4 Pre-Domestic Cultivation during the Late Pleistocene and Early Holocene in the Northern Levant

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Pre-domestic cultivation, or sowing and harvesting, of morphologically wild plants was an inevitable step in the adoption of cultivation which led to the development of agriculture in the ancient Near East. The overall transition from gatherers to established farmers with domestic crops probably spanned three millennia (Tanno and Willcox 2006, Fuller 2007). At a number of archaeological sites which date from 13,000 to 10,000 BP, remains of wild progenitors have been interpreted to be the result of cultivation rather than of gathering. Van Zeist and Bakker-Heeres (1986) and later Colledge (1998, 2001) suggested the possibility of pre-domestic cultivation for twelfth millennium levels at Mureybet. Van Zeist also used similar arguments for later levels at Cayönü (van Zeist and de Roller 1994). Hillman *et al*. (2001) argued for cultivation at the Epipalaeolithic site of Abu Hureyra, dated to about 13,000 years ago. In the southern Levant, Kislev (1997) argued for pre-domestic cultivation at Netiv Hagdud, dated to about 11,300 years ago, and Edwards *et al*. (2004) argued the same for Zahrat adh-Dhra. While it is fair to say that there is a consensus of opinion that pre-domestic cultivation predates morphological domestication by a millennium or more (Tanno and Willcox 2006, Fuller 2007, Brown *et al*. 2009), reliable data to confirm this hypothesis are hard to come by.

Archaeobotanical analyses of charred remains from recent excavations at Jerf el Ahmar in northern Syria have allowed us to identify pre-domestic cultivation with more certainty than before. Jerf el Ahmar is part of a complex of sites, dated to between *c*. 11,500 and *c*. 10,300 BP, (Figure 4.1) characterized by communal buildings, importation of precious materials, and sophisticated symbolic representations. Of the tens of thousands of cereal remains identified from these sites, all were morphologically wild (Figure 4.2). There was no evidence of morphological cereal domestication identified from nonshattering ears or nondehiscent pods in the case of legumes. As we shall see, in-depth studies of the charred material (Willcox *et al*. 2008, 2009) have produced evidence pointing to a long period of pre-domestic cultivation lasting from 11,500 to 10,300 BP. Indeed it is possible that small-scale cereal cultivation started some 13,000 years ago at Abu Hureyra (Hillman *et al*. 2001). But at this site cereal grains were far less frequent

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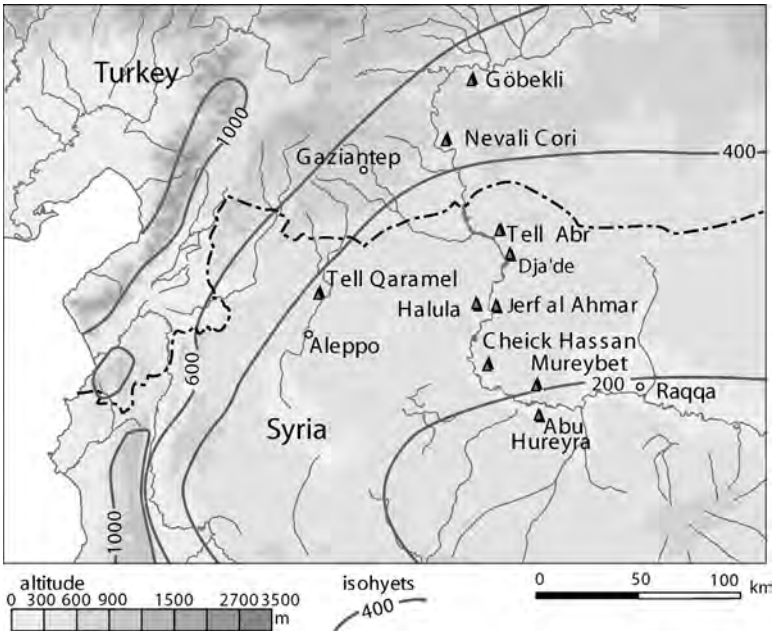

Figure 4.1. Position of the major sites mentioned in the text. Isohyets are given to show the rainfall gradient. Hallan Çemi (Table 4.1) is situated off the map to the northeast.

than seeds from nonfounder plants gathered from the flood plain, which continued to play a major role until the climatic amelioration of the early Holocene (starting *c*. 11,500 BP) when cereals and pulses became the dominant staples (Willcox *et al*. 2009).

Evidence presented here for the Euphrates sites demonstrates a protracted period of pre-domestic cultivation where the importance of the cereal economy is manifest in archaeological findings other than charred remains. Looking farther afield beyond the northern Levant, researchers are beginning to see a similarly complex and drawn-out process with a prolonged period of cultivation prior to domestication, for example in the southern Levant (Weiss *et al*. 2006, Feldman and Kislev 2007) and also in the Far East (Fuller 2007). Recent DNA work on einkorn, emmer, and barley are also showing a more complex picture (Kilian *et al*. 2006, 2007, Luo *et al*. 2007) compared with early studies (Heun *et al*. 1997).

1 The archaeological sites

In this section I give a brief description of the major sites mentioned in the text. For more detail the reader will need to refer to the archaeological reports. For site location and rainfall patterns the reader is referred to the map in Figure 4.1. Dating of the sites was based on a large number of ^{14}C dates. All dates are given as

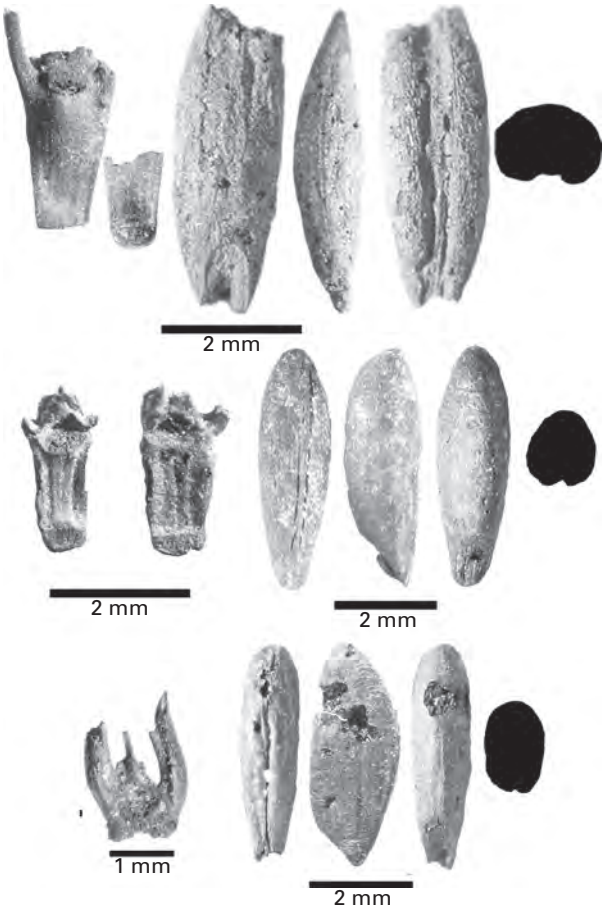

Figure 4.2. Charred wild cereal spikelet bases (left) and grains (right). Top, *Hordeum spontaneum* (wild barley) from Jerf el Ahmar. Middle, *Secale* sp. (rye) from Jerf el Ahmar. Bottom, *Triticum boeoticum* (single-grain einkorn) from Tell Qaramel. Note the basal abscission scar seen in the barley (top row, second from the left) and for rye the lower end of the rye spikelet bases (second row, first and second from left) is more reliable than the upper scar for distinguishing between wild and domestic.

calibrated years before present (BP). Date ranges for each site are given in the two upper lines in Table 4.1. The two earliest sites date to the end of the Pleistocene. Abu Hureyra 1 is late Natufian (13,250 to 12,750 BP), with occupation levels that date to the end of the Allerød and the beginning of the Younger Dryas. Not far away at Mureybet, the earliest levels (Mureybet 1) date to the final Natufian (12,500 to 12,000 BP) and coincide with the second half of the Younger Dryas (Ibañez 2008). The succeeding levels of Mureybet 2 are Khiamian (12,000 to 11,500 BP), and farther west at the site of Tell Qaramel the early levels date to the same period. The sites which concern us here, often termed PPNA, make up a complex of five sites which are situated at regular intervals along the left bank of the Euphrates. They were occupied at the beginning of the Holocene between

Table 4.1. Absolute counts of edible taxa identified from a selection of sites in the northern Levant where there are no signs of morphological domestication

Nonedible plants were excluded. The so-called founder crops (cereals and pulses) increase at the expense of nonfounder plants gathered from the flood plain during the early Holocene. Date ranges for the sites are based on calibrated ^{14}C dates, which are given in the top two rows. Low sample numbers from Tell 'Abr and Mureybet make these data less reliable.

	Abu Hureyra 1	Mureybet 1	Mureybet 2	Qaramel	Hallan Çemi	Tell 'Abr	Mureybet 3	Jerf el Ahmar 1	Jerf el Ahmar 2	Dja'de
from calBP	13,250	12,500	12,000	12,000	11,500	11,500	11,500	11,500	11,200	11,000
to calBP	12,750	12,000	11,500	11,500	11,200	11,200	11,200	11,200	11,000	10,300
Secale/Triticum grain	888	12	8	1,170	19	2,999	2,000	1,382	1,055	1,120
Triticum spikelet base	0	0	0	292	0	0	0	0	5	16
Secale sp. spikelet base	0	0	p	0	0	0	p	121	22	16
Hordeum spontaneum grain	0	3	2	217	124	190	164	2,353	6,474	3,763
H. spontaneum spikelet base	0	0	0	0	0	?	6	1,546	1,746	153
T. b. aegilopoides grain	0	0	0	1,108	0	90	1	18	49	302
T.dicoccoides	0	0	0	4	0	0	0	0	0	192
Lens sp.	48	1	6	1,113	11	230	28	452	1,147	5,850
Pisum/Vicia/Lathyrus	48	1	6	682	748	37	13	146	237	1,952
Cicer	0	0	0	0	0	0	0	0	0	3
Vicia faba	0	0	0	0	0	0	0	0	0	2
Vicia erilia	3	0	0	11	29	0	4	10	46	34
Stipa	1,573	0	0	526	76	0	0	2	51	272
Panicoid grasses	342	35	35	1	0	0	24	19	1	0
Cyperaceae	4,776	51	59	242	4,415	0	22	15	14	32
Rumex/Polygonum	4,848	312	1,037	11	3,748	0	351	359	126	37
Ficus carica	0	0	0	4	0	0	3	1	10	42
Amygdalus spp.	0	0	0	2,214	179	0	0	760	666	2
Pistacia sp. fragments	357	8	10	1,705	120	0	12	1,302	1,274	911
Rodent droppings	0	0	0	49	0	0	0	8	39	221
Totals of edible plants	12,883	423	1,163	9,300	9,469	3,546	2,628	8,486	12,923	14,920
Volume of sediment (l)	7,925	?	?	1,772	19,393	452	?	6,210	5,904	6,122
Number of samples	21	11	22	108	175	30	27	154	81	229
	Late Natufian	Late Natufian	Khiamian	Khiamian	PPNA	PPNA	PPNA	PPNA	PPNA	Early PPNB

Sources: Data for Abu Hureyra were provided by Sue Colledge, research assistant at the Institute of Archaeology, London. Data for Mureybet are from van Zeist and Bakker-Heeres (1986); for Jerf el Ahmar, Tell 'Abr, Dja'de, and Tell Qaramel, data are from Willcox *et al*. (2008). Data for Hallan Çemi provided by Manon Savard, Université du Québec à Rimouski.

11,500 and *c*. 10,300 years ago during a period of climatic amelioration (Willcox *et al*. 2009). These include Mureybet 3, Cheik Hassan, Jerf el Ahmar, Tell 'Abr and the recently discovered early levels at Dja'de, which also contains early PPNB levels. These sites are very similar in their architecture, symbolism, and chipped stone, suggesting cultural unity (Stordeur 2000, Stordeur *et al*. 2000). Further north in southeast Turkey, sites such as Demirköy, Göbekli (Schmidt 2006), and Hallan Çemi (Peasnall *et al*. 1998) also possess strong parallels (Helmer *et al*. 2004), but the plant economy at these more northern sites may have been different.

At Abu Hureyra, excavators found small shallow pits, which they interpreted as rudimentary dwellings (Moore *et al*. 2000). At Tell Qaramel (Mazurowski 2004), situated on the river Quwayq about 25 km north of Aleppo, much bigger round houses were found, constructed in stone and earth with well-defined hearths. In one house a large number of bucrania were found. Artifacts include Khiamian arrowheads and a rich ground-stone industry with chlorite bowls, shaft straighteners, querns, pounders and "batons polis". Similar objects also occur on PPNA sites in the area (Stordeur 2000, Stordeur *et al*. 2000). At Jerf el Ahmar the houses from the earliest levels are similar to those excavated at Tell Qaramel. Later levels have produced rectangular houses and large, sunken, round communal buildings, which were also found at Mureybet 3 and Tell 'Abr (Yartah 2004, 2005). Dja'de (Coqueugniot 2000) is chronologically the youngest site, dated to 11,000 to 10,300 BP. It has the oldest known geometric wall paintings in the Near East, which decorated a large, possibly communal building.

2 Large-scale use of cereals at Jerf el Ahmar

How important were cereals in the subsistence economy of PPNA sites? At the sites of Hallan Çemi and Demirköy in southeast Turkey, cereals are rare compared with other grains and so probably represented a minor component of the diet (the same was probably true for Natufian Abu Hureyra; see Table 4.1). In contrast, at Jerf el Ahmar 14,771 remains of charred wild barley, wild rye, and wild einkorn were recovered from occupation layers, suggesting that these cereals were a major component of the diet (see Table 4.1). Frequencies alone give a limited picture of the role of different food plants; thus my colleague Danielle Stordeur and I investigated the archaeological evidence for the role of cereals (Stordeur and Willcox 2009). We found that, like the charred grains, artifacts associated with processing were found throughout the site, particularly stone saddle querns, which were used to grind grain (Willcox 2002b). The arrangement of the querns is very instructive. Many were found in situ inside the buildings, frequently occurring three to a room, suggesting that grinding was being practiced in an organised manner with three querns working simultaneously in a single architectural and social unit. Figure 4.3 shows a room with a row of three quern bases which date to the later stages of the site, *c*. 11,000 BP. The querns were immobilised and made stable by being set into solid bases. The layout of the

Figure 4.3. Settings for three saddle querns in a room excavated at Jerf el Ahmar. Other rooms contained similar arrangements of querns, suggesting that cereal processing was being practiced on a large scale. Photo with permission from D. Stordeur.

querns suggests that cereals played an essential role in the everyday economy of the site and that cereal processing was probably intertwined with the social structure of village life (Stordeur and Willcox 2009).

Prior to the grinding of grains, dehusking was carried out to separate the edible grain from inedible chaff consisting of glumes and spikelet bases. The latter were found in vast quantities in the form of impressions in building earth at Jerf el Ahmar, Tell 'Abr, and Mureybet. The building earth was made of a mixture of fine sediment to which cereal chaff was added as a tempering medium to reduce shrinkage and increase strength (Willcox and Fornite 1999). This technique is still used today in many parts of the world, including northern Syria. When the buildings burned at Jerf el Ahmar (a frequent occurrence), the earth was baked and hardened, leaving perfect impressions of the chaff, consisting of awns, glumes, lemmas, and spikelet bases, which were finely fragmented (see Figure 4.4), suggesting that dehusking was carried out by pounding, perhaps in a wooden pestle with a mortar. Examination of large quantities of building earth showed that chaff was systematically used as a tempering medium. Buildings at Jerf el Ahmar were constructed from local chalk, covered with 5–10 cm of earth. Similarly, the roofs were constructed with wooden beams between which were laid twigs, straw, or reeds, which were then covered with chaff-tempered building earth. Chaff must have been available in massive quantities given the size of the buildings at Jerf el Ahmar and the fact that they were regularly maintained, destroyed, and rebuilt. The quantity is surprising if we take into account that the dehusking of hulled cereals, particularly barley, produces a low proportion of chaff to grain. Quantifying the volumes would be difficult, but common sense suggests that we are dealing with considerable volumes, which would have to be stored.

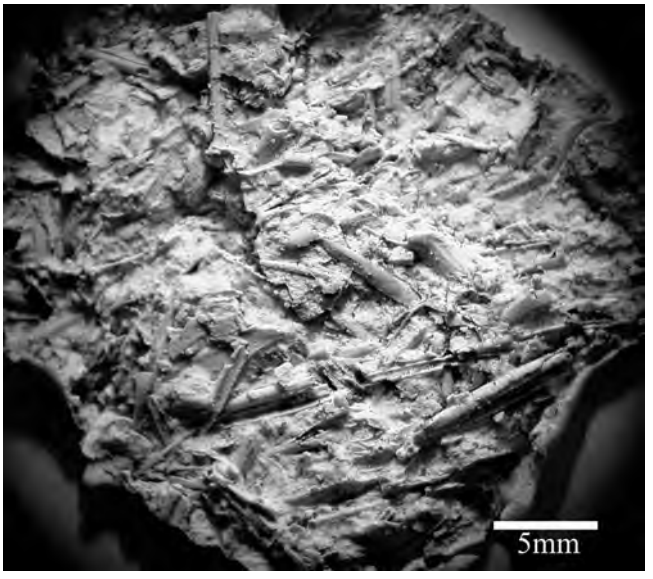

Figure 4.4. Photograph of a silicone cast of a fractured fragment of building earth from Jerf el Ahmar showing elements of cereal chaff. The chaff obtained from dehusking, mainly barley and rye, was used systematically as a tempering material in the building earth. This demonstrates that large quantities of chaff would have been available and that they would have to have been stored, ready for use when building work was carried out.

After the harvest and initial threshing to remove the straw, whole spikelets were probably stored prior to dehusking. Storage occurred in communal buildings at Tell 'Abr and possibly at Mureybet, where large quantities of pure charred cereal grain were found. Small cells (silos) located in the communal buildings at Jerf el Ahmar were used for storage (Stordeur *et al*. 2000). Indirect evidence for storage at Jerf el Ahmar comes from charred rodent droppings, many of which correspond in size to those of the domestic house mouse. Indeed, six archaeozoological finds of domestic mice (*Mus musculus domesticus)* were identified at Dja'de and one at Jerf el Ahmar (Cucchi *et al*. 2005). These mice most probably fed on stored grain. In total 47 charred droppings were found at Jerf el Ahmar and 221 at Dja'de (Table 4.1). Other early village sites where domestic house mice have been found include Hyonim B and Netiv Hugdud in the southern Levant, and Mureybet and Cafer Höyük in the north. Domestic mice were introduced to Cyprus by about 10,500 BP (Cucchi *et al*. 2005) and this may imply that important quantities of cereal were regularly imported.

Further evidence for intensive cereal use comes from finds of flint harvesting blades. They were identified by their characteristic gloss, caused by the build-up of a film of plant silica on the cutting edge of the tool (Anderson 1999). At a few sites these blades have been found hafted with bitumen in stone, bone, or wooden (charred) sickle handles. None were found at Jerf el Ahmar. These tools can be used for harvesting wild stands or cultivated fields. At Jerf el Ahmar and

contemporary sites on the Euphrates there is an increase in both size and quantity of these tools compared with earlier sites (F. Abbès, pers. commun.). This coincides with an increased reliance on cultivation.

3 Pre-domestic cultivation at Jerf el Ahmar

Five lines of evidence suggest that pre-domestic cultivation was practiced at Jerf el Ahmar during the early Holocene. Arguments in favor of cultivation of wild cereals and pulses were described in detail in an article published recently (Willcox *et al*. 2008). The following is a summary.

3.1 The decline of gathering

At Jerf el Ahmar a gradual reduction in gathering can be seen between lower and upper levels by the diminished frequencies of small-seeded grasses such as *Stipa*, panicoid types, and also other small-seeded grains such as Cyperaceae and *Polygonum*/*Rumex* (see Table 4.1 and Willcox *et al*. 2008). The decline in the gathering of these seeds was compensated for by an increase in the use of founder crops, notably barley, emmer, einkorn, lentil, and pea, which were probably cultivated. It appears that these changes in plant use represent an increasing reliance on cultivation.

3.2 The introduction of crops

In order to observe this we need to compare the presence of cereals and pulses across a wide chronological sequence in the Euphrates region of northern Syria. Thus we see that rye and two-grained einkorn were the only cereals present at late Pleistocene Abu Hureyra. At later sites such as Jerf el Ahmar, first barley, then single-grained einkorn and emmer were introduced. Climatic amelioration at the beginning of the Holocene may have opened the way for a wider choice of crops than those occurring locally. Pulses were also introduced; this can be seen at Dja'de, the most recent site where *Vicia faba* and *Cicer* were introduced from their natural habitats, which were probably located at a considerable distance.

3.3 Weeds of cultivation

Weeds of cultivation are plants that thrive when the soil is disturbed by cultivation. They have been evolving since the Neolithic and increasing in numbers as agriculture spread into new habitats. We examined (Willcox *et al*. 2008) the possibility of weeds taxa being present at Jerf el Ahmar as indicators of cultivation. Fifty-four taxa of wild and/or weed taxa were identified from charred seeds. Some, such as *Androsace maxima, Hyoscyamus, Peganum hamala*, and *Tribulus terrestris* were ruderals probably growing near the habitations. Others, for

example the small legumes, *Alyssum*/*Lepidium*, and wild grasses, could have been used as food plants before the advent of cultivation so they cannot be used as indicators of cultivation. Fifteen taxa that have no known use and are typically weeds of cultivation in modern fields and on Bronze Age sites, where the question of cultivation is not in question, were interpreted as weeds of cultivation. This number is small presumably because at this stage few species had had the time to come into contact with cultivation. The comparison of potential weed taxa from sites sampled in a similar way is revealing. Significantly, there is an increase in the number of taxa as cultivation becomes more of a possibility. Of the fifteen taxa from Jerf el Ahmar, only one occurs at Ohalo II (Kislev *et al*. 1992), eight at Abu Hureyra, and twelve at Tell Qaramel (Table 4.2). Some taxa may have occurred at low frequencies in wild cereal stands; as cultivation gained ground more species became incorporated into the new habitat, which is why the number and quantity of weed taxa increase.

3.4 Increase in grain size

An increase in grain size is often cited as a sign of domestication (Hillman *et al*. 2001). A study of barley grain size at Jerf el Ahmar and Dja'de demonstrated that there is a small increase in thickness and breadth between the lower and upper levels but that in the same geographical area there is no further increase for several millennia (Willcox 2004). This size increase could be due to phenotypic changes resulting from improved growing conditions or selection resulting from long-term cultivation. A third possibility is the introduction of a plump-grained population from elsewhere. It is improbable that genetic selection for plump grains would precede selection for nonshattering ears, because the former is complex and involves multiple genes compared with the latter (loss of dispersal) which involves one or two genes. For this reason it is probable that this increase represents a cultivated population where a higher proportion of grains reached full development compared with a wild population, where growing conditions would be variable and include marginal habitats, leading to a higher proportion of poorly formed grains. The other relevant species, einkorn, is problematic because of the difficulty of separating these grains from rye and because einkorn populations consist of two-grained and single-grained varieties, which are different in size but their proportions change. To conclude, it is possible that if cultivators chose the best soils for cultivation then this could result in an increase in grain size compared with populations from the wild.

3.5 The location of sites beyond wild cereal habitats

At most late Pleistocene/early Holocene sites in the Near East, the cereals identified correspond to those which one would expect to be growing locally and occur in the present-day vegetation. An exception is to be found at sites on the Euphrates in northern Syria, which today is an area too arid for wild einkorn

Table 4.2. Weeds of cultivation present at different sites in the Near East

The number of the taxa present at these sites increases with time. These sites were all extensively sampled so the increase may well result from cultivation, which became more intense. P, present; A, absent.

Taxon	Jerf	Qaramel	Hallan Çemi	Abu Hureyra	Ohalo II
Centaurea	P	A	P	A	A
Fumaria	P	A	P	A	A
Trigonella	P	P	A	A	A
Coronilla	P	P	A	A	A
Onobrychis	P	A	A	P	A
Erodium	P	A	A	P	P
Thymelaea	P	P	P	A	A
Adonis	P	P	P	A	A
Alyssum/Lepidium	P	A	P	P	A
Glaucium	P	P	A	P	A
Heliotropium	P	P	P	P	A
Silene/Gypsophila	P	P	P	P	A
Trifoliae	P	P	P	P	A
Bellevalia	P	P	P	P	A
Galium	P	P	P	A	P

and wild rye. The most southerly sites are almost 200 km south of present-day wild rye habitats and between 100 and 150 km south of wild two-grained einkorn habitats. With the cooler climatic conditions of the late Pleistocene these cereals may have extended farther south. How far south is difficult to estimate. Willcox (2005) pointed out that within today's natural distribution, rye does not occur on poor soil that develops on chalk bedrock, so despite cooler climatic conditions it is improbable that wild rye could have grown near the sites of Jerf el Ahmar and Abu Hureyra where these poor soils are found. However, Hillman *et al*. (2001) suggested that rye may have grown farther south during the Allerød, but that with the onset of the harsh climatic conditions of the Younger Dryas it would have retreated. They argued that the continued use of rye during the Younger Dryas at Abu Hureyra 1 implies that it was cultivated. Rye was also found at Mureybet 1 in levels corresponding to the Younger Dryas. At both these sites rye and einkorn are found at low frequencies compared with grains gathered from the flood plain.

Given that these sites are far from wild stands, several scholars discussed the possibility of transportation of grain. The distance between wild stands and villages could have increased as climate conditions forced wild stands to retreat, creating the need to import from farther and farther afield. Theoretically, imported grain from wild stands may have been used initially for consumption; a second step might have been the annual importation of grain from wild stands for sowing near the sites where the harvest from cultivation would be for consumption. This practice could have occurred for a prolonged period. Then a third step may have been sowing the grain harvested from cultivation. This would only

have happened if a surplus could be regularly relied upon from cultivation, which would eventually provide a local, secure, and dependable supply of grain. But this leads us to ask whether it was possible to cultivate wild rye and two-grained einkorn in areas where these plants would not have grown in the wild. The answer is yes, because under cultivation, fields would have been chosen in edaphically favorable locations, creating a microhabitat where competition from other plants had been removed (Valkoun *et al*. 1998, Willcox 2005). But there came a point when climate conditions became too extreme, which is why rye declines and barley increases at Jerf el Ahmar, the latter being much better adapted to the climate and soils of the Euphrates basin in northern Syria.

In summary, the arguments in favor of cultivation as opposed to gathering of wild cereals at Jerf el Ahmar only stand up to scrutiny when taken together. These arguments are reinforced by the evidence for large-scale cereal use outlined above; this does not exclude the possibility that gathering continued as a supplement. Given that five other sites on Euphrates, Tell 'Abr, Dja'de, Mureybet, and Cheik Hassan, have a similar material culture (Stordeur 2000) and are close geographically, it is possible that the inhabitants at these sites also cultivated cereals and pulses. But we should be careful not to extend our assumptions too far because at contemporary sites situated farther east and north such as Göbekli Tepe, Hallan Çemi, Demirköy, Nemrik, Qermez Dere, and M'lefaat (Neef 2003, Savard *et al*. 2006) there is less evidence and these authors interpret these sites as being inhabited by gatherers.

4 When did domestication appear?

In the Euphrates valley of northern Syria, reliable signs of morphological domestication, indicated by the partial loss of the dispersal mechanism in emmer and barley, are found in the earliest levels at the sites of Halula and Abu Hureyra 2, dated to *c*. 10,000 BP These are full-scale farming sites, which have domestic animals and cover a surface area at least ten times larger than the PPNA sites. Elsewhere the same tell-tale abscission scars left on spikelet bases were found at the sites of Nevali Çori, Cayönü, and Cafer Höyük dated to *c*. 10,500 years ago. The later date for domestication on the Euphrates in northern Syria may be due to a gap in the archaeological record. At these early domestication sites, wild types persist alongside the domestic types (van Zeist and de Roller 1994, de Moulins 1997, Pasternak 1998, Tanno and Willcox 2006).

5 Why was morphological domestication slow to become established?

Theoretically, less than 200 years of cultivation could have selected for a domestic population (Hillman and Davies 1990). Yet there is no evidence for plant domestication as seen in the loss of dispersal mechanisms for either

cereals or pulses at the Euphrates sites, despite prolonged cultivation. Cereals remained wild at least until 10,300 years ago, as seen at Dja'de, and this, at least 1,000 years after the first signs of cultivation at Jerf el Ahmar. Why, then, did domestication not appear earlier? One reason is that seed stock may have been regularly replenished from wild stands to counter poor harvests (droughts, disease, etc.), which may have been a frequent occurrence in the arid middle Euphrates. Another reason is that harvests may have occurred early in the season before the ears shattered, which would mean that the probability of selection for the rare mutants that had lost their dispersal mechanism would be extremely slim, and nonshattering ears would have had little advantage. We know that ears which shatter compete well with nonshattering ears in cultivated fields because wild einkorn and barley are common weeds of cereal fields in the Near East today. Studies on a wider geographical scale and for a variety of cereals indicate that morphological domestication was slow to be established and mixed populations of wild and domestic cereals persisted side by side for long periods (Fuller 2007, Tanno and Willcox 2006). This continued admixture suggests that during the early Neolithic, nonshattering and shattering forms were inseparable and so similar that Neolithic farmers treated them both as part of the crop.

Finally, on theoretical grounds, creating a population from a single mutant plant by conscious or unconscious selection would have the disadvantage of reducing genetic diversity, which was necessary to create crops with good yield stability (Abbo *et al*. 2010). Conscious selection is highly improbable for barley and wheat crops because domestic traits are not readily visible to the naked eye. In addition a single line would not have been viable under cultivation given the heterogeneous and irregular climatic and edaphic conditions, not to mention resistance to pathogens. This leads us to the conclusion that in order for healthy crops to develop they would need to have a variety of landraces consisting of several genotypes, as can be seen in pre-industrial crops.

6 Climate change and the adoption of cultivation

There are no palaeoclimate records or pollen spectra for the middle Euphrates region in northern Syria. For palaeoclimate reconstruction we have to rely on (1) information on past vegetation from the archaeobotanical record, (2) pollen cores from lake sediments, which occur far from our area, and finally (3) ice core data, which provide high-resolution information on global climate change.

How did climate change affect the availability of food plants in northern Syria? The early levels at Abu Hureyra 1 coincide with the Allerød. Temperatures were probably lower than at present. The pollen record indicates that forest vegetation was expanding in low-lying areas near the Mediterranean coast during this period and this may have been the case in northern Syria

because charcoal and seed analyses from Abu Hureyra indicate a forest–steppe vegetation consisting of *Pistacia atlantica* trees, grasses, and occasional oaks (Hillman 2000, Roitel and Willcox 2000, Willcox 2002a). These taxa occur today in vegetation zones found at higher altitudes. The use of rye at Abu Hureyra fits with the cool conditions of the late Pleistocene, but it would have been scarce because of the absence of suitable soils. *Polygonum*/*Rumex* gathered from the flood plain would have been a more reliable source of food than rye, the former being less affected by drought thanks to the water table, which was near the surface.

The Younger Dryas can be discerned from lake level changes, diatom analyses, and stable isotopes (Roberts *et al*. 2001). It was cooler and drier than today. The aridity may have been offset because low temperatures would have meant less evaporation and transpiration. *Pistacia*, grasses, and oak were exploited (van Zeist and Bakker-Heeres 1986, Willcox *et al*. 2009), so these resources were still available despite climate deterioration. Flood-plain species, which were less affected by the harsh conditions, made up an important part of the subsistence food plants at sites dating to the Younger Dryas.

The early Holocene is characterized by an increase in both temperature and rainfall. Tree species such as *Pistacia atlantica* were expanding in the Near East (Rossignol-Strick 1999) and this can be seen on the Euphrates valley sites by the high frequencies of *Pistacia* and *Amygdalus* charcoal and their fruits at Jerf el Ahmar and Dja'de (Hillman 2000, Willcox 2002b). As we have seen, cultivation appears to have been establishing itself during this period and more favorable climatic conditions may have facilitated this. But there is another climatic factor that may have contributed, the advent of more climatically stable conditions. It appears that at the beginning of the Holocene there is a reduction in short-term climatic variability. This has been identified from ice-core data, which show that the amplitude of oxygen isotope oscillations was high during the late Pleistocene and was reduced during the early Holocene (Figure 4.5). This implies that the Holocene climate was more stable with less short-term variation. It has been argued this stability may have helped in establishing cultivation during the PPNA in northern Syria (Willcox *et al*. 2009) between 11,500 and 11,000 BP. Founder crops of barley, single-grained einkorn, emmer, lentil, and pea began to be cultivated on Euphrates sites. Shortly afterwards new crops appear: faba beans, chick peas, and figs (see Table 4.1), having been introduced from elsewhere. Barley appears to have replaced rye, which could not tolerate the higher temperatures of the early Holocene.

Finally, a number of scholars agree that theoretically stable climatic conditions at the beginning of the Holocene were an important factor which allowed cultivation to develop into a reliable subsistence economy (Willcox 2000a,b, Richerson *et al*. 2001, Feynman and Ruzmaikin 2007, Hoek and Bos 2007). The Euphrates sites provide the demonstration of this through a direct correlation between the advent of stable climatic conditions and increased use of cultivation (Willcox *et al*. 2009).

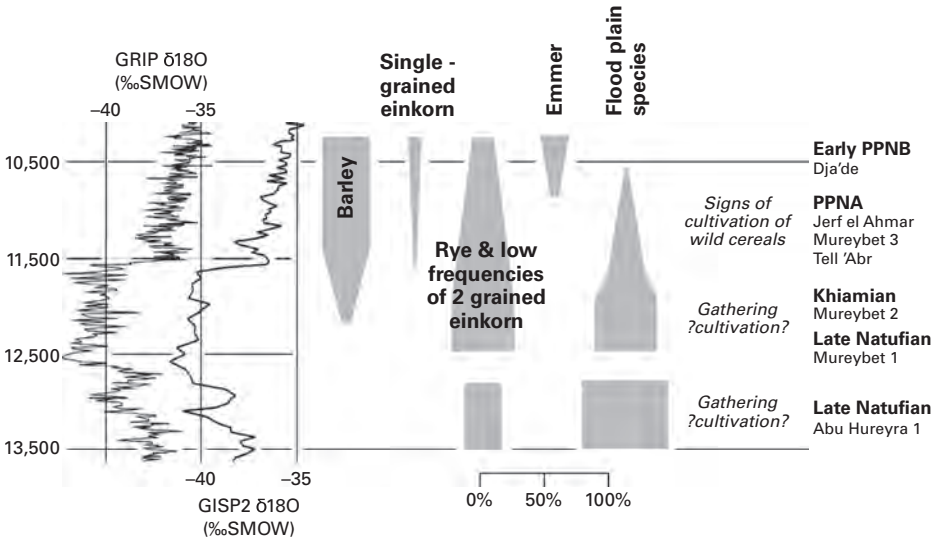

Figure 4.5. Approximate changes in the frequencies of the most common wild food plants from sites before the appearance of morphological domestication in the Euphrates valley in northern Syria, compared to the oxygen isotope curve (adapted from Hoek and Bos 2007, with their permission, and Willcox 2009). Rye is common during the late Pleistocene; it was used with small-seeded flood-plain species and goes out of use with the warmer conditions of the Holocene when barley and emmer become frequent. The amplitude of the oxygen isotope oscillations is high in the late Pleistocene, indicating unstable climatic conditions. With the Holocene the amplitude is less, indicating more stable conditions, which would allow cultivation to become a reliable means of subsistence. The break in the bars is because the archaeobotanical sequence is not continuous.

7 Conclusion

The archaeological sites examined here cover a period of more than 3,000 years, during which there were significant cultural developments and the first signs of cultivation. If small-scale cultivation occurred sporadically during the late Pleistocene, it may not have been sustainable because climate conditions were too unreliable for farming. Our archaeobotanical evidence suggests that the advent of stable climate conditions coincided with increased use of cultivation and may have facilitated its development into a sustainable economy when founder crops like barley, followed by emmer and then chickpea and faba bean, were brought into cultivation in the Euphrates area. The arrival of these new crops coincides with spectacular cultural developments. These are illustrated by the contrast between the humble Natufian dwellings at Abu Hureyra, which were mere shallow pits less than two meters in diameter, and the Khiamian houses at Tell Qaramel, which were constructed in stone and were several meters in diameter. By the PPNA large communal buildings were built at Tell 'Abr, Jerf el Ahmar, and Mureybet. The "kitchen" discovered at Jerf el Ahmar (Willcox 2002b) demonstrates a material investment in food preparation. Were these

developments a consequence of cultivation? This is not so easy to answer if we take into account Göbekli Tepe (Schmidt 2006) with its huge standing-stone circles. At present there is no evidence for cultivation at this site, although at present very few charred remains have been recovered. However it may not be coincidence that Göbekli Tepe is situated close to areas with the most extensive wild cereal stands.

Gathering and cultivation of wild cereals probably occurred simultaneously over a long period, which is why we see no sharp division from one economy to another, the transition being extremely gradual and episodic. Small-scale cultivation leaves little or no trace. The incentive to cultivate on a large scale could have been due to multiple factors, but the overriding factor would be difficulty in accessing wild stands or lack of sufficient quantities. Wild lentils, which are ubiquitous on early sites, may have been cultivated at an early date because of the rarity and the diminutive size of wild stands. Even when cereals and pulses were regularly cultivated, seed may have occasionally been obtained from wild stands and as long as this practice persisted any domestication traits which might appear would not be fixed in the population. The fixing of these traits and the establishment of a morphologically domesticated population would only occur when intensive cultivation was practiced exclusively and on a large scale.

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References

Abbo S, S Lev-Yadun, and A Gopher. 2010. Yield stability: An agronomic perspective on the origin of Near Eastern agriculture. *Vegetation History and Archaeobotany* **19**: 143–50.

Anderson P. 1999. Experimental cultivation, harvest and threshing of wild cereals. Pp. 118–44 *in* P Anderson (ed.) *Prehistory of Agriculture*. Monograph 40. Los Angeles, CA: Institute of Archaeology, University of California.

Brown TA, MK Jones, W Powell, and RG Allaby. 2009. The complex origins of domesticated crops in the Fertile Crescent. *Trends in Ecology and Evolution* **24**: 103–9.

Colledge S. 1998. Identifying pre-domestic cultivation using multivariate analysis. Pp. 121–31 *in* A Damania, J Valkoun, G Willcox, and C Qualset (eds.) *The Origins of Agriculture and Crop Domestication*. Aleppo, Syria: ICARDA.

Colledge S. 2001. *Plant Exploitation on Epipalaeolithic and Early Neolithic Sites in the Levant*. British Archaeological Reports, International Series 986. Oxford: J and E Hedges.

Coqueugniot E. 2000. Dja'de (Syrie), un village à la veille de la domestication (seconde moitié du 9e millénaire av. J.C.). Pp. 63–79 *in* J Guilaine (ed.) *Les Premiers Paysans du Monde, Naissance des Agricultures*. Paris: Errance.

Cucchi T, J-D Vigne, and JC Auffray. 2005. First occurrence of the house mouse (*Mus musculus domesticus* Schwarz & Schwarz, 1943) in the Western Mediterranean: A zooarchaeological revision of subfossil occurrences. *Biological Journal of the Linnean Society* **84**: 429–45.

de Moulins D. 1997. *Agricultural Changes at Euphrates and Steppe Sites in the mid-8th to the 6th Millennium B.C*. British Archaeological Reports, International Series 683. Oxford: Archaeopress.

Edwards C, J Meadows, G Sayej, and M Westaway. 2004. From the PPNA to the PPNB: New views from the southern Levant after excavations at Zahrat Adh-Dhra'2 in Jordan. *Paléorient* **30**/2: 21–60.

Feldman M and M Kislev. 2007. Domestication of emmer wheat and evolution of free-threshing tetraploid wheat. *Israel Journal of Plant Sciences* **55**: 207–21.

Feynman J and A Ruzmaikin. 2007. Climate stability and the development of agricultural societies. *Climate Change* **84**/3–4: 295–311.

Fuller D. 2007. Contrasting patterns in crop domestication and domestication rates: Recent archaeobotanical insights from the Old World. *Annals of Botany* **100**: 903–24.

Helmer D, L Gourichon, and D Stordeur. 2004. À l'aube de la domestication animale. Imaginaire et symbolisme animal dans les premières sociétés néolithiques du nord du Proche-Orient. *Anthropozoologica* **39**: 143–63.

Heun M, R Schäfer-Pregl, D Klawan *et al*. 1997. Site of einkorn wheat domestication identified by DNA fingerprinting. *Science* **278**: 1312–14.

Hillman G. 2000. Plant food economy of Abu Hureyra. Pp. 372–92 *in* A Moore, G Hillman, and T Legge (eds.) *Village on the Euphrates, From Foraging to Farming at Abu Hureyra*. New York, NY: Oxford University Press.

Hillman G and S Davies. 1990. Measured domestication rates in wild wheats and barley under primitive cultivation, and their archaeological implications. *Journal of World Prehistory* **4**: 157–219.

Hillman G, R Hedges, A Moore, S Colledge, and P Pettitt. 2001. New evidence of late glacial cereal cultivation at Abu Hureyra on the Euphrates. *The Holocene* **11**: 383–93.

Hoek W and J Bos. 2007. Early Holocene climate oscillations – causes and consequences. *Quaternary Science Reviews* **26**: 1901–6.

Ibañez J (ed.) 2008. *Le Site Néolithique de Tell Mureybet (Syrie du Nord), en Hommage à Jacques Cauvin*. British Archaeological Reports International Series, 1843 (1). Oxford: Archaeopress.

Kilian B, H Özkan, J Kohl *et al*. 2006. Haplotype structure at seven barley genes: relevance to gene pool bottlenecks, phylogeny of ear type and site of barley domestication. *Molecular Genetics and Genomics* **276**: 230–41.

Kilian B, H Özkan, H Walther *et al*. 2007. Molecular diversity at 18 loci in 321 wild and 92 domesticate lines reveal no reduction of nucleotide diversity during *Triticum monococcum* (einkorn) domestication: Implications for the origin of agriculture. *Molecular Biology and Evolution* **24**: 2657–68.

Kislev M. 1997. Early agriculture and palaeoecology of Netiv Hagdud. Pp. 209–36 *in* O Bar-Yosef and A Gopher (eds) *An Early Neolithic Village in the Jordan Valley*. Part 1.

The Archaeology of Netiv Hagdud. American School of Prehistoric Research Bulletin 43. Cambridge, MA: Peabody Museum.

Kislev M, D Nadel, and I Carmi. 1992. Epipalaeolithic (19,000 BP) cereal and fruit diet at Ohalo II, Sea of Galilee, Israel. *Review of Palaeobotany and Palynology* **73**: 161–6.

Luo M-C, Z-L Yang, F-M You *et al*. 2007. The structure of wild and domesticated emmer wheat populations, gene flow between them, and the site of emmer domestication. *Theoretical and Applied Genetics* **114**: 947–59.

Mazurowski R. 2004. Tell Qaramel excavations, 2003. *Polish Archaeology in the Mediterranean* **XV**: 355–70.

Moore A, G Hillman, and T Legge. 2000. *Village on the Euphrates, From Foraging to Farming at Abu Hureyra*. New York, NY: Oxford University Press.

Neef R. 2003. Overlooking the steppe forest: Preliminary report on the botanical remains from early Neolithic Göbekli Tepe (southern Turkey). *Neo-Lithics* **2**/**03**: 13–15.

Pasternak R. 1998. Investigations of botanical remains from Nevali Çori PPNB, Turkey. Pp. 170–7 *in* A Damania, J Valkoun, G Willcox, and C Qualset (eds.) *The Origins of Agriculture and Crop Domestication*. Aleppo Syria: ICARDA.

Peasnall BL, RW Redding, RM Nesbitt, and M Rosenberg. 1998. Hallan Çemi, pig husbandry, and post-Pleistocene adaptations along the Taurus-Zagros Arc (Turkey). *Paléorient* **24**: 25–41.

Richerson P, R Boyd, and R Bettinger. 2001. Was agriculture impossible during the Pleistocene but mandatory during the Holocene? A climate change hypothesis. *American Antiquity* **66**: 387–411.

Roberts N, J Reed, MJ Leng *et al*. 2001. The tempo of Holocene climatic change in the eastern Mediterranean region: New high-resolution crater-lake sediment data from central Turkey. *The Holocene* **11**: 721–36.

Roitel V and G Willcox. 2000. Analysis of charcoal from Abu Hureyra. Pp. 544–7 *in* A Moore, G Hillman, and A Legge (eds.) *Village on the Euphrates, From Foraging to Farming at Abu Hureyra*. New York, NY: Oxford University Press.

Rossignol-Strick M. 1999. The Holocene climatic optimum and pollen records of sapropel in the eastern Mediterranean, 9000–6000 BP. *Quaternary Science Reviews* **18**: 515–30.

Savard M, M Nesbitt, and MK Jones. 2006. The role of wild grasses in subsistence and sedentism: New evidence from the northern Fertile Crescent. *World Archaeology* **38**: 179–96.

Schmidt K (ed.) 2006. *Sie Bauten den Ersten Tempel: Das Rätselhafte Heiligtum der Steinzeitjäger. Die Archäologische Entdeckung am Göbekli Tepe*. Munich: CH Beck.

Stordeur D. 2000. New discoveries in architecture and symbolism at Jerf el Ahmar (1997–1999 Syria). *Neo-Lithics* **1**: 1–4.

Stordeur D, M Brenet, G Der Aprahmian, and J-Cl Roux. 2000. Les bâtiments communautaires de Jerf el Ahmar et Mureybet. Horizon PPNA. Syrie. *Palèorient* **26**: 29–44.

Stordeur D and G Willcox. 2009. Indices de culture et d'utilisation des céréales à Jerf el Ahmar. Pp. 693–710 *in* D Fabre (ed.) *De Méditerranée et D'ailleurs... Mélanges offerts à Jean Guilaine*. Toulouse: Archives d'Ecologie Préhistorique.

Tanno K and G Willcox. 2006. How fast was wild wheat domesticated? *Science* **311**: 1886.

Valkoun J, JG Waines, and J Konopka. 1998. Current distribution and habitat of wild wheats and barley. Pp. 293–9 *in* A Damania, J Valkoun, G Willcox, and C Qualset. (eds.) *The Origins of Agriculture and Crop Domestication*. Aleppo, Syria: ICARDA.

van Zeist W and JAH Bakker-Heeres. 1984 [1986]. Archaeobotanical studies in the Levant 3. Late-Palaeolithic Mureybet. *Palaeohistoria* **26**: 171–99.

van Zeist W and GJ de Roller. 1991/1992 [1994]. The plant husbandry of Aceramic Çayönü, SE Turkey. *Palaeohistoria* **33**/**34**: 65–96.

Weiss E, M Kislev, and A Hartmann. 2006. Autonomous cultivation before domestication. *Science* **312**: 1608–10.

Willcox G. 2000a. De la cueillette à l'agriculture. *Pour la science* **274**: 36–40.

Willcox G. 2000b. Nouvelles données sur l'origine de la domestication des plantes au Proche-Orient. Pp. 121–40 *in* J. Guilaine (ed.) *Les Premiers Paysans du Monde, Naissance des Agricultures*. Paris: Errance.

Willcox G. 2002a. Evidence for ancient forest cover and deforestation from charcoal analysis of ten archaeological sites on the Euphrates. Pp. 141–5 *in* S. Thiébault (ed.) *Charcoal Analysis. Methodological Approaches, Palaeoecological Results and Wood Uses*. British Archaeological Reports International Series 1063. Oxford: Archaeopress.

Willcox G. 2002b. Charred plant remains from a 10th Millennium B.P. kitchen at Jerf el Ahmar (Syria). *Vegetation History and Archaeobotany* **11**: 55–60.

Willcox G. 2004. Measuring grain size and identifying Near Eastern cereal domestication: evidence from the Euphrates valley. *Journal of Archaeological Science* **31**: 145–50.

Willcox G. 2005. The distribution, natural habitats and availability of wild cereals in relation to their domestication in the Near East: Multiple events, multiple centres. *Vegetation History and Archaeobotany* **14**: 534–41.

Willcox G. 2008. Nouvelles données archéobotaniques de Mureybet et la néolithisation du moyen Euphrate. Pp. 103–14 *in* J Ibañez (ed.) *Le Site Néolithique de Tell Mureybet (Syrie du Nord), en Hommage à Jacques Cauvin*. British Archaeological Reports International Series, 1843 (1). Oxford: Archaeopress.

Willcox G, R Buxo, and L Herveux. 2009. Late Pleistocene and Early Holocene climate and the beginnings of cultivation in northern Syria. *The Holocene* **19**(1): 151–8.

Willcox G and S Fornite. 1999. Impressions of wild cereal chaff in pisé from the tenth millennium at Jerf el Ahmar and Mureybet: northern Syria. *Vegetation History and Archaeobotany* **8**: 21–4.

Willcox G, S Fornite, and L Herveux. 2008. Early Holocene cultivation before domestication in northern Syria. *Vegetation History and Archaeobotany* **17**: 313–25.

Yartah T. 2004. Tell 'Abr 3, un village du Néolithique précéramique (PPNA) sur le Moyen-Euphrate. Première approche. *Paléorient* **30**: 141–58.

Yartah T. 2005. Les bâtiments communautaires de Tell 'Abr 3 (PPNA, Syrie). *Neo-Lithics* **1**: 3–9.