Veget Hist Archaeobot
DOI 10.1007/s00334-007-0121-y

ORIGINAL ARTICLE

Early Holocene cultivation before domestication in northern Syria

George Willcox · Sandra Fornite · Linda Herveux

Received: 12 October 2006 / Accepted: 14 February 2007

Abstract Charred plant remains from the sites of Tell Qaramel, Jerf el Ahmar, Dja'de and Tell 'Abr situated in northern Syria and dated to the tenth and ninth millennia cal B.C. demonstrate that a wide variety of wild pulses, cereals, fruits and nuts was exploited. Five lines of evidence suggest that cultivation was practised at three of the sites. (1) Wild einkorn, wild rye and lentils occur outside their natural habitats. (2) The founder crops barley, emmer and single-grained einkorn appear at different times. (3) An assemblage of weeds of cultivation was identified. (4) There is a gradual decrease in gathered plants such as small seeded grasses and *Polygonum/Rumex*. (5) Barley grains increase in breadth and thickness. Morphological domestication did not become established, perhaps because seed stock was regularly collected from wild stands. Charred rodent droppings indicate large-scale grain storage.

Keywords Archaeobotany · Syria · Neolithic · Cultivation · Wild cereals · Early farming

Introduction

Two recent articles hypothesize that the origins of cultivation of wild cereals and pulses considerably predate their domestication in the Near East (Tanno and Willcox 2006a; Weiss et al. 2006). Pre-ninth millennium (cal B.C.) sedentary sites in the Euphrates region, which have produced wild cereals and pulses include Abu Hureyra (Hillman 2000), Mureybet, (van Zeist and Bakker-Heeres 1984) and Göbekli (Neef 2003) (for site locations see map, Fig. 1). Hillman (2000) suggested that wild rye and einkorn were cultivated at Abu Hureyra on the Euphrates by about 11,000 cal B.C. One of his arguments was that the harsh climatic conditions of the Younger Dryas would have not allowed wild stands to grow in the region (Hillman et al. 2001). For Mureybet, Colledge (1998) suggested that there is evidence for pre-domestic cultivation on the basis of weeds of cultivation. Pre-ninth millennium sites situated farther east and north such as Hallan Çemi, Demirköy, Nemrik, Qermez Dere and M'lefaat (not shown in Fig. 1) also produced wild cereals and pulses, but evidence of cultivation is less forthcoming (Savard et al. 2006). Reliable signs of morphological domestication indicated by the partial loss of the dispersal mechanism in einkorn, barley and emmer do not appear until about 8,500 cal B.C. These have been found in levels commonly referred to as early PPNB at the sites of Nevalı Çori, Tell el Kerkh, Cayönü and Cafer Hüyök, but wild types persist (Tanno and Willcox 2006a, b; Pasternak 1998; van Zeist and de Roller 1994; de Moulins 1997). Later sites dated to the first part of the eighth millennium cal B.C. (middle PPNB) cover a bigger surface area and have evidence of well-established agriculture, demonstrated by morphological domestication of emmer and barley on all sites so far examined (Nesbitt 2002).

In this report we present new results of identifications of charred plant remains from the sites of Qaramel, Jerf el Ahmar, Dja'de and Tell 'Abr dated to the tenth and ninth millennia cal B.C. (for the location and dating see Figs. 1, 2). We concentrate on the similarities and differences of plant assemblages between sites, including in some instances Abu Hureyra and Mureybet, in order to trace how plant use

Communicated by A. Fairbairn.

G. Willcox (✉) · S. Fornite · L. Herveux
Archéorient, CNRS, Antenne de Jalès, Berrias,
07460 St-Paul-le-Jeune, France
e-mail: gwillcox@wanadoo.fr

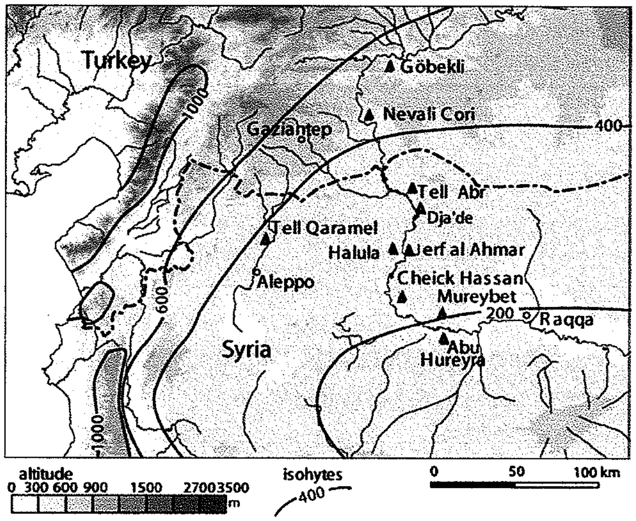

Fig. 1 Site location map giving the principal sites mentioned in the text

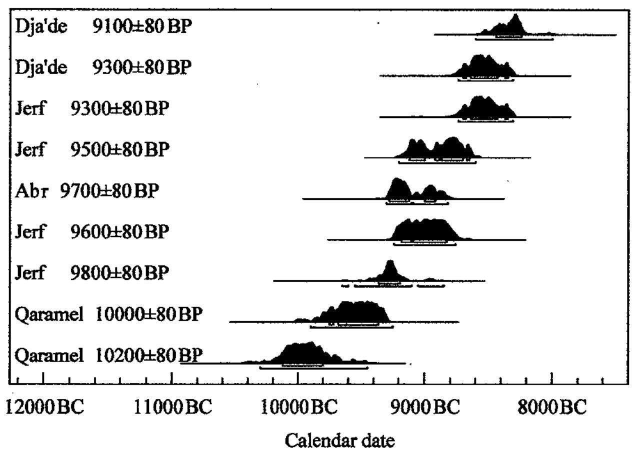

Fig. 2 The hypothetical date ranges for the four sites based on over 75 ^{14}C dates. It demonstrates the overall chronological trend of the four sites, but also the chronological overlap caused by the margin of error. Thus levels with similar dates may not be contemporary

and particularly the major cereal components changed. No attempt has been made at spatial or specific archaeological interpretations. This will be the subject of future publications for each individual site. Indeed some results have already been published (Willcox 2002a).

Many aspects of these ancient plant economies cannot be established with certainty, such as, how important cultivation was compared to gathering, or how far the wild stands were from the habitation sites where the cereals were stored and consumed. For some taxa we cannot be sure of their use, whether for food, fuel, crafting artefacts or whether they were simply unwanted weeds or ruderals. Despite these difficulties, we are coming to a better understanding of the origins of agriculture thanks to a number of recent archaeobotanical studies.

Materials and methods

Sampling was carried out using a simple 200 l flotation tank. Charred material, which floated was sieved with a 0.5 mm mesh. This may have resulted in loss of taxa such as *Juncus* and *Phragmites* but finer meshes were difficult to use because they clogged easily. Tests showed that finer sieving produced no significant identifiable material. The density of charred plant remains other than charcoal varied from sample to sample. The sampling procedure consisted of testing sediments by flotation and selecting layers where charred remains were concentrated. Certain areas were sampled intensely, for example the spectacular finds from a kitchen at Jerf el Ahmar, which have already been reported (Willcox 2002a).

The four sites span the period from the first quarter of the tenth millennium B.C. to the last quarter of the ninth millennium. Dating was based on over 50 radiocarbon dates. A selected range of dates and their calibration curves are given in Fig. 2. A brief description of each site is given below. For further details the reader is referred to the original archaeological reports.

Tell Qaramel (Mazurowski 2004), the earliest site, is situated on the river Quwayq about 25 km north of Aleppo. It is the only site of the four, which is not situated on the Euphrates. The area today has an average annual rainfall of 350 mm, which is higher than that of the Euphrates sites. Samples were only taken from the Khiamian period dated to approximately 10,000 cal B.C. The site consists of round houses, hearths and pits. In one house a large number of bucrania (aurochs skulls) were found. Artefacts include Khiamian arrowheads, a rich ground stone industry with chlorite bowls, shaft straighteners, querns, pounders and "batons polis".

Jerf el Ahmar (Stordeur 2000; Stordeur et al. 2000) is the most southerly site of the four, situated on the banks of the Euphrates in an area, which receives an average annual rainfall of 250 mm. This site was the most extensively sampled and it covers a period of approximately five centuries. The oldest levels contain houses, which are similar to those excavated at Tell Qaramel. Later levels have rectangular houses and sunken round communal buildings.

Dja'de (Coqueugniot 2000) has an annual average rainfall of about 300 mm and is situated 50 km upstream of Jerf el Ahmar. The site lies on a Pleistocene terrace overlooking the river. The earliest levels excavated are contemporary with the latest levels at Jerf el Ahmar and the upper levels date to approximately the end of the ninth millennium cal B.C. Much of the site consists of thick ash layers rich in charred remains. A funerary building was excavated and also a building containing wall paintings. Pits are common, but habitation structures, at least in the excavated area, are rare.

Tell ‘Abr (Yartah 2004, 2005) is situated about 25 km farther north in an area with an annual rainfall similar to that of Dja’de. The site is contemporary with the earlier levels at Jerf el Ahmar. Both round houses and communal buildings have been excavated. Only a small volume of sediment was sampled from this site. Three samples derived from a concentration of charred grain from one of the communal buildings destroyed by fire and appear to represent storage within it. Similar buildings were found at Jerf el Ahmar and Mureybet (Stordeur et al. 2000) but this is the first time that their use for storage has been demonstrated by the finds of charred grain.

Charred seeds from the four sites are generally in poor condition, often fragmented and lacking the testa. In addition, phenotypic variation, the high species diversity for the region as a whole and even the possibility of evolutionary changes means that species level identification for the majority of taxa is not possible. Because the testa is often missing, identification may rely on the internal seed structure. It is probable that hard-coated seeds such as *Galium* and *Adonis* survive preferentially and are over-represented compared to fragile seeds. Many of the identifications remain at genus level and in some cases represent more than one species. The taxa have then been divided into groups (Tables 2, 3, 4, 5, 6, 7, 8), which allow a more coherent interpretation. Several hundred illustrations of charred items including digital and SEM photographs, drawings and identification criteria are available for viewing at http://www.perso.orange.fr/g.willcox/. Bio-mineralised seeds of the Boraginaceae family of which *Arnebia* was particularly common have not been included because they were rarely carbonised, so we could not be sure that they were ancient.

Results

The total number of samples, the quantity of sediment, the volumes of charred remains and the number of identified items are given in Table 1. The number of samples and the quantity of sediment varied for each site, but were sufficient for making comparisons. Only 30 samples were obtained from Tell ‘Abr and most of the identified plant remains were concentrated in a few samples, which represent a burnt storage structure. The identified taxa have been divided into seven groups for the purposes of interpretation. Each group is presented as a table with absolute numbers of identifications and ubiquity, that is the percentage of samples in which a taxon is present regardless of quantity (Ub%). Each identifiable plant part, whether it was complete or a fragment, has been scored as one item.

Table 1 Volumes, number of samples and total items identified from the four sites

Site	Sediment (l)	Flot (ml)	Flot sorted (ml)	Samples	Total items
Tell ‘Abr	1,520	?	?	30	4,528
Dja’de	6,122	38,052	24,552	227	32,964
Jerf el Ahmar	12,114	25,802	23,104	266	34,067
Tell Qaramel	1,772	5,934	3,500	108	12,247

Wild cereals (Table 2)

Absolute identification scores and percent of ubiquity based on the total number of samples are given in Table 2. A selection of cereal items is given in the bar chart (Fig. 3), providing absolute numbers of finds and their relative proportions. No reliable evidence for domestication was found among the cereal remains. A few specimens of domestic-type fused barley spikelets were found, but they would be expected in a wild population where the basal spikelets do not shatter (Kislev 1992).

A large proportion of the charred grains were identified as *Triticum/Secale*, which includes wild rye and two-grained wild einkorn; these two species are difficult to distinguish from their grains, particularly in the charred state. This taxon is common at all four sites presented here (Fig. 3) and also at the earlier Euphrates sites of Mureybet and Abu Hureyra. Fortunately rye and einkorn can be distinguished on the basis of their spikelet bases. Rye spikelet bases were common at Jerf el Ahmar, rare at Dja’de and totally absent at Tell Qaramel, whereas einkorn spikelet bases were rare at Jerf al Ahmar, more common at Dja’de and made up all the finds at Tell Qaramel. Concerning rye at the earliest site on the Euphrates, no spikelet material was present at Abu Hureyra, but *Triticum/Secale* grains were common and according to Gordon Hillman (personal communication) the vast majority of the indeterminate grains were rye. At Mureybet (van Zeist and Bakker-Heeres 1984) rye spikelet bases were identified from impressions in pisé (Willcox and Fornite 1999). No einkorn was identified.

Some wild einkorn produces spikelets with a single grain (*Triticum* 1 g in Table 2 and Fig. 3). These are readily identifiable by their convex ventral face and so can be distinguished from *Triticum/Secale*. The changes in frequencies of single-grained einkorn are revealing from a chronological point of view. At the earliest sites of Mureybet and Abu Hureyra no einkorn was present and it was rare at Tell ‘Abr and in the earliest levels at Jerf el Ahmar; finds become increasingly more frequent in the

Table 2 Scores for grains and spikelet bases of wild cereals from the four sites

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
H. spontaneum gr	190	57	3,763	79	9,639	91	217	36
H. spontaneum base			153	11	3,325	58		
H. domestic rachis			2	1	8	2		
Triticum/Secale gr	2,999	86	1,120	64	2,539	81	1,170	46
Secale spk base			16	3	144	11		
Triticum base			16	5	5	2	292	9
T. boeoticum 1 gr	90	40	302	32	67	11	1,108	68
T. dicoccoides gr			192	21			4	2

Note that 10% of domestic barley type rachis fragments can occur in wild populations (Kislev 1992)

later levels (Fig. 4) and at Dja'de. These einkorn grains, like the einkorn spikelet bases, increase through time on the Euphrates sites.

Tell Qaramel is situated about 75 km west of the Euphrates, and single-grained einkorn and *Triticum/Secale* are present there in equal quantities, which is similar to proportions in modern wild populations in southeast Turkey where both two-grained and single-grained spikelets can be found on the same ear. These proportions combined with the absence of rye spikelet bases demonstrates that Tell Qaramel differs from the Euphrates sites because einkorn was commonly used and rye was absent.

Emmer was absent at the earlier Euphrates sites including Tell 'Abr and Jerf el Ahmar. It appears for the first time at Dja'de (Table 2). Three or four centuries later in the middle PPNB emmer became the principal wheat in the region, while rye disappears completely and einkorn remains are rare.

Wild barley, absent at Tell Abu Hureyra, the earliest site in the region, appears at Mureybet at the opening of the Holocene but is rare (van Zeist and Bakker-Heeres 1984). At the later Euphrates sites of Jerf el Ahmar and Dja'de it becomes increasingly frequent. This species is not common at Tell Qaramel. Of the wild cereals, it is the most resistant to high temperatures and drought. Unlike rye and einkorn, barley grows today on the poor chalk soils of the middle Euphrates. Its appearance is probably linked to the increase in temperature following the Younger Dryas. Being better adapted than rye to climatic and soil conditions there, barley was adopted as a crop. On the basis of other evidence it would seem probable that a combination of climate change and incipient cereal cultivation led to this species becoming increasingly frequent. At Jerf el Ahmar there is evidence based on both ubiquity and absolute

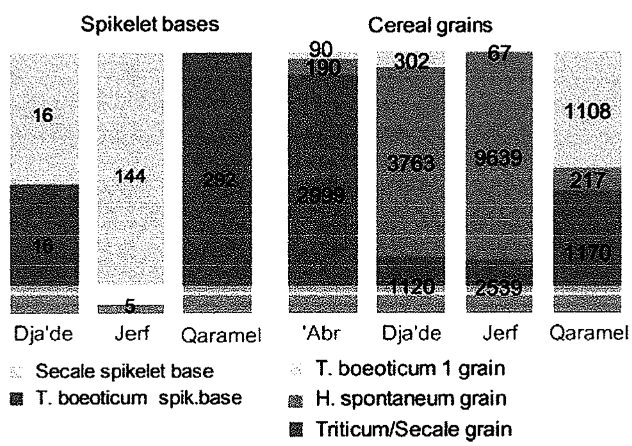

Fig. 3 *Left* absolute scores and proportions of *Secale* and *T. boeoticum* spikelet bases, Qaramel has only *T. boeoticum*, Jerf el Ahmar has predominantly *Secale* and Dja'de has equal proportions of each. *Right* absolute scores of single-grained *T. boeoticum*, *Hordeum spontaneum* and *Secale/Triticum* types. Taking into account grain identification and spikelet bases at Qaramel, *T. boeoticum* dominates, *Secale* is absent and *H. spontaneum* rare. At Jerf el Ahmar and Dja'de, *H. spontaneum* dominates and *Secale* is common while *T. boeoticum* is rare but increases with time (see Fig. 4)

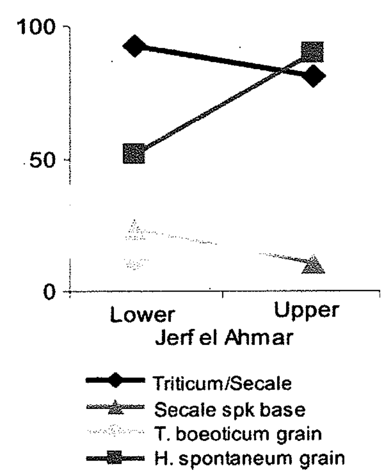

Fig. 4 Changes in the ubiquity frequencies of cereal items between early and late periods at Jerf el Ahmar (see also Tables 9, 10). These trends where barley and einkorn increase and rye diminishes follow an intra-site trend on Euphrates sites

Table 3 Scores for the identification of wild grasses excluding the cereals

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
H. murinum/bulbosum gr			632	40	2,100	68	63	16
H.murinum/bulbosum base					1	1		
H. bulbosum bulb					5	1		
Aegilops base			10	3	144	6		
Aegilops gr			13	5	7	3	1	1
Bromus	1	3	56	12	106	15	2	2
Stipa gr	11	13	272	12	118	5	526	11
Stipa twisted awn			14	4				
Taeniatherum base			69	8	70	12		
Taeniatherum gr			1,816	34	126	23	5	3
Poa bulbosum bract			14	2	17	3	36	1
Poaceae	87	23	3,488	63	2,380	45	267	39
Poaceae base			12	5	52	8		
Poaceae culm base			27	7	6	2		
Panicoid type					20	4	1	1
Phalaris							1	1
Echinaria			1	0.5			1	1
Eremopyron			42	11	9	4		
Lolium			7	3	4	1	3	3

frequencies that wild barley increases progressively from early to late levels (Fig. 4 and see also Tables 9, 10). At Tell 'Abr barley is not common, probably because the samples came from a storage structure which mainly contained *Triticum/Secale.*

Grasses (Table 3)

The small wild barleys (*H. murinum/bulbosum*) which make up a complex of four related species including *H. murinum* (Nesbitt 2006) are the most common wild grasses found on the sites. *H. bulbosum*, despite being a perennial with bigger grains and bulbs (swollen basal culms), has also been included in this group because in the charred state it is not easy to distinguish it from the other four species. This species was identified from the bulbs. *Taeniatherum caput-medusae*, the only species of its genus, was identified from both grain and spikelet material. It was recovered from three of the sites. *Aegilops* is present both in the form of spikelet bases and grains, the former having thick glumes which probably survive charring more readily than wild cereals. In a single archaeological context at Jerf el Ahmar, 118 spikelet bases were found concentrated as though they represented the residue of threshing. These spikelet bases compared well with those of *A. speltoides*. Another common taxon was *Stipa*, also represented by its twisted awns. These grass taxa as an assemblage could represent weeds of cultivation or part of a gathered assemblage, which included wild cereals. If they were consumed, their generally smaller size compared to the larger grained wild cereals and lower frequencies indicate they would have represented a small part of the food resources at these sites compared to wild cereals. This was not the case further north in south-east Turkey where Savard et al. (2006) established that small seeded grasses were the most common at Hallan Çemi and Demirköy. These sites are considered to have been inhabited primarily by gatherers. Weiss et al. (2004) demonstrated a gradual decline in the use of small seeded grasses between the Epipalaeolithic and the PPNB.

Seeds from wild and/or weed taxa (Table 4)

This group of 54 taxa includes 18 (marked with * in Table 4), which have no apparent use for food, fibres, dyes etc. This assemblage in relation to its interpretation as weeds of cultivation is discussed in more detail below. Other wild/weed taxa could have been used as food plants, for example *Alyssum/Lepidium*, a Crucifer type, and *Polygonum/Rumex* were found in high concentrations in a limited number of samples suggesting intensive use. Taxa such as *Atriplex* and *Verbascum* may have been used as fuel. Others such as *Androsace maxima, Hyoscyamus, Peganum hamala* and *Tribulus terrestris* were ruderals probably growing near the habitations. Finally, high concentrations of *Ziziphora* at Tell Qaramel suggest that this aromatic plant had some particular use. Similarly high levels were found at Hallan Çemi (Savard et al. 2006).

Table 4 Scores for taxa of wild plants

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
*Adonis**	1	3	48	13	55	11	7	6
*Ajuga/Teucrium**			4	1				
*Alyssum/Lepidium**			**488**	15	2	1		
Androsace maxima			8	3	32	6	2	
Apiaceae			1	1	5	2	5	4
Apiaceae type 1			158	9			46	5
Astragalus	4	13	290	27	224	32	7	5
Atriplex			4,554	69	1	1		
*Bellevalia**			27	7	201	8	30	15
Brassicaceae	**806**	60					18	6
Brassicaceae type 1					**532**	10		
Brassicaceae type *Brassica*			60	5	20	6		
*Bupleurum**							91	13
*Centaurea**			338	31	20	4		
Chenopodiaceae	1	3	28	4	103	5	2	2
Chenopodiaceae type 2			294	27	10	3		
Compositae	1	3			5	2	27	7
Compositae type 1			**105**	4				
*Coronilla**			4	2	3	1	4	4
Crucianella					1	1	3	2
Cucurbitaceae type *Bryonia*			2	1	28	6		
Cyperaceae			8	3	32	9	242	44
*Erodium**	3	7	66	7	33	9		
Erodium spiral beak*					7	1		
Fabaceae type 1			932	35	203	23	3	2
*Fumaria**			24	9	8	2		
*Galium**			67	16	195	31	2	2
*Glaucium**			288	16	14	3	8	4
*Heliotropium**			19	8	18	4	7	6
Hyoscyamus			31	8			19	6
insect			6	1	3	1	12	4
Lamiaceae	1	3	8	3			53	7
Malva			1	1	8	1	4	4
Medicago							1	1
Medicago pod							1	1
Medicago radiata			6	2	4	2	4	4
*Nigella**							1	1
*Onobrychis**			107	15	6	2		
*Ornithogalum**			2	1	14	4	2	
*Papaver**							2	
Papaveraceae					2	1		
Peganum harmala			1	1				
Plantago			2	1	1	0		
Polygonum/Rumex			37	7	**497**	38	11	4
rhizome			4	2			1	1
Rubiaceae					4	0		
*Silene/Gypsophila**	8	1	148	19	**519**	40	13	8

Table 4 continued

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
Solanaceae			1	0				
*Thymelaea**			5	2	31	6	1	1
*Tragopogon**					2	1		
Tribulus terrestris			2	1	1	1		
Trifolieae			317	23	**232**	30	75	19
Trigonella			7	2	7	2	3	3
Trigonella astroites			10	1	15	4	5	3
Vaccaria			1	0			2	1
Valerianella			2	1			5	4
Verbascum			1	0	2	1	5	2
Ziziphora					27	2	**959**	53
Indeterminate			3,014	57	2,867	72	520	45

Those marked with * are part of a proposed weed assemblage. The numbers marked in bold are taxa which have high concentrations in some samples and low ubiquity which suggests that they were gathered for a specific use

Large seeded legumes (Table 5)

This group is common on all sites, both in abundance and ubiquity. Fragmentation and the absence of the testa limited the precision of identifications. A few well-preserved specimens with the testa intact were identified as *Pisum elatius*, the progenitor of the domestic pea. The low numbers of this species are due to poor preservation. Many of the pulses identified as *Pisum/Vicia/Lathyrus* may have been *Pisum elatius*.

The most abundant pulse was *Lens*. No species identification was possible but this taxon closely resembles *L. orientalis*. This species is not a common component of Near Eastern vegetation and is often restricted to small stands, making gathering an arduous task. Its abundance on the sites, combined with the fact that the middle Euphrates is not an ideal habitat for this species suggest that it may have been cultivated. *Vicia ervilia*, *Lathyrus* and *Vicia* may have been weeds of cultivation. *Cicer* and *Vicia faba* were new cultivars that appear for the first time at Dja'de; other early finds come from Tell Kerkh (Tanno and Willcox 2006b).

Fruits of trees and shrubs (Table 6)

Pistacia (assumed to be *P. atlantica*) fruits were very abundant as they are on most early agriculture sites in the Near East. Wood charcoal was also abundant indicating that that *P. atlantica* was far more widespread at this time. The nuts of this species are still gathered and consumed in Turkey and Syria today. Oil is extracted from the nuts and a drink similar to coffee is still produced on a commercial scale in Turkey. At Tayyibeh in central Syria farmers cultivate *Pistacia atlantica* for its nuts. In recent years it has been planted in government reforestation programs in the arid zones of northern Syria. This species appears to have been economically important during the tenth and ninth millennia B.C.

Fragments of *Amygdalus* cf. *communis* stones are common at Tell Qaramel while at Jerf el Ahmar another taxon,

Table 5 Scores for Fabaceae seeds from the four sites

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
Pisum elatius			13	3	3	1	1	1
P./Vicia/Lathyrus	37	26	1,952	68	482	55	682	63
Lathyrus			9	4	2	1	8	6
Lens	230	70	5,850	84	1,820	77	1,113	78
Vicia							19	8
Vicia ervilia			34	9	62	16	11	5
Vicia faba			2	1				
Cicer			3	1				

Table 6 Scores for fruits and edible nuts from tree and shrub taxa

Shrubs and trees	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
Pistacia whole fruit			23	4	4	1	64v	12
Pistacia frags	2	7	911	47	2,650	63	1,705	58
Amydalus cf *communis*							2,214	48
Amygdalus webbii/orientalis					1,588	56		
Vitex agnus-castus					34	4		
Vitis sylvestris			4	2				
Quercus acorn							3	2
Ficus carica			42	8	11	3	4	4
Fruit frag			3	1	1	1	5	2
Celtis					1	1	400	35
Capparis			166	11	339	22		

A. orientalis/webbii, occurs. It is not known whether these almonds were toxic. If so, they could have been consumed because the toxicity can easily be removed by roasting. The difference in almond taxa between Tell Qaramel and Jerf el Ahmar (none were found at Dja'de), the occurrence of *Celtis* and acorns only at Tell Qaramel, and the presence of *Vitex agnus-castus* only at Jerf el Ahmar would appear to reflect the differences in the plant associations found near the sites. Like other sites dated to the end of the Younger Dryas and the beginning of the Holocene, the vegetation consisted of plants which could grow in the area today if human pressure was removed. This suggests that the climate of the Younger Dryas did not greatly affect the vegetation in this part of the Near East (Bottema 1995; Roitel and Willcox 2000).

Ficus carica seeds do not occur on the early Euphrates sites of Abu Hureyra and Mureybet phases 1 and 2. At Jerf el Ahmar and Qaramel they are insignificant, but are more common at Dja'de. In the southern Levant where figs were in frequent use at an earlier date, it has been proposed that they were cultivated and even domesticated during the ninth millennium cal B.C. (Kislev et al. 2006).

Processed plant remains (Table 7)

Charred clusters of fused seed fragments resembling seed cakes, and amorphous charred masses were commonly encountered. These appear to be the remains of prepared food and could potentially provide information about diet and food processing. At the time of writing only the complete seed cake found at Jerf el Ahmar has been studied (Willcox 2002a). The remaining samples will be studied at a later date.

Charred animal droppings (Table 8)

This is the first time charred rodent droppings have been observed on early farming sites. The regular occurrence of small rodent droppings, which correspond in size approximately to those of the domestic house mouse, is highly significant because it suggests that storage of grain was widely practised at these sites. Six archaeozoological finds of domestic mice (*Mus musculus domesticus*) were identified at Dja'de and one at Jerf el Ahmar (Cucchi et al. 2005). 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. This rodent was also introduced to Cyprus by about 8,500 cal B.C. (Cucchi et al. 2005). Recovery of small rodent remains requires special techniques, which are not always applied, so this species may have been more widely distributed than the archaeozoological finds suggest.

Table 7 Scores for charred finds of processed food and flower bases

	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
Seed cake					11	4	9	1
Amorphous frags	56	40	116	48	119	43	43	19
Flower base			17	3	2	1	17	9
Asteraceae capitulum			33	3	1	1		

Table 8 Scores for charred animal droppings found at three of the sites

Charred coprolites	Abr		Dja'de		Jerf		Qaramel	
	T	Ub%	T	Ub%	T	Ub%	T	Ub%
Ungulate			2	1				
Small rodent			221	25	51	11	49	25

Archaeozoological analyses suggest that the small rodent droppings were probably of *Mus musculus domesticus*, the common house mouse. Those of the ungulates are more problematical

These finds (including Tell Qaramel) demonstrate that the house mouse was taking advantage of stored grain at many sites in the Near East at the beginning of the Holocene. This suggests that we are dealing with a very common wild rodent that was pre-adapted to human habitation, which it regularly colonised. However, the mouse's successful introduction to Cyprus and other parts of the world resulted from regular large-scale movement of grain. Whether transport of grain could have helped mice to colonise areas outside their natural habitats in the Near East at an earlier date is not known.

Discussion of the evidence for cultivation

The location of sites beyond wild cereal habitats

A good sign of pre-domestic cultivation is the presence of wild cereals outside their natural habitats. The sites of Jerf el Ahmar, Cheik Hassan, Mureybet and Abu Hureyra are almost 200 km south of current-day wild rye habitats and between 100 and 150 km south of wild einkorn habitats. Today the climate of the middle Euphrates is too hot and dry for wild rye and wild einkorn. Willcox (2005) suggests that wild rye and wild einkorn habitats were limited in the middle Euphrates by the poor chalk soils, which are not suitable for these species. Even at higher latitudes, with cooler temperatures and a higher rainfall, wild rye does not grow on these soils.

The frequency of wild rye on middle Euphrates sites suggests that it was at its maximum during the cool Younger Dryas and that it diminished with the onset of global warming as habitats retreated north, following the regional climatic gradient, in response to increased temperatures.

Given lower temperatures during the Younger Dryas could these cereals have grown nearer the sites? As stated in the introduction we cannot know the distances that wild stands were from the sites. The distance would have varied depending on the climatic conditions and the relative positions of the sites (Willcox 2005). Rye would have been collected from areas with more acidic soils, such as those found on basalt. The nearest basalt outcrops are located a few days' walk north-east of Dj'ade and Tell 'Abr. Given cooler climatic conditions than today, these are the most likely habitats for rye and it is possible that a few smaller stands extended further south.

The southernmost Euphrates sites lay beyond, or were in a marginal position in relation to wild rye stands during the Younger Dryas. If they were far from wild stands this would have created an incentive to cultivate at an early date as suggested by Hillman (2000). Alternatively, if they were near, then over-exploitation and climate warming would have reduced availability, creating an incentive to cultivate at the beginning of the Holocene.

Transport of grain over varying distances is an inevitable factor whether we are dealing with 5 km or 150. When transport of grain for consumption becomes impractical for one reason or another, then the import of seed for cultivation, of which only a tenth of the grain weight would be needed compared with that for consumption, becomes an option. At a later date seed from cultivation would be put aside for planting; in the long term this would have been the preferred option, providing a local, secure and dependable supply of grain. There is, of course, no evidence of pack animals. The rivers Euphrates and Balikh were probably not easily navigable. However, taking into account the extraordinary architectural finds at the site of Göbekli, which is included in the same cultural area as Jerf el Ahmar and Tell 'Abr, we should not underestimate the technical capabilities of the inhabitants of these sites.

Wild einkorn, like wild rye, is ill adapted to the edaphic and Holocene climatic conditions of the middle Euphrates. For this reason one would expect it to decline like rye; the fact that it increases strongly suggests that it was being brought into cultivation from elsewhere. The same can be argued for the appearance of emmer. Under cultivation, these cereals would have been able to thrive in adverse climatic and edaphic conditions, because fields would have been situated in favourable microhabitats where competition had been removed (Valkoun et al. 1998; Willcox 2005).

Tell Qaramel is situated in a different region with a higher rainfall. The absence of rye at this site compared to the Euphrates sites can be explained by the absence of basalt in the area and the proximity of potential einkorn habitats on decalcified soils, which form on the hard limestone soils not far from the site. We cannot argue that Tell Qaramel was beyond the area of wild cereals.

A reduction in small gathered seeds from non-founder plants

During the tenth millennium in the northern Levant the gathering of small seeded grasses, rye, Polygonaceae and Cyperaceae show a progressive decline (Weiss et al. 2004; Willcox 2005). Figure 5 illustrates this decrease on Euphrates sites. At Jerf el Ahmar this gradual reduction in the use of small-seeded taxa such as *Polygonum/Rumex* and small-seeded grasses can be seen by comparing the early and late levels (Tables 9, 10). We suggest that this is evidence that the gathering of wild plants gradually gave way to the cultivation of founder crops.

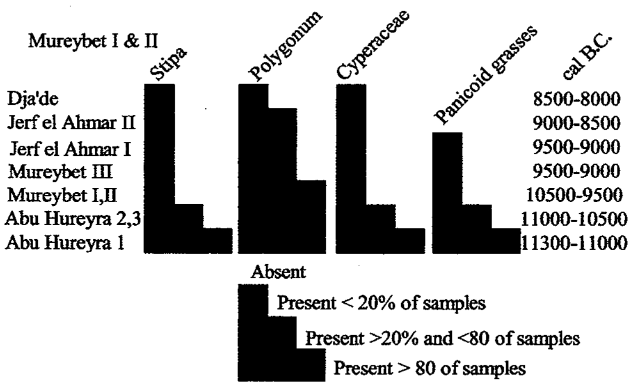

Fig. 5 Ubiquity frequencies of non-founder small seeded taxa from four sites on the Euphrates. They become less frequent as the gathering of wild plants diminishes and cultivation of founder crops increases

The gradual adoption of founder crops in the middle Euphrates

Table 11 gives cereal finds from the Euphrates sites and demonstrates on a presence/absence basis the progressive increase of barley, single-grained einkorn and emmer. As we have already discussed, these changes may result from several factors, such as proximity of wild stands or changes in climate, but the overriding factor was that these founder species were being progressively brought into cultivation. Barley is absent at Abu Hureyra, but it appears at Mureybet and then increases in frequency. Wild barley, unlike wild rye, is adapted to an arid, warmer climate. It would have tended to expand at the beginning of the Holocene when it came into contact with cultivation and was adopted as a cultivar. Finally at Dja'de, the most recent site, emmer, *Vicia faba* and *Cicer* all appear for first time far from their natural habitats.

Weeds of cultivation

Taxa marked with * and given in Table 4 resemble an assemblage of weeds of cultivation, to which can be added some of the pulses and wild grasses. The relative ubiquity percentages are given in Fig. 6, the figures being taken from Table 4. Although these taxa can also occur in low frequencies in wild cereal stands, they proliferate under cultivation. At Bronze Age sites weed assemblages are comparable (L. Herveux, in preparation). In contrast these taxa are less frequent on Epipalaeolithic sites. Of the 16 selected taxa from Jerf el Ahmar only one occurs at Ohalo II (Kislev et al. 1992), eight at Abu Hureyra and 12 at Tell Qaramel (Table 12). This comparison suggests that weeds of cultivation increase with time.

Table 9 Selected taxa from Jerf el Ahmar, which show a significant increase in frequencies in later levels

Periods:	Early	Late	Early	Late
Phases:	4 + 5	1 + 2	3 + 4 + 5	1 + 2 + 3
Total samples:	81	76	159	154
Total items:	12,097	10,638	17,431	15,972
T. boeoticum base				
T		3	1	4
T. boeoticum grain				
T	18	41	26	49
Ub%	11	18	10	14
H. spontaneum gr				
T	2,353	5,234	3,593	6,474
Ub%	52	90	93	65
H. spontaneum base				
T	1,546	1,622	1,670	1,746
Ub%	64	84	50	59
Ornithogalum				
T	1	13	1	13
Ub%	1	6	1	6
Bellevalia				
T	34	106	73	145
Ub%	25	47	23	34
Vicia ervilia				
T	10	31	24	45
Ub%	20	28	12	21

Two combinations of phasing are given with absolute totals (T) and ubiquity (Ub%)

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 from several sites including Jerf el Ahmar and Dja'de demonstrated that there is a small increase in thickness and breadth between the lower and upper levels at Jerf el Ahmar but that in the same geographical area there is no further increase for several millennia (Willcox 2004). It is highly improbable that the small increase represents selection within a population for larger grains, particularly when spikelet bases are all of wild type. It is more likely that it represents either the adoption of a plump-grained population from elsewhere, probably the case for single-grained einkorn, or that favourable growing conditions under cultivation produced a higher proportion of fully developed grains than would occur in a wild population. There is no evidence that grain length increased. This change in size may thus be the result of increased reliance on cultivation.

Table 10 Selected taxa from Jerf el Ahmar, which show a significant decrease in frequencies in later levels

Periods:	Early	Late	Early	Late
Phases:	4 + 5	1 + 2	3 + 4 + 5	1 + 2 + 3
Total samples:	81	76	159	154
Total items:	12,097	10,638	17,431	15,972
Triticum/Secale gr				
T	1,382	396	2,041	1,055
Ub%	92	81	83	77
Secale base				
T	121	18	125	22
Ub%	23	10	13	6
Polygonum/Rumex				
T	359	73	412	126
Ub%	57	34	44	32
Panicoid				
T	19	0	20	1
H. murinum/bulbosum				
T	614	116	724	226
Ub%	66	44	49	38
Ziziphora				
T	26	0	27	1

Two combinations of phasing are given with absolute totals (*T*) and ubiquity (*Ub%*)

Cultivation without domestication

There is no evidence at these four sites for plant domestication seen in the loss of dispersal mechanisms for either cereals or pulses. Theoretically the domestication process could have been rapid (Hillman and Davies 1990). Why then, if we propose cultivation at these sites, did domestication not appear earlier? Seed stock may have been regularly replenished from wild stands to counter poor harvests, which may have been frequent in the arid middle Euphrates. In addition, if harvests occurred early in the season before the ears shattered, then the probability of selection for the rare mutants that had lost their dispersal mechanism would be extremely slim. Finally, recent evidence from a study of spikelet bases from a number of sites suggests that domestication was slow to become established (Tanno and Willcox 2006a).

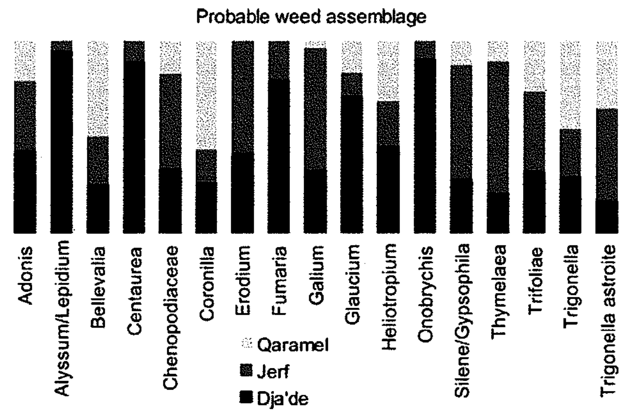

Fig. 6 Each bar compares the ubiquity percentages between sites for each potential weed taxon. For the ubiquity values see Table 4. We interpret the overall pattern as being suggestive of an assemblage of weeds of cultivation

Conclusions

Gordon Hillman suggested that the inhabitants of Abu Hureyra were cultivators by about 11,000 cal B.C. Sue Colledge (1998) identified a weed flora at Mureybet. At Jerf el Ahmar and Dja'de we have demonstrated five lines of evidence which suggest cultivation of wild cereals and

Table 11 Finds of wild cereals from Euphrates sites

	Abu Hureyra 1	Mureybet I & 2	Mureybet III	Tell' Abr	Jerf el Ahmar	Göbekli	Dja'dé	Nevali
Triticum/Secale	>5,000	19	>500	2,999	2,539	5	1,120	?
Triticum base	?	?	?	?	5	?	16	>3,000
Secale sp. Base	?	p	p	?	145	?	16	0
H. spontaneum gr	0	5	164	190	9,639	16	3,763	89
H. spontaneum base	0	0	6	?	3,325	?	153	P
Einkorn 1 gr	0	0	0	90	67	?	302	661
T. dicoccoides	0	0	0	0	0	?	192	129
Sediment (1)	>10,000	ca. 310	ca. 310	4,520	16,600	?	6,122	?
Number of samples	21	31	31	30	430	1	229	267
Approx. Date	11,000 cal B.C.		9,250 cal B.C.			8,500 cal B.C.		

0 = absence significant. ? = absence not significant. Presence/absence demonstrates that new founder crops were brought into cultivation at different times between 11,000 and 8500 B.C. Factors effecting why cereals were brought into cultivation at different times may include climate change, varying proximity to wild stands, and most importantly the adoption of cultivation

Table 12 Presence/absence of a selected weed assemblage (first identified at Jerf el Ahmar) showing that while these taxa are almost absent from the Kebaran site, the Natufian, Kiamian and PPNA sites have progressively more weeds of cultivation which may reflect the increasing adoption of cultivation at these sites

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

pulses. Tell 'Abr has less information but falls into the same pattern as the Euphrates sites. Tell Qaramel has fewer signs of cultivation. This site occurs in a moister area where wild einkorn and barley could have grown naturally. The similar quantities of charred rodent droppings compared to Jerf el Ahmar and Dja'de are evidence for the intensity of cereal use, including storage. There is no evidence that new cultivars were introduced, but the high frequencies of lentils and the potential weed assemblage suggest cultivation despite the probability that wild einkorn would have been readily available in the area.

On a more general level, 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. It is possible that with sedentary life, societies, which collected and stored seeds from annual plants practised small-scale cultivation from an early date, but this would leave little evidence. The incentive to cultivate could have been due to multiple factors, but the overriding factors would be difficulty in finding 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 their rarity. Even when cereals and pulses were regularly cultivated, seed may have been obtained from wild stands for long periods, which would explain why morphological evidence of domestication was slow to appear, only becoming established when intensive cultivation was practised exclusively and on a large scale.

Acknowledgments Our thanks to archaeologists E. Coqueugniot (CNRS Lyon), R. Mazurowski (Warsaw University), D. Stordeur (CNRS Jalès) and T. Yartah (Antiquities Department, Damascus, Syria) for helping with sampling in the field and entrusting the plant remains to us. We also thank F. Barbot who helped with the sorting. This project was partially funded by a European project (ICA3-CT-2002–10022).

References

Bottema S (1995) The Younger Dryas in the eastern Mediterranean. Quaternary Sci Rev 14:883–891

Colledge S (1998) Identifying pre-domestication cultivation using multivariate analysis. In: Damania AB, Valkoun J, Willcox G, Qualset C (eds) The origins of agriculture and crop domestication. ICARDA, Aleppo (Syria), pp 121–131

Coqueugniot E (2000) Dja'de (Syrie), un village à la veille de la domestication (seconde moitié du 9e millénaire av. J.C.). In: Guilaine J (ed) Les premiers paysans du monde, naissance des agricultures. Paris, Errance, pp 63–79

Cucchi T, Vigne JD, Auffray JC (2005) First occurrence of the house mouse (*Mus Musculus Domesticus*, Schwarz and Schwarz 1943) in the Western Mediterranean : a zooarchaeological revision of subfossil occurrences. Biol J Linnaean Soc 84:429–445

de Moulins D (1997) Agricultural changes at Euphrates and steppe sites in the mid-8th to the 6th millennium B.C. BAR International Series 683, Oxford

Hillman G (2000) Plant food economy of Abu Hureyra. In: Moore A, Hillman G, Legge T (eds) Village on the Euphrates, from foraging to farming at Abu Hureyra. Oxford University Press, New York, pp 372–392

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

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

Kislev M (1992) Agriculture in the near east in the 7th millennium B.C. In: Anderson P (ed) Préhistoire de l'agriculture. Paris: Monographie du CRA n6, Editions CNRS, pp 87–94

Kislev M, Hartmann A, Bar-Yosef O (2006) Early domesticated fig in the Jordan valley. Science 312:1372–1374

Kislev ME, Nadel D, Carmi I (1992) Epipalaeolithic (19,000 B.P.) cereal and fruit diet at Ohalo II, Sea of Galilee, Israel. Rev Palaeobot Palynol 73:161–166

Mazurowski R (2004) Tell Qaramel excavations, 2003. Polish Archaeol Mediterr 15:355–370

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

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. Studies in Near Eastern production, subsistence and environment 6. ex oriente, Berlin, pp 113–132

Nesbitt M (2006) Identification guide for Near Eastern grass seeds. Institute of Archaeology, UCL, London

Pasternak R (1998) Investigations of botanical remains from Nevali Çori PPNB, Turkey. In: Damania A, Valkoun J, Willcox G, Qualset C (eds) The origins of agriculture and crop domestication. ICARDA, Aleppo (Syria), pp 170–177

Roitel V, Willcox G (2000) Analysis of charcoal from Abu Hureyra. In: Moore AMT, Hillman G, Legge T (eds) A village on the Euphrates. Oxford University Press, Oxford, pp 544–547

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(2):179–196

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

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

Tanno K, Willcox G (2006a) How fast was wild wheat domesticated? Science 311:1886

Tanno K, Willcox G (2006b) The origins of cultivation of *Cicer arietinum* L. and *Vicia faba* L.: Early finds from north west Syria (Tell el-Kerkh, late 10th millennium B.P.). Veget Hist Archaeobot 15:197–204

Valkoun J, Giles J, Waines J, Konopka J (1998) Current distribution and habitat of wild wheats and barley. In: Damania A, Valkoun J, Willcox G, Qualset C (eds) The origins of agriculture and crop domestication. ICARDA, Aleppo (Syria), pp 293–299

van Zeist W, Bakker-Heeres JAH (1984[1986]) Archaeobotanical studies in the Levant 3. Late-Palaeolithic Mureybet. Palaeohistoria 26:171–199

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

Weiss E, Kislev M, Hartmann A (2006) Autonomous cultivation before domestication. Science 312:1608–1610

Weiss E, Wetterstrom W, Nadel D, Bar-Yosef O (2004) The broad spectrum revisited: evidence from plant remains. PNAS 101:9551–9555

Willcox G (2002) Charred plant remains from a 10th Millennium B.P. kitchen at Jerf el Ahmar (Syria). Veg Hist Archaeobot 11:55–60

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 (2005) The distribution, natural habitats and availability of wild cereals in relation to their domestication in the Near East: multiple events, multiple centres. Veg Hist Archaeobot 14:534–541

Willcox G, Fornite S (1999) Impressions of wild cereal chaff in pisé from the tenth millennium at Jerf el Ahmar and Mureybet: northern Syria. Veg Hist Archaeobot 8:21–24

Yartah T (2004) Tell ‘Abr 3, un village du Néolithique précéramique (PPNA) sur le Moyen-Euphrate. Première approche. Paléorient 30:141–158

Yartah T (2005) Les bâtiments communautaires de Tell ‘Abr 3 (PPNA, Syrie). Neolithics 1/05:3–9