Veget Hist Archaeobot (2012) 21:95–106
DOI 10.1007/s00334-011-0318-y

ORIGINAL ARTICLE

Plant use in three Pre-Pottery Neolithic sites of the northern and eastern Fertile Crescent: a preliminary report

Simone Riehl · Marion Benz · Nicholas J. Conard · Hojjat Darabi · Katleen Deckers · Hassan Fazeli Nashli · Mohsen Zeidi-Kulehparcheh

Received: 2 October 2010 / Accepted: 21 August 2011 / Published online: 7 September 2011
© Springer-Verlag 2011

Abstract The beginnings of agriculture throughout the Fertile Crescent are still not completely understood, particularly at the eastern end of the Fertile Crescent in the area of modern Iran. Archaeobotanical samples from Epipalaeolithic/PPNA Körtik Tepe in southeastern Turkey and from the Pre-Pottery Neolithic sites of Chogha Golan and East Chia Sabz in south western Iran were studied in order to define the status of cultivation at these sites. Preliminary results show the presence of abundant wild progenitor species of crops at the Iranian sites before 10600 cal. B.P., and very few wild progenitor species at Körtik Tepe dated to 11700–11250 cal. B.P. The Iranian sites also indicate size increase of wild barley grain across a sequence of 400 years through either cultivation or changing moisture conditions.

Keywords Near East · Turkey · Iran · PPN sites · Origins of agriculture · Gathering · Cultivation

Communicated by G. Willcox.

S. Riehl (✉)
Institut für Naturwissenschaftliche Archäologie and Senckenberg Center of Human Evolution and Palaeoecology, University of Tübingen, Rümelinstraße 23, 72070 Tübingen, Germany
e-mail: simone.riehl@uni-tuebingen.de

M. Benz
Institut für Vorderasiatische Archäologie, University of Freiburg, Platz der Universität 3, 79085 Freiburg, Germany

N. J. Conard · M. Zeidi-Kulehparcheh
Institut für ältere Urgeschichte and Senckenberg Center of Human Evolution and Palaeoecology, University of Tübingen, Burgsteige 11, 72070 Tübingen, Germany

H. Darabi · H. F. Nashli
Institute of Archaeology, University of Tehran, Teheran, Iran

K. Deckers
Institut für Naturwissenschaftliche Archäologie, University of Tübingen, Rümelinstraße 23, 72070 Tübingen, Germany

Introduction

One of the most intriguing questions in the history of humanity concerns the transition from hunter-gatherer to early farming communities, which has been extensively addressed through the investigation of Epipalaeolithic and PPN sites in general, and of archaeobotanical remains in particular, since the 1960s.

Most scholars agree that pre-domestication cultivation occurred at a number of Epipalaeolithic (14500 to 11500 cal. B.P.) and PPNA sites (11500 to 10600 cal. B.P.) (Willcox et al. 2009; Hillman et al. 2001), while fully domesticated crop assemblages are only evident from the early PPNB (10600 to 8800 cal. B.P.) onwards (Nesbitt 2002). This leaves a wide chronological window for consideration of the transitions from pre-domestication cultivation to cultivation of domesticates (Willcox et al. 2008; Weiss et al. 2006; cf. Gopher et al. 2001). Most of these results originate from the western and northern Fertile Crescent, while the eastern region remains archaeologically almost unexplored. The map of archaeobotanical investigations at PPN sites shows this very well (Fig. 1; compare also archaeobotanical investigations of prehistoric sites in Miller 2003).

While more precise information on the time of domestication can be gathered through direct dating of archaeobotanical remains (cf. Nesbitt 2002), biomolecular methods for the location of crop domestication have been used since

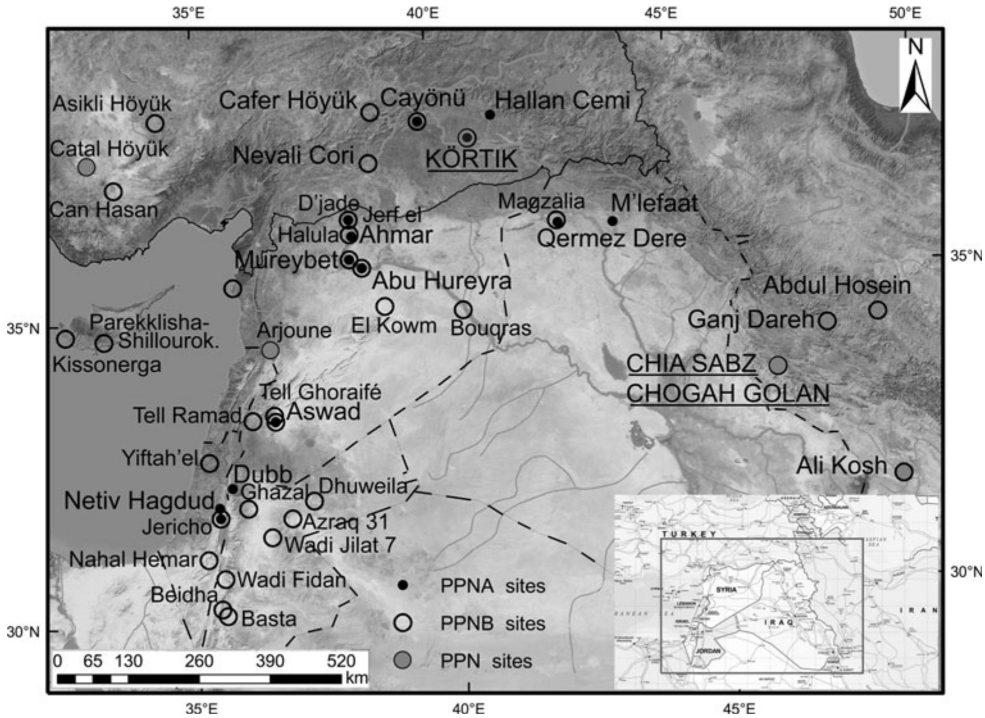

Fig. 1 Map of archaeobotanical data from PPN sites and the three study sites described here (*underlined*). Note the comparatively sparse distribution of investigated PPN sites in Iran

the 1980s (Heun et al. 1997, 2008; Salamini et al. 2002; Özkan et al. 2005; Brown et al. 2009). These point to specific locations for individual crops such as, for example, the inactive Karaçadağ shield volcano as a location of einkorn domestication (Heun et al. 1997; Haldorsen et al. 2011), and in general emphasize very narrow, independent centres of domestication. In contrast, interpretation of archaeological evidence more often highlights the cultural unity of larger areas, and macroregional expansions of previous populations as the basis for the development of agriculture (Bar-Yosef 1998). Bar-Yosef's model of the Late Natufian (12700 to 11500 cal. B.P.) expansion from the southern Early Natufian may well explain early cultivation in the northern Fertile Crescent. In a similar vein, some scholars postulate an expansion of plant domestication from the Levantine corridor to the Taurus-Zagros region during the PPNB (cf. Miller 2003).

In contrast, there are archaeological and biomolecular data that suggest independent domestication in the Iranian region. While earlier studies did not observe continuity in the cultural development from the Epipalaeolithic to the Neolithic due to the limited data sets, more recent investigations of Epipalaeolithic sites on the central Iranian plateau indicate some continuity with Neolithic sites (Azarnoush and Helwing 2005, p. 201). Biomolecular studies by Baum et al. (1997), Morrell and Clegg (2007) and Jones et al. (2008) provide support for the possibility of an independent centre of domestication of barley in the eastern Fertile Crescent or further east. Work on the origins of tetraploid wheat (Özkan et al. 2005) also points to the north eastern region of the Fertile Crescent as an important region of early domestication, or in their words "indicate that the Turkish Karaçadağ population intermixed with some Iraq-Iran lines, has a topology consistent with that of the progenitor of domesticated genotypes" (Özkan et al. 2005). Archaeobotanical data from the eastern part of the Fertile Crescent are still too limited to support such hypotheses.

Locations and chronology

Chogha Golan, an aceramic Neolithic settlement with 8 m of pre-pottery deposits, was discovered during surveying of the Mehran plain (Ilam Province) in the late 1990s. The site was identified by chipped stone, building debris and pockets of burnt sediment. Most of the architectural features are remnants of mud brick walls and enclosures associated with plaster floors. The site has been excavated since the summer of 2009 by a German-Iranian team under the leadership of Nicholas J. Conard and Mohsen Zeidi, and is part of the larger research unit of TISARP (Tübingen-Iranian Stone Age Research Project) (Zeidi and Conard in press). Eleven archaeological horizons (AH I–XI) have been found and bioarchaeologically sampled. The lower layers IV, VIII and XI contain highly loose sediment with thin stratified burnt and ashy layers. They are very rich in organic remains, and will allow a detailed reconstruction of the regional settlement history, including probable changes in the use of plants and animals. Initial analysis of the faunal remains indicates that a wide range of species was exploited: caprines, wild boar, gazelles, equids, large bovids, rodents, reptiles, birds, mussels and even freshwater crustaceans. The inhabitants of Chogha Golan used a variety of ground stone tools, mortars and grinding slabs for grinding and pounding foods and other materials.

Four AMS dates are so far available from horizons AH III, IV and VIII, with AH III roughly dating between 9900 and 9600 cal. B.P., AH IV dating between 10200 and 9900 cal. B.P. and AH VIII dating between 10600 and 10650 cal. B.P. (Table 1). The earlier sequence at Chogha Golan (AH VIII) is thus contemporaneous with Tell Mureybet IV in the Middle Euphrates region, AH III is roughly simultaneous with the wild but managed goats of Ganj Dareh. AMS dating for AH XI is underway, but the earliest dates from AH VIII are roughly 1,000 years earlier than PPN Ganj Dareh.

East Chia Sabz (also known as Chia Sabz-e Shraghi) is located at the left bank of the Seymareh River in Kuh Dasht/Lorestan in the central Zagros, 30 m above the present river bed, and has been cut by two gullies in the west and east. It is buried by alluvial sediments and due to its position inside the Seymareh Dam reservoir has been excavated in a rescue project by Iranian archaeologists under the leadership of Hojjat Darabi and Hassan Fazeli. Archaeobotanical samples were taken from the site in 2009. The relative chronology of East Chia Sabz covers a time range of 2,700 years. Three AMS dates are available from two excavated trenches, placing the site between 10500 and 9600 cal. B.P. (Table 1).

The absolute dating of both sites makes them chronologically simultaneous with the Levantine early and middle PPNB according to Kuijt (2000) and Akkermans and Schwartz (2003) or the transitional phase between PPNA and PPNB according to Benz (2011), although culturally the different steps of the neolithization process are not simultaneous in the western and the eastern Fertile Crescent and generally not directly comparable in their cultural expressions. Both Iranian sites are with their oldest ages simultaneous with Nevali Çori in Southeast Anatolia, final Jerf el Ahmar and Dja'de in Syria and Yiftahel, and Jericho and Beidha in the Levant. The earlier horizons at Chogha Golan are at least 1,000 years older than the earliest PPN layers of Ganj Dareh and roughly 1,500 years older than Ali Kosh.

Körtik Tepe in southeastern Turkey, approximately 20 km southwest of Batman, is a rescue excavation by the University of Diyarbakir under the leadership of V. Özkaya since 2000, in relation with the building of the Ilisu dam. Since 2009, a Turkish-German cooperation has started involving the University of Freiburg, under the leadership of Marion Benz. The settlement is extremely rich in artefacts and contains, besides intramural burials, burnt layers very rich in plant material. AMS data acquired during the 2009 campaign ranges from 11700 to 11250 cal. B.P. and places the site into the transition from the end of the Younger Dryas to the early Holocene (Benz et al. in press). It is roughly contemporaneous with Hallan Çemi, Qermez Dere and Mureybet II.

All three sites are tells, containing some evidence of building material such as mud brick remains. In addition Körtik Tepe contains a large number of graves. Building material on tell sites can generally be interpreted as representing long-term settlement, although whether with continuous occupation has to be examined. In the case of Chogha Golan only a small area has been excavated and the layout of the settlement is unknown. The fact, however, that tells are generally represented by settlement debris suggests that the archaeobotanical remains represent accumulations originating from common food preparation and other activities related to it.

Socio-cultural patterns

In general, archaeologists associate massive cultural and social change with the transition from predominant hunting and gathering to farming, some describing it as the primary phenomenon of the neolithization process (Hole 1984;

Table 1 Radiocarbon AMS data from Chia Sabz and Chogha Golan. Dating was conducted at the AMS laboratory of the Universities of Erlangen and Kiel; calibration after Reimer et al. (2004)

Sample description	Labcode	B.P.	cal. B.P.	cal. B.C. (2σ)
Chia Sabz, Fabaceae, trench II	Erl-14835	9228 ± 39	10394 ± 80	8558–8314
Chia Sabz, *Pistacia* shell, trench Ib	Erl-14836	8928 ± 37	10065 ± 99	8245–7966
Chia Sabz, Fabaceae, trench III	Erl-14837	8709 ± 37	9658 ± 63	7832–7598
Chogah Golan, *Hordeum*, AH VIII	KIA43836	9425 ± 45	10656 ± 53	8814–8602
Chogah Golan, *Hordeum*, AH IV	Erl-14839	8887 ± 37	10037 ± 94	8234–7938
Chogah Golan, Poaceae, AH III	Erl-14840	8805 ± 38	9839 ± 81	8181–7731
Chogah Golan, *Hordeum*, AH III	Erl-14838	8770 ± 40	9788 ± 84	7967–7648

Gebel 2010), whether rightly or not remaining to be seen (cf. Watkins 2010). Some restate this aspect as the reduction of generalized reciprocity, a characteristic of hunter-gatherer groups, which is abandoned with increasing food production (Bernbeck 2001; Benz 2010). This aspect is perhaps reflected in differences in treatment of plant foods and cultivation technology between the PPNA and PPNB. For example, Kuijt and Finlayson (2009) ascribe the shift from having granaries outside during the PPNA and inside buildings during the PPNB period, to changing systems of ownership and property as granaries shifted from communal ownership to the control of households or individuals. During the PPNA people created monumental communal buildings for the first time, of which Göbekli Tepe and Jericho are only the most prominent examples. One explanation of this trend is that it became necessary to demonstrate group identity and territorial commitment by setting landmarks. Standardized architectural styles of the communal buildings in the middle Euphrates Region (for a recent overview see Kornienko 2009) and common burial rites concur with the wide communication and exchange networks in the region, but different specific symbolic repertoires also clearly point to the segregation of some groups. Possibly access to different resources and landscapes became more restricted. Whereas in the southern Levant social change has been discussed intensively (e.g. Kuijt 2000), these aspects are poorly investigated for the Iranian region (Bernbeck 2001).

The material culture at Chogha Golan is very rich with a large number of mortars and grinding tools which have been interpreted as indicating intensive sophisticated plant processing technologies (Zeidi et al. in press). Similarly, at Körtik Tepe, the very rich archaeological assemblages support the argument of a broad-spectrum subsistence economy (Özkaya 2009; Arbuckle and Özkaya 2006). Despite difficulties in proving permanent settlement (Boyd 2006), the architecture at Körtik Tepe, renovation of floors inside the houses as well as many burials under living floors with differentiated burial customs hints at a sedentary population with a complex social structure (Özkaya 2009). The question of whether evidence for social differentiation at the site correlates with different subsistence patterns is to be addressed by comparing stable C/N isotope data from plant remains to those from human bone remains.

Environmental conditions

Well dated palynological results are scarce for the Near East. Key archives for the vegetation development at the transition from the Pleistocene to the Holocene are available from Huleh (Baruch and Bottema 1999), Ghab (Niklewski and Van Zeist 1970; Yasuda et al. 2000), Lake Van (Wick et al. 2003; Litt et al. 2009), Lake Zeribar (Van Zeist and Bottema 1977) and from marine sediment cores from the eastern Mediterranean (Rossignol-Strick 1993, 1995). Other more recent investigations, such as those at Lake Urmia, do not contain results on the environmental dynamics during the Pleistocene-Holocene transition (Djamali et al. 2008).

Despite chronological problems, differences in vegetation development between the West and the East are clear (Wright and Thorpe 2003). The pollen diagrams from Huleh and Ghab hardly show any Younger Dryas signal, while pollen profiles from lakes further inland clearly show the impact of this event. The Younger Dryas event is also comparatively weak in the oxygen isotope data from Soreq Cave (Bar-Matthews et al. 1997, 2003). Deciduous oak pollen only slowly increases in the Zeribar and Van diagrams after the Younger Dryas impact, while it returns immediately along the Mediterranean coast. In the Zeribar and Van region, Poaceae dominate the pollen profiles at the end of the Younger Dryas. Aridity has been discussed as a reason for the slow expansion of deciduous oak in the Early Holocene (Stevens et al. 2001), which is in some contrast to earlier palynological investigations in the area (El-Moslimany 1987).

According to the available pollen diagrams, wild grasses formed a major component of the vegetation after the end of the Younger Dryas in all the different regions of the Fertile Crescent and thus a broad variety of different large-seeded grasses would have been available everywhere, despite differences in woodland cover. Taking the argument of abundant grasses as a precondition for the emergence of cultivation and domestication of cereals into account, these basic conditions would have been met throughout the Fertile Crescent, assuming the available pollen diagrams are reliable. Some archaeological hypotheses, however, are focused on the later expansion of oak in the eastern Fertile Crescent, and by referring to this fact argue for a later appearance of agriculture in the East due to unfavourable climate conditions (cf. Wright 1993).

With the limited bioarchaeological data set from Iran, it is impossible at the moment to evaluate whether local environmental conditions may have provided different options for subsistence behaviour at the end of the Pleistocene than in the western Fertile Crescent. With the current fieldwork at Chogha Golan and East Chia Sabz we are working to eliminate this problem by producing new palaeoenvironmental data.

The long-term research goals in our PPN projects are:

– To develop an understanding of the socio-cultural patterns that accompanied the neolithization process in the northern and the eastern part of the Fertile Crescent.

– To contribute to the reconstruction of palaeoenvironmental dynamics in areas so far under-investigated, such as Iran.
– To achieve a detailed picture of the levels of cultivation and domestication at the project sites.
– To reassess earlier neolithization models for the eastern Fertile Crescent.

The aims of this contribution are to introduce the first archaeobotanical results from the three sites to interested readers and to formulate working hypotheses to be verified throughout the duration of the research projects.

Methods

In all, 420 archaeobotanical samples have been processed at the three sites in 2009, at Körtik Tepe by machine flotation and at Chogha Golan and East Chia Sabz by bucket flotation, using sieves with mesh sizes of 200 µm. At all three sites sampling continued in 2010 and is also planned for 2011. Processing methods had to be adapted to the excavation, and the mean sample size was 10 litres at all three sites. So far 26 samples with ca. 5,100 seed and chaff remains (10 samples from Chogha Golan, 4 samples from East Chia Sabz and 12 samples from Körtik Tepe) have been analyzed for this preliminary report in the archaeobotanical laboratory of the Institute of Archaeological Science at the University of Tübingen. Identification according to morphological criteria was conducted with the Tübingen reference collection using a Leica GZ6 binocular. Documentation of identified objects was performed with a VHX-500F Keyence digital microscope. Charcoal identification for the Körtik Tepe material was undertaken in order to characterise the vegetation zone around the site, using a Leitz Laborlux 12ME. The charcoal fragments from the Iranian sites are currently under investigation.

Because of the preliminary state of the analysis, no transformation of absolute counts into proportions or ubiquities has been made. Instead find density, expressed as numbers of records per litre of sediment, is given.

Functional, contextual and spatial estimations, such as the origin of particular taxa and samples will only be possible after the archaeological findings and contexts have been analyzed.

Sizes of wild barley grains from the investigated sites were measured with an eyepiece graticule. Beside the evolution of the tough rachis, the developmental transition from wild to domesticated cereals has been linked to grain size increase throughout the pre-domestication cultivation process (Willcox 2004; Fuller 2007). According to these considerations, grains of wild barley and wild wheat species increase in size before the development of the tough rachis, which would explain the phenomenon of a presence of large domestic-type grains already at the beginning of the PPNB (Fuller 2007). Fuller (2007) relates this development to the practice of tillage, which would give advantage to large grains when buried under soil. According to this argumentation increase in grain size within PPN sites may indicate pre-domestication cultivation.

Results

At Chogha Golan, 68 botanical taxa have so far been identified, represented by roughly 3,000 seed and chaff remains belonging to five different archaeological horizons, with the youngest layer of this data set, layer IV, dating to roughly 10200 cal. B.P. and the oldest, layer VIII, dating to 10600 cal. B.P. An even older layer XI containing large amounts of carbonized seeds has been discovered and sampled during the recent excavations.

The most numerous finds of layers IV–VIII belong to the Poaceae and Fabaceae families (Table 2).

The seed density is highest in layer VIII and particularly in the upper layer IV. The difference in seed density between these two layers is well reflected in the different taxa groups, except for *Aegilops* sp. chaff remains, which appear to decrease in find density. This may suggest a shift from the collection of mainly *Aegilops* sp. to the preferred use of other large-seeded grasses, such as *Hordeum spontaneum*. In layer IV the first domesticated-type rachis segments of barley appear, indicating a possible emergence of potentially genetically changed cultivars by 10200 cal. B.P., however, they occur in very low proportions, consistent with the non-brittle lower rachis segments occurring in wild populations of barley and reported by Kislev (1997).

From East Chia Sabz, more than 1,200 seed and chaff remains have been analysed so far from trenches Ib (10100 cal. B.P.) and II (10500 cal. B.P.). While the sediments of trench Ib mainly represent accumulations along a slope, diverse architectural contexts and 7 different strata have been discovered in trench II.

As at Chogha Golan, although not to the same degree, *Aegilops* sp. is more numerous in the older samples, while rachis internodes of *H. spontaneum* and other large-seeded grasses are more frequent in the younger samples (Table 3). Also the large-seeded Fabaceae are more numerous in the younger layers and glume base fragments of hulled wheat species occur in the younger samples of trench Ib for the first time. Preservation of the glume base fragments is not sufficient to differentiate clearly between the wild and the domesticated types (Fig. 2). *Hordeum* grains of the same samples still belong to the wild type.

Table 2 Absolute counts of selected taxa per litre sediment in different archaeological horizons at Chogha Golan; each archaeological horizon is represented by two samples (decreasing find density in dark grey, increasing find density in light grey)

Archaeological Horizon	VIII	VII	VI	V	IV
AMS dating (cal. B.P.)	10600				10200
Number of taxa	45	21	32	18	42
Sum of all records	518	142	278	161	1,796
Sediment volume (l)	16	16	6	10	12
Fabaceae					
Fabaceae, small	18	5	19	4	44
Fabaceae, large	3	1	6	2	22
Poaceae					
Aegilops sp., glume base	18	4	30	3	5
Aegilops sp.	1		1		
Hordeum spontaneum, rachis	1	1	7	3	29
Hordeum cf. *spontaneum*, grain	4		3	1	19
Hordeum, domesticated-type rachis					1
Taeniatherum caput-medusae/crinitum			1		4
Triticum spp.	1		2		7
Poaceae, large (incl. above taxa)	14	2	13	1	43
Poaceae, large, glume base fragments	20	5	40	7	43
Poaceae, medium		1	6	2	54
Poaceae, small	4	2	5	13	89

Table 3 Absolute counts of selected taxa per litre sediment in different archaeological trenches at Chia Sabz (decreasing proportions in dark grey, increasing proportions in light grey)

Trench	2	1b
AMS dating (cal B.P.)	10500	10100
Number of taxa	29	21
Sum of all records	492	613
Sediment volume (l)	10	30
Caryophyllaceae		
Silene sp.	1.3	2.1
Rubiaceae		
Galium sp.		2.6
Fabaceae		
Fabaceae, small	2.2	1.8
Lathyrus sp.	0.4	0.7
Lens sp.	0.2	0.8
Vicia/Lathyrus	0.5	2.0
Poaceae		
Aegilops sp., glume base	1.6	1.0
Aegilops sp., grain	0.1	0.1
Hordeum cf. *spontaneum*	0.9	0.4
Hordeum spontaneum, rachis	0.1	0.7
Poaceae, chaff	1.3	1.3
Poaceae, large	0.1	1.3
Poaceae, medium		0.1
Poaceae, small	0.8	0.2
Hulled *Triticum*, glume base, wild/domesticated		1.0
Triticum type grain	0.1	

At both sites, East Chia Sabz and Chogha Golan, the almost complete package of the wild forms of the founder crops are represented, which are *Hordeum* (barley), *Triticum* (hulled wheats), *Lens* (lentil), *Lathyrus sativus* (grass pea), and *Vicia ervilia* (bitter vetch).

Roughly 900 seeds from 8 samples belonging to 78 taxa have been identified from Körtik Tepe so far (Table 4). Find density is considerably lower than in the Iranian sites which generally show very well preserved organic remains. Chronological differentiation within the Körtik Tepe assemblage has not been possible so far, due to the preliminary character of the analyses, but the stratigraphy provided a sequence of 12 radiocarbon dates between 11700 and 11250 cal. B.P.

Large-seeded Poaceae contribute the main portion at 24.3% and occur in every sample. *Taeniatherum caput-medusae/crinitum* is relatively frequent, as well as the small-seeded grass *Imperata* sp. Compared to the more recent Iranian sites, wild progenitor species of modern crops are rare. In all, the wild progenitor taxa at Körtik Tepe account for less than 6% of the whole assemblage and thus indicate that humans were not predominantly exploiting these taxa. Furthermore, while at the two Iranian sites the ratio between seed and chaff is roughly 4:1, it is 166:1 at Körtik Tepe, indicating that cereal-processing remains are not particularly represented in the samples from Körtik Tepe, and probably that processing of wild grasses was not conducted in this site. Of the three barley chaff finds, one rachis appears to be of the domesticated-type, probably representing the non-disarticulating type present in wild barleys. *Triticum*-type grains appear with 7 records as well as two grains of the *Triticum* cf. *boeoticum*/*Secale* type, but no glume bases of these taxa have been found so far. Some other taxa occur in relatively large proportions, such as *Chenopodium* sp., *Camelina* cf. *microcarpa*, *Scirpus maritimus* (but see also Wollstonecroft et al. 2011) and *Rumex* sp. which may have been used for consumption, although conclusions have to wait on full contextual analysis of the site.

Preliminary anthracological data from 6 samples and 1,487 fragments resulted in 14 taxa, which can be classified in roughly two ecological zones:

1. Park woodland zone with *Quercus* spp., *Amygdalus* sp., Maloideae, *Pistacia* sp., *Celtis* sp. and *Rhamnus* sp.
2. Riverine gallery forest with *Tamarix* sp., *Populus/Salix, Vitis* sp., *Alnus* sp., *Fraxinus* sp. and *Acer* sp.

The major taxa were deciduous oak and tamarisk represented in ca. 20% of the fragments identified. *Populus/Salix* and *Fraxinus* sp. were also present in larger

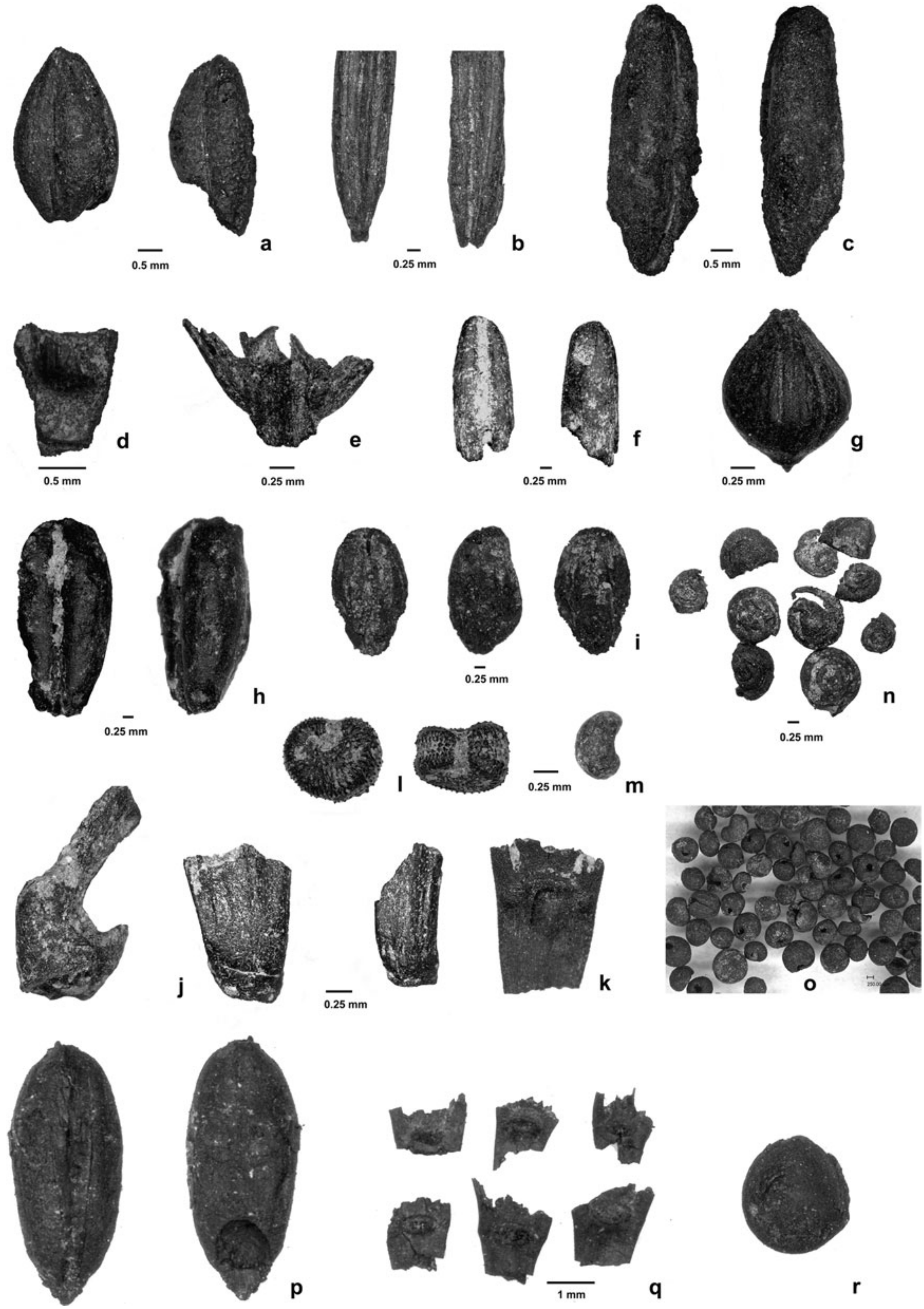

Fig. 2 Some of the most frequent taxa in the archaeobotanical assemblages from Körtik Tepe (**a**–**g**), East Chia Sabz (**h**–**o**) and Chogha Golan (**p**–**r**); *Hordeum* cf. *spontaneum* grains (**a**, **p**), *H. spontaneum* rachis remains (**k**, **q**), *Hordeum* sp. domesticated-type rachis (**d**), *Triticum dicoccoides/dicoccum* grain (**h**), *T. dicoccoides/dicoccum* glume base fragments (**j**), *Triticum* type grain (**i**), *Triticum/Secale* grain (**c**), *Secale* type grain (**f**), *Taeniatherum* sp. grain (**b**), *Taeniatherum* sp. rachis (**e**), *Lens* sp. (**r**), *Scirpus* sp. (**g**), *Silene* sp. (**l**), *Papaver* sp. (**m**), *Salsola* sp. (**n**), *Galium* sp. (**o**)

proportions than most other taxa, respectively 11 and 7% of the fragments identified.

Discussion

At Chogha Golan, the small-seeded Poaceae and Fabaceae play a major role in the assemblage and sum to more than 40% (Fig. 3). Large-seeded grasses, amongst them wild barley and *Aegilops* sp., are also well represented. Other wild taxa are relatively rare.

At East Chia Sabz, large-seeded Fabaceae, particularly of the *Lathyrus/Vicia* type, and of lentil occur in large proportions which contrasts to their occurrence at the other two sites. As well as *Hordeum* and *Aegilops* species, representatives of *Triticum boeoticum/dicoccoides* and triticoid grain forms occur in relatively high proportions. Proportions of nuts are also relatively high. More than 25% of the assemblage is composed of *Silene* sp. and *Galium* sp., taxa considered in historic periods to represent weeds. East Chia Sabz is also the only site amongst the three with salt-tolerant *Salsola* sp. and *Gypsophila* sp. finds, indicating the presence of drier patches in the landscape.

Körtik Tepe, which provides the broadest assemblage, consists of more than 25% of large-seeded grasses, particularly *Taeniatherum* sp., but no *Aegilops* sp. and only a few wild barley and wild wheat remains are present. A particularly large number of probably gathered taxa such as different species of the Brassicaceae, *Chenopodium* sp., *Papaver* sp. etc. are present from Körtik Tepe as well. *Scirpus maritimus* which may have also been gathered, indicates the presence of a shifting creek, the probable branch of the modern Batman Çayı, and is in good agreement with other sites of early cultivation at the end of the Younger Dryas, making extensive use of the floodplains, as has been discussed in Willcox et al. (2009).

The charcoal remains suggest that Körtik Tepe lay in an oak park-woodland with gallery forests, probably along the ancient Batman Çayı, at the beginnings of the Holocene. This is supported by the seed remains. The abundance of taxa such as *Astragalus* sp. and *Taeniatherum caput-medusae/crinitium*, however, indicate relatively open patches.

The specific composition of the macrobotanical assemblage may be related to the climate and vegetation history of the area according to palynological results (Wick et al. 2003; Litt et al. 2009). The correlating sequence in the pollen diagram shows dominating *Artemisia* and Chenopodiaceae units, but tree species are also represented, although in much smaller proportions. The quantitative comparison of the pollen and the charcoal data indicates a heavily exploited environment by the Körtik Tepe people.

Table 4 Absolute counts per litre sediment of the most frequent and numerous taxa from Körtik Tepe

AMS dating (cal. B.P.)	11700–11250
Number of taxa	78
Sum of all records	941
Sediment volume (l)	109
Poaceae	
Poaceae, large	1.43
Imperata sp.	0.49
Taeniatherum caput-medusae/crinitum	0.39
Poaceae, medium	0.29
Agropyron/Eremopyrum	0.14
Triticum-type	0.06
Hordeum sp.	0.06
Poaceae, small	0.06
Triticum cf. *boeoticum/Secale*-type	0.02
Fabaceae	
Trigonella sp.	0.25
Astragalus sp.	0.19
Fabaceae, large	0.16
Fabaceae, small	0.10
Onobrychis sp. pod fragment	0.03
Coronilla sp.	0.08
Asteraceae	
Centaurea sp.	0.17
Brassicaceae	
Brassicaceae	0.38
Alyssum sp.	0.11
Camelina cf. *microcarpa*	0.28
Caryophyllaceae	
Silene sp.	0.10
Chenopodiaceae	
Chenopodium sp.	0.58
Chenopodiaceae/Amaranthaceae	0.17
Chenopodium/Atriplex	0.15
Cyperaceae	
Scirpus maritimus	0.65
Cyperaceae	0.06
Lamiaceae	
Lallemantia sp.	0.05
Papaveraceae	
Papaver sp.	0.06
Polygonaceae	
Rumex sp.	0.07
Polygonaceae	0.08
Rumex/Polygonum	0.27
Rubiaceae	
Galium sp.	0.03

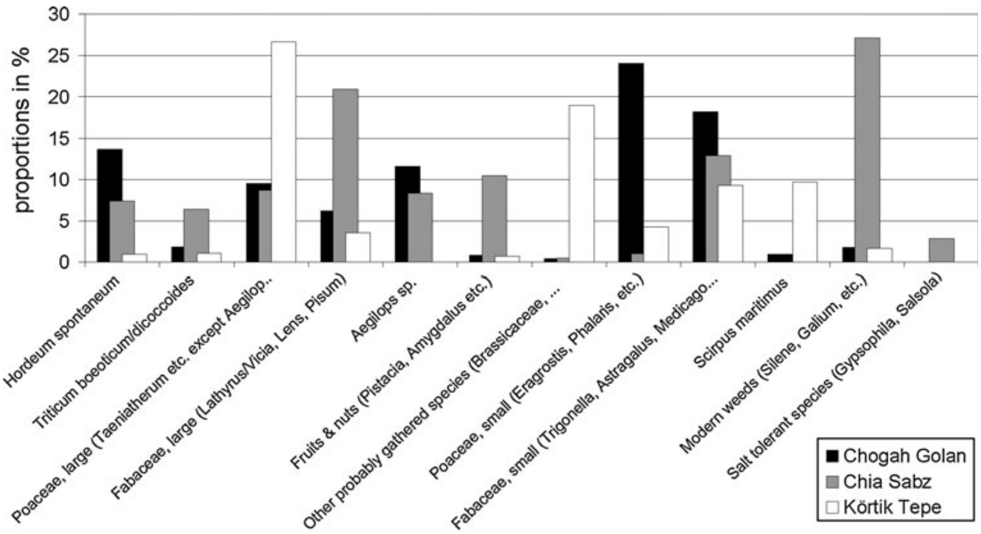

Fig. 3 Proportions of the main taxa and plant categories at Chogha Golan, East Chia Sabz, and Körtik Tepe

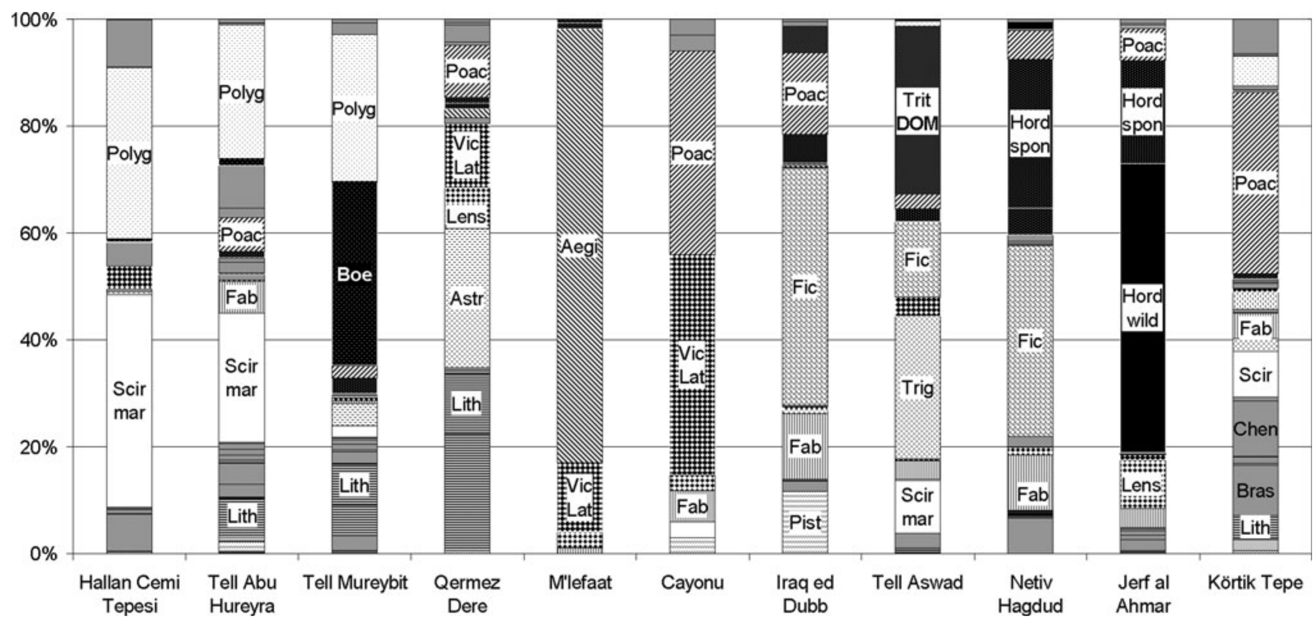

Fig. 4 Proportions of collected and cultivated plant taxa at different Epipalaeolithic and PPNA sites roughly ordered by dominating taxa; Aegi: *Aegilops* spp., Astr: *Astragalus* spp., Boe: *Triticum boeoticum*, Chen: Chenopodiaceae, Bras: Brassicaceae, Fab: Fabaceae (small and large-seeded), Fic: *Ficus* sp., Hordspon: *Hordeum spontaneum*, Hordwild: *Hordeum* spp. (wild) Lens: *Lens* sp., Lith: Lithospermum, Pist: *Pistacia* spp., Poac: Poaceae (small and large-seeded), Polyg: Polygonaceae, Scirmar: *Scirpus maritimus*, Trig: *Trigonella* sp., TritDOM: domesticated *Triticum* spp, *T. monococcum/dicoccum*, VicLat: *Vicia/Lathyrus*; Data for Hallan Çemi Tepesi, Qermez Dere and M'lefaat has been extracted from Savard (2004), for the remaining sites from Shennan et al. 2005

The status of cultivation at the three sites

The preliminary results do not show secure evidence for plant domestication at any of the three project sites. The presence of a low proportion of domesticated-type barley rachises at Chogha Golan and Körtik Tepe can be best explained by their natural occurrence in wild populations. The hulled wheat glume bases at East Chia Sabz are too fragmentary to allow any distinction between wild and domesticated specimens.

However, two lines of evidence point to pre-domestication cultivation at Chogha Golan and East Chia Sabz, with differences in the development and intensity of cultivation practice between the two.

The first line of evidence is the general increase in the proportion of large seeds and seeds of crop wild relatives through time.

At the earliest of the project sites, Körtik Tepe, a wide range of small- and large-seeded wild plants was harvested around 11700–11250 cal. B.P., with a composition of the

Table 5 Grain dimensions of barley in different horizons of the Iranian sites (measured objects in brackets), including seed measurements from Ganj Dareh according to Van Zeist et al. (1984)

Site/no. of measurements()	Mean length (mm)	Mean breadth (mm)	Mean thickness (mm)
Chogah Golan AH IV (10)	6.10	2.60	1.80
Chogah Golan AH VIII (5)	5.30	2.36	1.52
Chia Sabz, Ib (12)	6.00	2.30	1.80
Chia Sabz, II (9)	4.20	1.80	1.20
Körtik Tepe (6)	4.90	2.00	1.30
Ganj Dareh (11)	6.55	2.87	–

assemblage similar to sites of the same geographic region (Fig. 4). The broad range of plants gathered points to intensive use. As at other sites in the region, use of grasses was not limited to the wild progenitor species of modern crops (cf. Hillman in Moore et al. 2000; Colledge 2001; Savard et al. 2006).

Roughly 33% of the seed assemblage at Körtik Tepe is of large seeds, compared to 53% at East Chia Sabz, and 55% at Chogha Golan. In addition, seeds of wild relatives of crops are comparatively rare at Körtik Tepe, but are more abundant in the 600–1,000 years later Iranian sites, with some evidence of increase in frequency throughout time. The concentration of crop wild relatives at the Iranian sites points to a shift in land use, consistent with cultivation of a narrower range of species rather than gathering of a wide range.

The second line of evidence is the grain sizes of *H. spontaneum* which have been measured and so far show site-internal size increases from the older archaeological horizon VIII to the younger layers IV at Chogha Golan, and from the older samples of trench II to the younger samples from trench Ib at East Chia Sabz within a time range of 400 years (Table 5).

There is a weaker line of evidence also consistent with cultivation. The shift from *Aegilops* to *H. spontaneum* at Chogha Golan VIII–IV, if not an artifact of small seed numbers, could be evidence for specialization on wild relatives of crops.

Conclusions

The intensive exploitation of plants at Körtik Tepe is evidenced by the very broad seed assemblage. Grasses were most intensively gathered, and species of the pulses, goosefoot, and mustard family, as well as rushes, also occur with high counts and frequency. A different plant profile occurs at the Iranian sites, with a wide range of wild progenitor species occurring around 10500 cal. B.P. at East Chia Sabz and at Chogha Golan around 10600 cal. B.P., with dating of the earliest layers AH XI at Chogha Golan still pending. The use of wild progenitor species in a time equivalent to the Levantine early PPNB supports the hypothesis of an independent development of cultivation in the investigated Iranian sites, and thus of independent domestication of crops such as barley in the Zagros region. Further evidence from later sites will be necessary in order to establish whether domesticates appear at the same time—by the middle PPNB—as they do in the west and northern parts of the Fertile Crescent.

Acknowledgments We thank the German Research Foundation (DFG) for funding the archaeobotanical analyses from Körtik Tepe, Chogha Golan and East Chia Sabz and the University of Tübingen and the Senckenberg Center for Human Evolution and Palaeoecology (HEP) for providing the infrastructure. We also thank the reviewers, above all Mark Nesbitt and George Willcox for valuable comments on the previous version of the manuscript.

References

Akkermans PMMG, Schwartz GM (2003) The archaeology of Syria. From complex hunter-gatherers to early urban societies (ca. 16000–300 B.C.). Cambridge University Press, Cambridge

Arbuckle BS, Özkaya V (2006) Animal Exploitation at Körtik Tepe: An early aceramic site in Southeastern Turkey. Paléorient 32:113–136

Azarnoush M, Helwing B (2005) Recent archaeological research in Iran—Prehistory to Iron Age. Archaeologische Mitteilungen aus Iran und Turan 37:189–246

Bar-Matthews M, Ayalon A, Kaufman A (1997) Late Quaternary paleoclimate in the Eastern Mediterranean region from stable isotope analysis of speleothems at Soreq Cave, Israel. Quat Res 47:155–168

Bar-Matthews M, Ayalon A, Gilmour M, Matthews A, Hawkesworth CJ (2003) Sea-land oxygen isotopic relationships from planktonic foraminifera and speleothems in the eastern Mediterranean region and their implication for paleorainfall during interglacial intervals. Geochim Cosmochim Acta 67:3,181–3,199

Baruch U, Bottema S (1999) A new pollen diagram from Lake Hula. In: Kawanabe H, Coulter GW, Roosevelt AC (eds) Ancient lakes: their cultural and biological diversity. Kenboi Production, Belgium

Bar-Yosef O (1998) The Natufian culture in the Levant, threshold to the origins of agriculture. Evol Anthropol 6:159–177

Baum BR, Nevo E, Johnson DA, Beiles A (1997) Genetic diversity in wild barley (Hordeum spontaneum C. Koch) in the Near East: a molecular analysis using random amplified polymorphic DNA (RAPD) markers. Gen Res Crop Evol 44:147–157

Benz M (2010) The principle-of-sharing: an introduction. In: Benz M (ed) The principle of sharing—segregation and construction of social identities at the transition from foraging to farming. Studies in Early Near Eastern Production, Subsistence, and Environment 14. Berlin, pp 1–18

Benz M (2011) Comments on radiocarbon dates of Epipalaeolithic and Early Neolithic sites of the Near East. http://www.exoriente.org/associated_projects/ppnd.php

Benz M, Coşkun A, Weninger B, Alt KW, Özkaya V (in press) Stratigraphy and Radiocarbon Dates of the PPNA Site of Körtik

Tepe, Diyarbakır. Paper presented at the 32. Uluslar arasi kazi, arastirma ve arkeometri sempozyumu 24–28 May 2010. Istanbul. http://www.exoriente.org/associated_projects/ppnd_site.php?s=81

Bernbeck R (2001) Forschungsperspektiven für das Iranische Neolithikum. Archäol Mitt Iran Turan 33:1–18

Boyd B (2006) On 'sedentism' in the Later Epiaplaeolithic (Natufian) Levant. World Archaeol 38:164–178

Brown TA, Jones MK, Powell W, Allaby RG (2009) The complex origins of domesticated crops in the Fertile Crescent. Trends Ecol Evol 24:103–109

Colledge S (2001) Plant exploitation on Epipalaeolithic and Early Neolithic sites in the Levant. Brit Archaeol Rep, Int Ser, Oxford

Djamali M, De Beaulieu J-L, Shah-hosseini M, Andrieu-Ponel V, Ponel P, Amini A, Akhani H, Leroy SAG, Stevens L, Lahijani H, Brewer S (2008) A late Pleistocene long pollen record from Lake Urmia, NW Iran. Quat Res 69:413–420

El-Moslimany AP (1987) The late Pleistocene climates of the Lake Zeribar region (Kurdistan, western Iran) deduced from the ecology and pollen production of non-arboreal vegetation. Vegetatio 72:131–139

Fuller D (2007) Contrasting patterns in crop domestication and domestication rates: recent archaeobotanical insights from the Old World. Ann Bot 100:903–924

Gebel HGK (2010) Commodification and the formation of Early Neolithic social identity. The issues as seen from southern Jordanian Highlands. In: Benz M (ed) The principle of sharing. Segregation and construction of social identities at the transition from foraging to farming. Studies in Early Near Eastern Production, Subsistence, and Environment 14. Berlin, pp 35–80

Gopher A, Abbo S, Lev-Yadun S (2001) The "when", the "where" and the "why" of the Neolithic revolution in the Levant. Doc Praehist 28:49–61

Haldorsen S, Akan H, Çelik B, Heun M (2011) The climate of the Younger Dryas as a boundary for Einkorn domestication. Veget Hist Archaeobot 20:305–318

Heun M, Schaefer-Pregl R, Klawan D, Castagna R, Accerbi M, Borghi B, Salamini F (1997) Site of einkorn wheat domestication identified by DNA fingerprinting. Science 278:1,312-1,314

Heun M, Haldorsen S, Vollan K (2008) Reassessing domestication events in the Near East: Einkorn and *Triticum urartu*. Genome 51:444–451

Hillman GC, Hedges REM, Moore A, Colledge S, Pettitt P (2001) New evidence of Lateglacial cereal cultivation at Abu Hureyra on the Euphrates. Holocene 11:383–393

Hole F (1984) A reassessment of the Neolithic revolution. Paléorient 10:49–60

Jones H, Leigh FJ, Mackay I, Bower MA, Smith LMJ, Charles MP, Jones G, Jones MK, Brown TA, Powell W (2008) Population-based resequencing reveals that the flowering time adaptation of cultivated barley originated east of the Fertile Crescent. Mol Biol Evol 25:2,211–2,219

Kislev ME (1997) Chapter eight. Early agriculture and paleoecology of Netiv Hagdud. In: Bar-Yosef O, Gopher A (eds) An early Neolithic village in the Jordan valley. Part 1. The archaeology of Netiv Hagdud. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, pp 209–236

Kornienko KV (2009) Notes on the cult buildings of northern Mesopotamia in the Aceramic Neolithic period. J Near East Stud 68:81–101

Kuijt I (2000) Life in Neolithic farming communities: social organization, identity, and differentiation. Kluwer/Plenum, London

Kuijt I, Finlayson B (2009) Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley. Proc Natl Acad Sci 106:10,966–10,970

Litt T, Krastel S, Sturm M, Kipfer R, Örcen S, Heumann G, Franz SO, Ülgen UB, Niessen F (2009) 'PALEOVAN', International Continental Scientific Drilling Program (ICDP): site survey results and perspectives. Quat Int 28:1,555–1,567

Miller N (2003) Archaeobotany in Iran, past and future. In: Miller N, Abdi K (eds) Yeki bud, yeki nabud. Essays on the archaeology of Iran, in honour of William M.Sumner. The Cotsen Institute of Archaeology, University of California, Los Angeles, pp 9–15

Moore AMT, Hillman GC, Legge AJ (2000) Village on the Euphrates: from foraging to farming at Abu Hureyra. Oxford University Press, New York

Morrell PL, Clegg MT (2007) Genetic evidence for a second domestication of barley (Hordeum vulgare) east of the Fertile Crescent. Proc Natl Acad Sci 104:3,289–3,294

Nesbitt M (2002) When and where did domesticated cereals first occur in southwest Asia? In: Cappers RTJ, Bottema S (eds) The dawn of farming in the Near East. Ex Oriente, Berlin, pp 113–132

Niklewski J, Van Zeist W (1970) A late Quaternary pollen diagram from northwestern Syria. Acta Bot Neerl 19:737–754

Özkan H, Brandolini A, Pozzi C, Effgen S, Wunder J, Salamini F (2005) A reconsideration of the domestication geography of tetraploid wheats. Theor Appl Gen 110:1,052–1,060

Özkaya V (2009) Excavations at Körtik Tepe. A New Pre-Pottery Neolithic A Site in Southeastern Anatolia. NeoLithics 2:3–8

Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Bertrand CJH, Blackwell PG, Buck CE, Burr GS, Cutler KB, Damon PE, Edwards RL, Fairbanks RG, Friedrich M, Guilderson TP, Hogg AG, Hughen KA, Kromer B, McCormac G, Manning S, Ramsey CB, Reimer RW, Remmele S, Southon JR, Stuiver M, Talamo S, Taylor FW, Van der Plicht J, Weyhenmeyer CE (2004) Intcal09 Terrestrial radiocarbon age calibration 0–26 cal kyr BP. Radiocarbon 46:1,029–1,058

Rossignol-Strick M (1993) Late Quaternary climate in the Eastern Mediterranean region. Paléorient 19:135–152

Rossignol-Strick M (1995) Sea-Land correlation of pollen records in the Eastern Mediterranean for the Glacial-Interglacial transition: biostratigraphy versus radiometric time-scale. Quat Sci Rev 14:893–915

Salamini F, Özkan H, Brandolini A, Schäfer-Pregl R, Martin W (2002) Genetics and geography of wild cereal domestication in the Near East. Nat Rev 3:429–441

Savard M (2004) Epipalaeolithic to early Neolithic subsistence strategies in the northern Fertile Crescent. The archaeobotanical remains from Hallan Çemi, Demirköy, M'lefaat and Qermez Dere, Department of Archaeology. University of Cambridge, Cambridge

Savard M, Nesbitt M, Jones MK (2006) The role of wild grasses in subsistence and sedentism: new evidence from the northern Fertile Crescent. World Archaeol 38:179–196

Shennan S, Conolly J, Colledge S (2005) The origin and spread of Neolithic plant economies in the Near East and Europe. Database of the AHRC project, vers. 8 Nov 2005

Stevens LR, Wright HE, Ito A (2001) Changes in seasonality of climate during the Lateglacial and Holocene at Lake Zeribar, Iran. Holocene 11:747–756

Van Zeist W, Bottema S (1977) Palynological investigations in western Iran. Palaeohistoria 19:19–85

Van Zeist W, Smith PEL, Palfenier-Vegter RM, Suwijn M, Casparie WA (1984) An archaeobotanical study of Ganj Dareh Tepe, Iran. Palaeohistoria 26:201–224

Watkins T (2010) New light on Neolithic revolution in south-west Asia. Antiquity 84:621–634

Weiss E, Kislev M, Hartmann A (2006) Autonomous cultivation before domestication. Science 312:1,608–1,610

Wick L, Lemcke G, Sturm M (2003) Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. Holocene 13:665–675

Willcox G (2004) Measuring grain size and identifying Near Eastern cereal domestication: evidence from the Euphrates valley. J Archaeol Sci 31:145–150

Willcox G, Fornite S, Herveux L (2008) Early Holocene cultivation before domestication in northern Syria. Veget Hist Archaeobot 17:313–325

Willcox G, Buxo R, Herveux L (2009) Late Pleistocene and early Holocene climate and the beginnings of cultivation in northern Syria. Holocene 19:151–158

Wollstonecroft MM, Hroudová Z, Hillman GC, Fuller DQ (2011) *Bolboschoenus glaucus* (Lam.) S.G. Smith, a new species in the flora of the ancient Near East. Veget Hist Archaeobot 20:459–470

Wright HE (1993) Environmental determinism in Near Eastern prehistory. Curr Anthr 34:458–469

Wright HE, Thorpe J (2003) Climatic change and the origin of agriculture in the Near East. In: Mackay A, Battarbee R, Birks J, Oldfield F (eds) Global change in the Holocene. Arnold, London, pp 49–62

Yasuda Y, Kitagawa H, Nakagawa T (2000) The earliest record of major anthropogenic deforestation in the Ghab Valley, northwest Syria: a palynological study. Quat Int 73(74):127–136

Zeidi M, Conard NJ (in press) Preliminary report on the chipped lithic assemblage from Chogha Golan, a PPN site in the foothills of the Zagros Mountains, Ilam Province, Iran. Ex Oriente Series

Zeidi M, Riehl S, Napierala H, Conard NJ (in press), Chogha Golan: A PPN Site in the Foothills of the Zagros Mountains, Ilam Province, Iran (Report on the First season of Excavation in 2009) submitted for 7ICAANE IN London