnt, within buildings, they likely represent a mixture of activities. As noted above, the use of *H. vulgare* and *T. dicoccum* as staple food crop is well established, with some scholars also suggesting that barley may have been grown for beer production already at this time (Dineley 2004). No sample from within a tannur or oven context contained charcoal, which may then be considered an indicator for dung fuel. However, ethnographic studies have shown that ovens and hearths are regularly cleaned (e.g., Miller 1984), and this is largely believed to be the case in the past as well (e.g., Byrd and Banning 1988; Graham and Smith 2012; Portillo et al. 2014) meaning we should be searching for charcoal in secondary deposits rather than within the household. As most of the archebotanical samples taken from Tell Tawila represents the debris or rubbish from house infills, these are the type of secondary deposits where the tannur cleanings might have ended up. The charcoal analysis is clear in that shrubby taxa dominate the Halaf record, perhaps then suggesting that wood was a minor constituent of the fuel economy at the site. However, if dung fuel were being used, it might be expected to see higher proportions of wild taxa representing the grazing of animals (Miller 1997). As noted earlier, this is not the case during the Halaf period. On the other hand, the high proportion of chaff as a by-product of processing grains may represent foddering (Miller 1996). In short, we cannot state to what extent the archeobotanical assemblage at Tell Tawila represents dung as fuel. Recent studies have suggested that the most direct way of determining the presence of dung is through the analysis of dung spherulites (Canti 1997; Portillo and Albert 2011; Smith et al. 2018), something which may be possible to investigate at Tell Tawila in the future.

Notwithstanding dung was possibly used as fuel, charcoal was present as well. However, the find of a lot of small-diameter shrubby plants and the almost total lack of fragments from trees suggest the presence of a shrubby steppe or steppe. A proportion of typical riverine taxa (*Fraxinus* sp., *Phragmites* sp., *Populus/Salix*, *Tamarix* sp., *Ulmus* sp.) is indicative of perennial water in the surroundings. Compared to Euphrates sites (Deckers and Pessin 2010), this proportion is however extremely low, which suggests that the riverine vegetation along the Wadi Huera was probably not very dense. Highest percentages of *Prosopis* sp. (3.6%) were found in samples from layer IIa where also Chenopodiaceae percentages were highest (1.2%). *Prosopis* is a typical indicator plant for overgrazing when it extensively occurs. Animals eat the

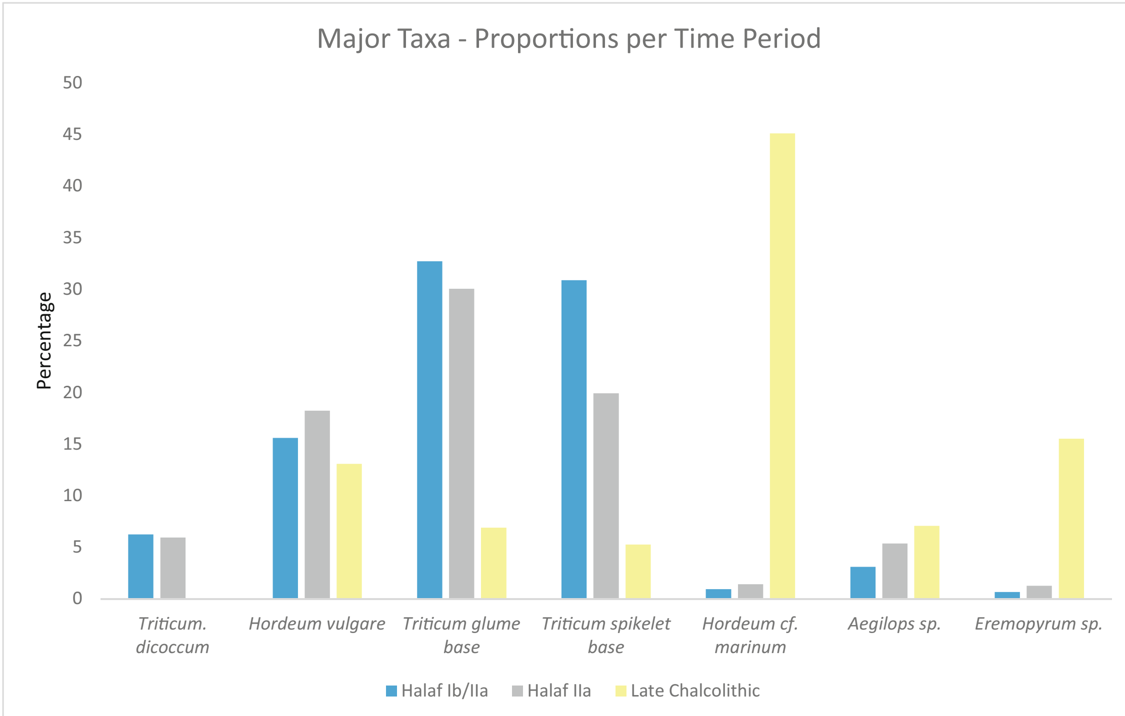

Fig. 7 Proportions of major taxa per time period

seed pods and in this way spread the seeds. In Australia, for example, *Prosopis* species became recently a major problem since they reduce the productivity of the pastoral lands by taking over useful grasslands and using too much valuable water resources (Department of the Environment and Heritage and the CRC for Australian Weed Management 2003). *Prosopis* thrives well on alluvial soils, among crops and on saline grounds and river banks (Al-Oudat and Qadir 2011). *Pinus brutia/halepensis* from the Halaf IB/IIa layers was probably derived at the site from the circum-Mediterranean region (Zohary 1973: figs. 134 and 135).

Changes in plant subsistence patterns in the Late Chalcolithic

The LC seed and fruit assemblage that derives from deposits that have evolved roughly 1500 years later is substantially different from that of the Halaf period. The high proportions of *Eremopyrum*, *Aegilops*, and *Hordeum* cf. *marinum* are comparable to few sites in the Near East (see the "Results" section). As there are only 7 samples from this period, context is important. None of the LC samples comes from the infill of roundhouses. However, they nonetheless represent secondary deposits of backfill, suggesting they too do not represent a single event but rather the disposal of accumulated material. Sample F.150, the richest sample (containing 1115 out of 1714 seeds for the period), was interpreted as the backfilling of a pit with ashes, scattered with reddish earth fragments. The second richest sample, F.155 (containing 255 out of 1714 seeds for the period), is noted as coming from a debris layer of soft ash sediment with burnt rammed earth residues. All of the LC samples came from ashy deposits. It cannot be excluded that these samples represent post-processing rubbish, perhaps separated during the sieving stages (see fig. 1, stages 8–10 in Stevens 2003), though this seems unlikely as there are few chaff remains in the LC deposits. It could also be argued that as these samples are dominated by wild grasses, they therefore represent the remains of dung cleaned out of hearths or perhaps the fodder of animals (see the discussion above). In other words, on their own, the large-seeded cereal taxa in these seven samples cannot conclusively be said to have been also used for human consumption. However, through our use of multiple lines of inquiry, we argue that there is strong support for the idea that these large-seeded grasses represent human consumption. The stable carbon isotopes from the barley remains show a signal for strong drought stress. If this is attributed to a general limitation in water availability during the Late Chalcolithic in the environs of the settlement, the increased occurrence of *Eremopyrum*, wild barley, and *Aegilops* may indicate compensation for increased crop failure. The increase in hunted game during the LC (Fig. 6) may then be either linked to the diversification in plant subsistence or a shift to increased foraging strategies to fulfill the calorific needs of the population. The presence of an arid environment in the Tawila surroundings is also reflected in the charcoal remains from the Late Chalcolithic period. Again, the find of a lot of small-diameter shrubby plants indicates the presence of a shrubby steppe or steppe during that period. The Late Chalcolithic charcoal includes however a small proportion of oak difficult in its interpretation. It may have been collected from elsewhere, e.g., for construction wood, although the context of the samples does not provide evidence for this: of the two LC samples which contain *Quercus*, one comes from the ashy deposits of a pit and the other from burnt rammed earth residues. While the local climatic data derived from the stable carbon isotope measurement of barley and emmer grain data indicate more arid growth conditions for the cereals compared to the Halaf occupation, the increased *Quercus* proportion may represent a time lag in vegetation response to climate change (Vicente-Serrano et al. 2013). Interestingly, the Lake Van paleo-vegetation data for southeastern Turkey shows that around 4000 BC, *Quercus* (oak) started to reach its maximum abundance in that region, while *Pistacia* (pistachio) started to decline (Wick et al. 2003). Anthracological data from other Chalcolithic sites, e.g., Tell Brak and Tell Hamoukar in the Upper Khabur Basin of northeastern Syria, indicates a southern expansion of oak at that time (Charles et al. 2010; Deckers 2016). The diameters of the oak from Tell Brak were however mostly small, which was used as an argument in support of its local presence in the surroundings at that time (Charles et al. 2010), and it may also relate to the presence of shrub-like oak as has been indicated for the third millennium BC (Deckers 2016). GIS-based land cover reconstructions by ecological interpretations of seed/grain data for the Late Chalcolithic period (4400–3100 BCE) for the adjacent Upper Khabur Basin in northeastern Syria indicate the presence of a mixture of dry shrub steppe and desert steppe in that area (de Gruchy et al. 2016). This and also the large quantities of shrub-like taxa among the Tawila charcoals indicate that if oak was present in the Tawila surroundings in the Late Chalcolithic period, it was a minor constituent of the mostly shrubby steppe or steppe.

Human adaption to local factors

Tell Tawila occupies an area with an annual precipitation of 200–250 mm (Becker 2011) which does allow for dry farming (Wilkinson et al. 1994). There remain many questions on the climate of the Wadi Al-Hamar during the Halaf, but the stable carbon isotope data from barley and emmer reflect drier conditions during the earlier Halaf sequence compared to the later Halaf. Macrobotanical evidence from Tell Aqab in the Khabur River Basin to the west (McCorriston 1992) and palynological evidence from northern Mesopotamia have suggested increased aridity in the early Halaf, leading to a climate similar to the modern for large parts of Syria, in particular the north (Akkermans 1993). Although the precipitation levels at Tell Tawila may have been sufficient for farming, the interannual variability of rainfall is too great to ensure consistent crops, and crop failure was likely a relatively common issue (McCorriston 1992; Hald 2010). Oates and Oates (1976) estimated that at Tell Afair, Iraq, a site with similar precipitation levels as Tell Tawila, crop failure occupied 2 years out of 5. In other words, any changes towards a more arid climate may have resulted in much greater rates of crop failure. This could also account for the shift seen in the archeobotanical assemblage and in the stable isotope data between the Halaf and the LC.

It is possible that a combination of climatic changes, crop failures, and cultural developments in the period between the Halaf and the LC led to a movement of populations. Wilkinson (2000) presents a comprehensive survey of the Halaf and Ubaid periods in Upper and Lower Mesopotamia. He argues for a transitional period where settlements became smaller and more seasonal in northern Mesopotamia in the early Halaf, with only a few major centers. Over time, settlements became more permanent, but it is thought that there was a constant movement of people as settlements ebbed and flowed. Wilkinson states that movement of people between settlements took place, rather than a sudden rise or fall in population levels, which would both result in the impression of drastic population changes. Akkermans and Schwartz (2003, pp. 121–131) argue that while population levels were likely relatively stable throughout the Halaf, perhaps with some increase, population density in larger parts of Upper Mesopotamia was low. However, he highlights the importance of pastoralism as a means of subsistence, arguing for intense competition and high population density in the more desirable areas of the region (Akkermans and Schwartz 2003, pp. 128–129). With a relatively mobile population, and competition for desirable land, a decline in desirability would likely lead to even further mobility as the search for better grazing and hunting areas increased. As noted earlier, there are numerous indications that around the middle Holocene, the climate turned towards higher aridity with several sudden shifts (Fiorentino et al. 2008; Bar-Matthews and Ayalon 2011; Roberts et al. 2011; Riehl 2012). Climatic changes have frequently been linked to periods of population mobility (Bar-Yosef and Belfer-Cohen 1989; Belfer-Cohen and Bar-Yosef 2002; Kuper and Kröpelin 2006) although the response to such changes cannot be entirely generalized (Riehl 2012). With Tell Tawila occupying an area where precipitation was already unpredictable, and a mobile population, increased aridity could lead to a decreasing population. With fewer people available to farm and tend to the animals, wild animals and plants may have been a more viable subsistence strategy. The zooarcheological record at Tell Tawila further indicates a shift towards greater exploitation of wild resources in the form of hunted game during the Late Chalcolithic (see Fig. 6; Becker et al. 2007). This pattern is also seen at other sites, and an increase in hunted game has been demonstrated in the region into the Ubaid period (Grossman and Hinman 2013).

Conclusion

The macrobotanical record of Tell Tawila during the Halaf period fits neatly into the regional pattern. *H. vulgare* and *T. dicoccum* were the staple crops and a small number of additional economic plants such as *T. aestivum/durum*, *Lens culinaris*, and *Vicia sativa* being present. The charcoal remains, with only a very small proportion of tree taxa, indicate the presence of shrubby steppe in the surroundings of the site. Although the usage of dung as the primary fuel source is likely, this cannot be verified without further study. In spite of what appears to be stable access to domesticated plant resources, the reliance on wild game shown in earlier studies highlights the flexibility of subsistence strategies during the Halaf. The Late Chalcolithic assemblage presents something very different on the surface. The disproportionally high levels of *Eremopyrum* and *Hordeum* cf. *marinum* are yet to be seen at any site of this time period. Reliance on wild game over domesticated animals further increased. We put forth that this pattern is the result of a period of increased aridity which is supported by our stable carbon isotope evidence. Increasing aridity would have led to crop failure throughout the region, which in turn led to higher population mobility and displacement, and a shift towards a subsistence more reliant on wild resources. While the changes in the Late Chalcolithic appear drastic, they highlight the importance of adaptation to local conditions. When put into a greater context of post-Neolithic sites in northern Mesopotamia, the data we present add further credence to the idea that flexibility in risk reduction strategies are what constitutes the norm, rather than standardized methods of subsistence.

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