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When and where did domesticated cereals first occur in southwest Asia?

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Introduction

Pioneering archaeological and botanical fieldwork from the late 1950s to early 1970s established two key points about the origins of the cereal-based farming economies of Europe and southwest Asia. They had their origin in the "fertile crescent" that stretches from the Levant to the Zagros mountains, and the earliest domesticated plants appeared in the archaeological record about 10,000 radiocarbon years ago.

Two lines of evidence were important. First, botanical evidence showed that the wild ancestors of most of the Neolithic crops grew only in, or were concentrated in, the fertile crescent (Harlan and Zohary, 1966). Second, excavation of archaeological sites and analysis of plant remains showed that the earliest settlements with domesticated plant remains were in or near to the fertile crescent (van Zeist, 1976). The first farming villages of a given region appear later the further away they are from the fertile crescent (Ammerman and Cavalli-Sforza, 1971; Ammerman and Cavalli-Sforza, 1984).

At the same time, the similarity in timing of the first domesticated plants about 10,000 years ago, and the earliest phase of the Neolithic (Pre-Pottery Neolithic A) at 10,300 years ago was obvious. Most syntheses of Near Eastern prehistory suggested that a key defining factor for Neolithic societies was that they depended on farming. There are good reasons besides timing for linking a major change in societal organisation – the development of the Neolithic – to the beginning of farming. It has long been noted (and most recently eloquently expounded by Jared Diamond (1997)) that ethnographically documented hunter-gatherer societies are relatively mobile and have low population densities, while farming societies are sedentary, support high population densities, and have largely displaced hunter-gatherer societies world-wide. These attributes are linked to the far higher productive capacity of farming systems, in particular their ability to spread cultivation beyond the area occupied by the wild ancestors of crop plants.

Challenges to this straightforward view – that domestication, agriculture and the Neolithic are more-or-less contemporaneous – has come from two directions. First, it has been argued that domestication occurs significantly earlier or later than the beginning of the Neolithic; second, it is being increasingly argued that the establishment of agricultural societies occurs much later than the initial domestication of plants.

The aim of this paper is to focus on the first question, by looking in detail at the date and location of the first domesticated plants in the fertile crescent. In order to avoid writing a comprehensive review of agricultural origins in southwest Asia, I do not discuss the essential precursor of domestication, the cultivation of wild plants (see Sue Colledge's paper in this volume), and the question of when societies using domesticated plants can be said to be fully agricultural (see David Harris's paper).

Instead, I have taken the opportunity to discuss the identification of domesticated plants in the archaeological record in more detail than is usual. Differences of opinion regarding the detection and dating of early domestication have become increasingly apparent in the last decade but it is rare, outside the confines of individual site reports, to find detailed discussion of the archaeobotanical data that underpins these different interpretations. In this paper and its appendix, I critically review the evidence for domesticated plants at Epipalaeolithic and Pre-Pottery (Aceramic) Neolithic sites in the fertile crescent. Overall the approach I take is that promoted in a classic paper by Harlan and de Wet (1973), in which they argue that data for early agriculture must be judged by its quality, and that evidence should further be judged by how well it integrates with other data. Evidence that conflicts with wider patterns needs to be strong.

Site (phase)	Country	Period	Date (uncal. years BP)	Crop status	WILD EIN	WILD EM	WILD BAR	WILD RYE	DOM EIN	DOM EM	NAK WHT	DOM BAR	NAK BAR	DOM RYE
Ohalo II	Israel	Epipal. (Kebaran)	19400	Wild										
Wadi al-Hammeh 27	Jordan	Epipal. (Natufian)	12200-11900	Wild										
Iraq ed-Dubb (below)	Jordan	Epipal. (Natufian)	11200-10800	?										
Hayonim Cave & Terrace	Israel	Epipal. (Natufian)	12300-10000	Wild										
Abu Hureyra (I)	Syria	Epipal. (Natufian)	11500-10000	Wild										
Mureybit (I-III)	Syria	Epipal. & PPNA	10500-9600	Wild										
Qermez Dere	Iraq	PPNA	10150-9600	Wild										
Netiv Hagdud	Israel		10000-9400	Wild										
M'lefaat	Iraq		9900-9650	Wild										
Iraq ed-Dubb (structures)	Jordan		9950	?										
Jerf al Ahmar	Syria		9800-9700	Wild										
Tell Aswad (I)	Syria		9700-9300	?										
Jericho (VIIA-X)	Palestine		9400-9200	?										
Dja'de	Syria	Early PPNB	9600-9000	Wild	?									
Wadi el-Jilat 7	Jordan		9500-9200	?										
Nevalı Çon	Turkey		9250	Dom.										
Çayönü (grill-cobble)	Turkey		9200-8600	Dom.		?								
Nahal Hemar (3-4)	Israel		9200-8100	Dom.										
Cafer Höyük (XIII-IX)	Turkey		9200-?9000	Dom.										
'Ain Ghazal	Jordan	Middle PPNB	9200-8000	Dom.										
Beidha	Jordan		9100-8550	Dom.										
Ganj Dareh	Iran		9000-8400	?										
Abdul Hosein	Iran		9000-8400	Dom.										
Abu Hureyra (2A)	Syria		9000-8300	Dom.										
Cafer Höyük (III-IV)	Turkey		9000-8500	Dom.										
Tell Aswad (II)	Syria		8900-8500	Dom.										
Aşıklı Höyük	Turkey		8800-8500	Dom.										
Jericho (Tr I: XI-XXII)	Palestine		8800-8650	Dom.										
Wadi el-Jilat 7	Jordan		8800-8500	Dom.										
Ghoraife	Syria		8800-8300	Dom.										
Jarmo	Iran		8750	Dom.										
Ali Kosh (BM)	Iran		8750	Dom.										
Halula	Syria		8700-7900	Dom.										
Tell Sabi Abyad II	Syria	Late/Final PPNB	8500-8000	Dom.										
Wadi Fidan A	Jordan		8500-8100	Dom.										
Ras Shamra (Vc)	Syria		8500-8000	Dom.										
Gritille	Turkey		8500-7800	Dom.										
Can Hasan III	Turkey		8400-7700	Dom.										
Azraq 31	Jordan		8350-8300	Dom.										
Dhuweila (I)	Jordan		8350-8200	Wild										
Tell Bouqras	Syria		8350-7850	Dom.										
Tell Ramad (I)	Syria		8300-8100	Dom.										
Abu Hureyra (2B)	Syria		8300-8000	Dom.										
Wadi Fidan C	Jordan		8100-7600	Dom.										
El Kowm II - Caracol	Syria		7800-7700	Dom.										
Atlit-Yam	Israel		7700	Dom.										

Table 1. Archaeobotanical records for cereals in the Epipalaeolithic and Pre-Pottery Neolithic periods. Shaded box indicates identification based on chaff (and thus, most reliable); dotted box indicates identification based on grain alone. Identifications follow original publication with some changes which are explained in the appendix. Domestication status of barley grains is uncertain unless supported by identification of chaff. ? indicates uncertain identification. Assessments of overall domesticated or wild status for plants at the site are my own. Abbreviations: EIN Einkorn; EM Emmer; BAR Barley; NAK WHT Free-threshing (naked) wheat; DOM Domesticated. Periodisation is on a strictly chronological rather than cultural basis.

Determining the date of the first appearance of domesticates is important for three reasons:

- Domestication gives a firm date before which we should be looking for cultivation of wild plants, in particular of the wild ancestors of crops. If domestication occurs early in the Neolithic, it means we should be looking for cultivation in the Epipalaeolithic; if it occurs later in the Neolithic, say in the PPNB, we should be looking at the early Neolithic. Dating the beginning and end of cultivation of wild plants is essential for assessing the success of explanations of agricultural origins that invoke environmental, technological or socio-cultural changes occurring at a particular time.
- Domestication itself marks a significant change in the nature and productivity of plants. In particular, the loss of ability to disperse seed means that domesticated plants are more productive, because less seed is lost in harvesting.
- Domestication marks the beginning of farming. If farming does have the society-changing role ascribed to it, then a firm date for its beginning is needed in order to look for other, subsequent, changes in ancient societies.

Although domestication is only one stage in the transformation from cultivation of wild plants by hunter-gatherers to fully agricultural societies, it is a useful marker because it is more easily detected in the archaeological record than cultivation, and it represents an important change in its own right.

Terminology

The study of agricultural origins has long been beset by confusion. In the last thirty years archaeologists have drawn on examples from ethnography and zoology to argue for a continuity between gathering and cultivation of wild plants, and agriculture (Higgs and Jarman, 1969; Rindos, 1984). This interest in continuity has, naturally, led to an intergrading of terms, for example, with the term agriculture sometimes applied to any form of management of plants and animals (cf. Tudge, 1998) – a sense so broad as to lose any use.

In this paper I use certain terms in more specific senses, now widely understood by archaeologists:

- gathering is the collection of wild plants from their natural habitat. Modifications to natural habitat, if any, involve low investment of labour, for example burning.
- cultivation is the sowing and harvesting of wild plants in tilled soil
- domestication is the process in which humans take control of the reproduction of plants and animals, and consciously or unconsciously select for attributes favourable to human use. For cereals control of reproduction means repeated sowing and harvesting of the same population, and the key attribute selected for is loss of the ability to disseminate seed without human intervention.
- farming or agriculture involves (for cereal and pulse crops) the cultivation of domesticated plants.

Like Harris (1989), I see the succession from gathering to cultivation of wild plants, their domestication, and agriculture, as an evolutionary continuum involving increasing input of human energy per unit area of exploited land.

Chronology

All dates given are in uncalibrated radiocarbon years before present (BP). Although it is now possible to calibrate radiocarbon dates back to about 20,000 radiocarbon years BP, calibration has not yet been widely applied to the Neolithic or earlier periods. Period terms such as PPNA are used here simply as a convenient shorthand for sites similar in date, and do not necessarily imply cultural similarities. This particularly applies to the division of PPNB sites into early, middle and late, a scheme developed for the Levant, which I have applied to sites across the fertile crescent.

Appendix of early sites

The appendix to this paper reviews evidence for dating and domesticates for the key sites, and provides detailed justification and citations supporting the assertions made in the main text. It should be read in conjunction with table 1. The appendix covers all Epipalaeolithic and Pre-Pottery Neolithic sites from which cereal remains have been recovered (the concentration on cereals is explained below). Only selected phases from multi-period sites are included in table 1. Where plant remains from a particular phase are too scanty to give useful information (e.g. the basal round building phase at Çayönü) or are unchanged from earlier levels, they are not included in the table. Assessments of foraging or farming status are my own. This table updates that published by Nesbitt and Samuel (1996: 66-67).

Identifying plant domestication: importance of charred plant remains

The approach taken here centres on charred cereal remains from archaeological excavations. Other types of proxy data for plant domestication have proved frustrating or misleading. Pollen and phytoliths are insufficiently diagnostic to species, while stone tools such as sickles and grinding stones are linked to plant use, not specifically to domesticates. Those parts of pulse crops such as pea, lentil and bitter vetch, that survive charring – the seeds – have proved not to have reliable criteria for domestication (Butler, 1989), with the exception of smooth seed coats in pea, present from the seventh millennium bc. Identification of other early domesticated pulses is usually made on the basis of more or less pure, sizeable stores of the species in question, and on their presence in areas outside the distribution of the wild ancestor. For the Neolithic founder crops, the earliest pulse stores identified so far are of lentils and broad bean (*Vicia faba*) from middle-PPNB Yiftah'el, Israel (8800 BP) (Garfinkel *et al.*, 1988; Kislev, 1985), and a store of 500 chickpeas from Pottery Neolithic (7550-7350 BP) Höyücek in western Turkey (Nesbitt and Martinoli, In press). Legume domestication has been authoritatively reviewed in a recent paper by Ann Butler (1999).

Indicators of cultivation and domestication of cereals

Publications up to the 1980s were relatively uncritical of claims for early domestication, in part reflecting the small number of archaeobotanists working in this field, and the incomplete publication of many important sites. Identifications of domesticated cereals were usually made on grain shape. During the 1980s, archaeobotanists became more critical of these early identifications, and developed new criteria.

Grain shape

Grain shape is problematic in two respects. First, the grains of some different genera within the Triticeae tribe of the grass family closely resemble each other. In particular, the grains of wild einkorn (*Triticum boeoticum*), wild rye (*Secale* spp.) and *Dasypyrum villosum* are very similar in appearance. In most cases *Dasypyrum villosum* can be ruled out because it is primarily a coastal species, growing only in Turkey. However, different species of rye grow, like wild einkorn, throughout most of the fertile crescent. Although anatomical characteristics have been described that separate rye from wild wheat grains (Hillman *et al.*, 1993), these have not been applied except at Abu Hureyra. Identifications of grain are therefore ambivalent unless supported by chaff, which is far more diagnostic for each genus. Within the wheats, it is unclear how reliably wild einkorn or emmer grains can be separated, taking into account the effects of charring on grain shape. In table 1 wheat identifications are as reported in the original report; identifications of wild einkorn may include wild rye, unless confirmed by chaff.

The second problem lies in distinguishing grains of domesticated and wild cereals. Modern domesticated wheats have much larger grains than wild, with distinctive differences in shape. These differences are clearly visible on material dating back to the Pottery Neolithic, but are less clear for the Pre-Pottery Neolithic period. However, with well-preserved material identifications made on wheat grain shape should be reliable, and are accepted in table 1. Identifications made on grain fragments are less certain, and it is on these grounds that I have queried the identification of emmer at PPNA Jericho (see appendix).

Barley is far more problematic. Current-day wild barley (*Hordeum spontaneum*) has large grains that are comparable in shape and size to those of domesticated barley, and there is agreement among many archaeobotanists that the grains cannot be distinguished on the basis of morphology (van Zeist and Bakker-Heeres, 1982: 204). However, it is highly plausible that, as with other crops, if size was plotted through time in one region, subtle differences in size might be discerned that could be used to demonstrate domestication. This approach has been pioneered by Sue Colledge in her analysis of plant remains from Levantine sites (Colledge 2001: 183-223). However, because the differences are subtle on modern material, the application of a simple cut-off point above which all grains are considered domesticated seems inappropriate, particularly given the great variability in grain size and shape seen in much later samples of domesticated barley. I consider identifications of domesticated barley made on grain shape alone to be uncertain. In table 1 identifications of domesticated cereals made on the basis of grain alone are distinguished from those confirmed by chaff.

Chaff morphology

The rachis and glumes of cereals are much more diagnostic of domesticated status. The increasing use of large-scale flotation, and the study of daub impressions, has enabled recovery of much larger quantities of chaff than seen at earlier excavations. In particular, wild einkorn chaff can be easily separated from wild rye (Willcox and Fornite, 1999). However, the most important attribute of chaff morphology is its direct relationship to domestication. Grain shape is in part problematic because we remain uncertain about how rapidly it changed in

the domestication process. There are hints – such as the wild-type emmer grain accompanied by domesticated-type chaff from Çayönü – that the increase in grain size was later than changes in rachis characteristics that control seed dispersal (van Zeist and de Roller, 1991/1992: 76). We know that loss of natural dispersal mechanisms (which are mediated by the rachis) is fundamental to domestication. In wild wheat, barley, and rye, the ripe rachis naturally disarticulates below each spikelet at maturity, allowing the spikelets to fall to the ground. The disarticulation scar is thus clean and untorn. In the domesticated cereals the rachis stays intact, and is only broken during post-harvest threshing. This process involves tearing spikelets from each other. The resulting scar will be rough and the rachis often torn. These differences are clearly visible on both ancient and modern material (and are well discussed and illustrated by Hillman and Davies (1990)).

There are two reasons why chaff has not entirely clarified the question of domestication. First, it is sometimes absent, or uncommon relative to grains; for example, no wheat or rye chaff was recovered from the Natufian levels at Abu Hureyra. Secondly, as Kislev (1989) was the first to point out, the lower spikelets of wild cereals do not naturally disarticulate. If whole ears of wild cereals are collected and threshed, up to 10% of the rachis scars will be of domesticated, torn type. This first became apparent at the site of Netiv Hagdud in Israel, where over 3000 well-preserved barley rachises were found to contain about 4% domesticated type scars.On this basis the site was first published as an agricultural settlement (Bar-Yosef and Kislev, 1986; Kislev *et al.*, 1986). Following experiments in harvesting and threshing current-day wild cereals, and the observation of the presence of a small proportion of domesticated-type rachis segments in these, Kislev has since reinterpreted Netiv Hagdud as a site at which wild cereals were being collected or cultivated.

Although the proportions of domesticated (torn) to wild (clean) type scars at Ohalo II (13%) and Netiv Hagdud (4.1%) are consistent with collection of wild cereals, the position at the few early farming sites for which we have abundant chaff is less consistent, with exclusively domesticated types present at some sites (for example, 100% domesticated-type wheat chaff at Çayönü), and a mixture of domesticated and wild types at others, but in proportions (such as 27% domesticated-type barley internodes at Tell Aswad and 50% at Tell Ramad) that either point to a flourishing weed flora of wild cereals (and both wild einkorn and wild barley are prolific weeds in some parts of the fertile crescent today), or to an intermediate status of crops in which domesticated and wild cereals are growing together.

Occurrence of novel crop species

Many of the difficulties in identifying early cereals is because they are so similar to their wild progenitors. Later, more "advanced" types of cereals evolved that have easily visible morphological characteristics not present in wild cereals. These later types are thus an excellent marker for the presence of domestication. In the wheats, these take the form of the free-threshing wheats, with morphological changes to the rachis which make it even less able to disarticulate than in domesticated einkorn and emmer and which are highly recognisable in charred material. Both free-threshing wheat grain and chaff are easily recognised, and free-threshing wheat is present from about 9000-8500 BP onwards (table 1). Naked barley, a distinctive type with naked grains to which the lemma and palea do not adhere, appears at sites from about the same time. The presence of domesticated plants from the middle-PPNB onwards is therefore clear, although this does not help clarify the status of earlier sites.

Presence outside natural range

The presence of a species outside the range of the wild ancestor is a powerful argument for its dispersal by humans, whether though the cultivation of the wild or domesticated form. This approach has successfully applied to the olive, where its markedly increased distribution in the Chalcolithic period points to earlier cultivation than previously suspected (Liphschitz *et al.*, 1991).

The main difficulty with wild cereals is that we are not entirely sure of the wild distribution 12-10,000 years ago. We have two sources of information: the current distribution, which may have changed somewhat owing to changes in climate and human impact, and archaeobotanical finds. The problem with these is that records relatively close to the fertile crescent may represent wider natural distribution in the past, or they may represent the transport of a favoured resource outside its range. For example, the origin of the wild einkorn and rye grains at Abu Hureyra, where no chaff was found, remain uncertain.

The current-day distribution of the main wild wheats is shown in figure 1; evidence from Hillman's ecological studies (Hillman, 1996), and from early sites in northern Mesopotamia (Nesbitt, 2001), strongly suggests that the wild cereals were spread further southwards in the past.

The most intriguing evidence for early cereals well outside the fertile crescent is from Cyprus, and is discussed below.

Reliability of dating

The development of accelerator radiocarbon dating in the 1980s enabled the dating of single charred grains. This allowed the resolution of some long-standing suspect dates, notably a grain of domesticated emmer from Nahel Oren dated by the excavators to the Kebaran period, but radiocarbon dated to 2940 BP (Legge, 1986). Accelerator dating has been widely applied to charred seeds, but despite its availability (and the availability of funding for free dating to be carried out at the accelerator unit in Oxford), many Neolithic sites are poorly dated, a problem compounded by the lack of attempts at synthesis of periodisation since some useful ventures of the 1980s (Aurenche *et al.*, 1987; Hours *et al.*, 1994). The problem is particularly acute for the PPNB period, which shows a high degree of development, including (as will be argued here) in subsistence practices. Excavation reports often shy clear of even attribution to one of the three phases, early, middle and late, of the PPNB, *let alone* more specific dating. Some problems with specific sites are discussed in the appendix to this paper.

Intrusive grains?

In addition to these general problems, the question of whether grains are as ancient as the level in which they are found continues to be an issue. I will discuss two cases, Iraq ed-Dubb, which needs resolution by accelerator dating, and Abu Hureyra, which raises the question of the reliability of some radiocarbon dates.

The Jordanian cave site of Iraq ed-Dubb contains Natufian, PPNA and Iron Age and later deposits. Both the Natufian and PPNA cereals are dominated by wild-type or indeterminate barley spikelet forks (see appendix for details). The Natufian samples also contain two spikelet forks of domesticated-type hulled wheat, while the PPNA levels contain 7 such forks. Only one wheat grain, resembling wild einkorn, is present. Although this site is sometimes cited as important evidence for early agriculture in the southern Levant (e.g. Garrard 1999: 76), I have assigned it to uncertain status in table 1, because those plant remains which are abundant (the barley) are consistent with use of wild cereals, while the domesticated-type chaff is rare. Given that the PPNA levels are overlain by upper levels of unknown composition, the possibility of intrusion from later levels (which were not

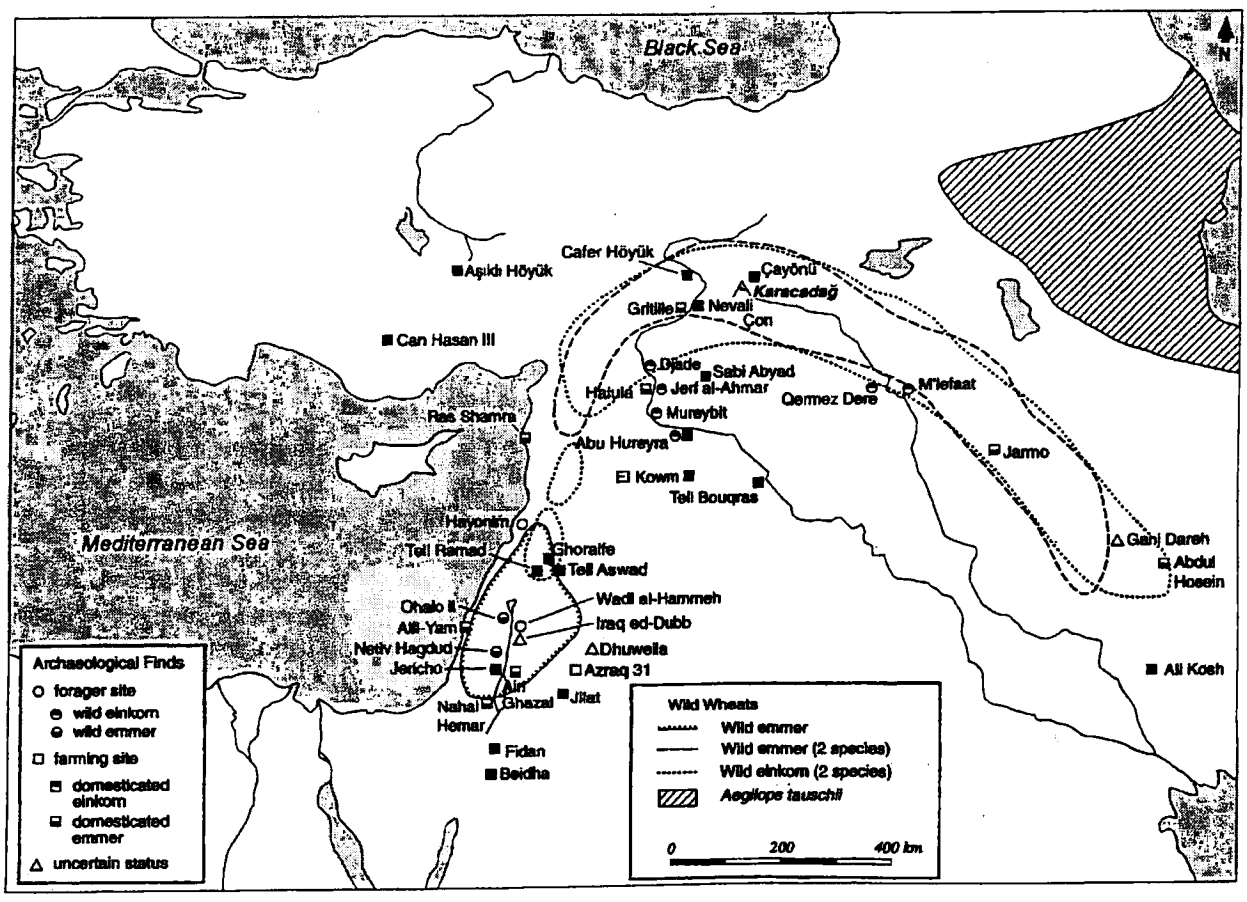

Figure 1. Distribution of Epipalaeolithic and Pre-Pottery Neolithic sites that have evidence of cereals, in relation to current-day distribution of wild wheats growing in primary (non-weedy) habitats. Wild barley distribution is not shown but is broader than that of wild einkorn or wild emmer, effectively encompassing the range of both wild wheats.

sampled) is too great. If the Natufian wheat remains are to be treated, as Colledge (2001: 143) suggests, "with extreme caution" because of mixing with PPNA material, similar considerations must apply to the PPNA deposits. The Iraq-ed-Dubb material would benefit from radiocarbon dating.

At Abu Hureyra, much seed material has been dated, but I have concerns about the consistency of the dating. 9 grains of domesticated rye have been reported from Epipalaeolithic (Natufian) levels at Abu Hureyra. Of these, five have been accelerator dated, three to the Epipalaeolithic period (11140, 10930, 10610 BP), one to the "Intermediate Period" (9860 BP), when the site may have been unoccupied (Moore 1992: 854-5), and one to the Neolithic period (8275 BP). There are thus three domesticated rye grains that considerably predate the Neolithic, and one that is early PPNA.

The illustrated grains do have the shape and large size of domesticated grains (Hillman *et al.*, 2001: 389; Moore *et al.*, 2000: 380-381). What of the dating? All the radiocarbon dates for Abu Hureyra grains are shown in table 2. Dates on grains recovered from Neolithic levels are consistent with other dates from this period. I have three concerns regarding the Epipalaeolithic grains:

- Of the 12 domesticated-type grains of various cereals recovered from the Epipalaeolithic levels and dated, 8 proved to have Neolithic dates. It is clear that intrusion does occur at the site, doubtless owing to the usual factors such as burrowing animals (cf. Legge 1986: 18-19). Given that the Epipalaeolithic samples are dominated by wild cereal grains, there is a consistent overall pattern – domesticated grains in the Neolithic, wild in the Epipalaeolithic. The simplest explanation for a minor anomaly would be incorrect dating of the four anomalous grains.
- Most of the wild grains in the Epipalaeolithic levels and the domesticated grains in the Neolithic levels are consistent in date with stratigraphy and with seeds from nearby levels. The dates of the anomalous grains are not consistent with other material from the same or nearby samples. For example, levels 418 and 419 are contemporary (Moore *et al* 2000: 111), but the rye grain from 418 dates to 11140 BP, while that from 419 dates to 10610 BP. Overall the Neolithic intrusive grains appear very variable in date (compare the four grains from level 449), consistent with their intrusion from different deposits above the Epipalaeolithic levels. The four anomalous grains show a similar pattern of very varied dates.
- There is evidence from Abu Hureyra and other sites that accelerator dating can result in anomalous dates. At Abu Hureyra a wild einkorn grain from the Epipalaeolithic level 468 was dated to 6100 BP, well after the end of occupation of the site. At the PPNA site of Qermez Dere in northern Iraq six dates were obtained from shallow occupation at a relatively short-lived site, as follows:

OxA-3752	QD90 CBR 502.1,charred seeds, *Lens*	10145±90
OxA-3753	QD90 CBR 502.2, charred seed fragments	11990±100
OxA-3754	QD89 RCK 501.1,charred seeds, *Lens*	9580±95
OxA-3755	QD90 RDI 502.1,charred seeds, *Lens*	9710±85
OxA-3756	QD89 RDM 501.1,charred seeds, Vicieae	10115±95
OxA-3757	QD89 RDN 510.1,charred seeds, *Lens*	9640±85

Overall the dates show good stratigraphic consistency, except for OxA-3753, which is about 1800 years older than others from the site (Watkins, 1995). There is no obvious explanation for this. These anomalies suggest that accelerator dating may occasionally result in unusable dates. If sufficient samples are sent for dating, it may be possible to generate significant numbers of anomalous dates. This hypothesis could be tested by dating a comparable number of domesticated cereal grains from the Neolithic layers to see whether anomalous dates would occur in these too. Overall, 18 grains have been dated from the Epipalaeolithic levels, of which 5 (27%) were anomalous (4 early, 1 late); only 5 seed samples (all of mixed fragments, none of individual grains) have been dated from the Neolithic levels.

Overview of evidence for plant domestication

In the light of the above review of key grain, chaff and dating criteria, what do plant remains tell us about the dating of cereal domestication?

Epipalaeolithic

Three sites have provided abundant evidence of cereal use. At Ohalo II the frequency of domesticated-type barley internodes (4 out of 30) is consistent with use of a wild population. Wild emmer was also used. At Abu Hureyra, no cereal chaff was recovered from the Epipalaeolithic layers. Grain morphology is mostly consistent with use of wild einkorn and rye. At the nearby site of Mureybit the cereal component is dominated by wild wheat and rye grains. Wild barley grains are also present, with six wild-type barley rachises. Wild rye grains

Period	Trench	Phase	Level	Material	Laboratory number (OxA-...)	Date (uncal BP)
Neolithic: Domesticated	B	2	216	Grain fragments of einkorn and emmer	1190	8500
	B	2	218	Grain fragments of einkorn and barley	2169	8640
	E	4	375	Grain fragments of barley, emmer and grasses	2167	8270
	G	2	62	Grain fragments of domesticated wheat	1931	7890
	G	2	62	Grain fragments of wild rye and wheat	1930	8180
Epipalaeolithic: Domesticated	E	3	401	Domesticated einkorn spikelet fork	6336	8140
	E	3	411	Domesticated free-threshing wheat	6417	8170
	E	3	418	Domesticated rye grain	8718	11140
	E	2	419	Domesticated rye grain	8719	10610
	E	2	455	Domesticated rye grain	5995	10930
	E	2	449	Domesticated rye grain	5994	9950
	E	2	449	Domesticated rye grain	5843	8275
	E	2	426	Domesticated einkorn grain	7122	8290
	E	2	449	Domesticated einkorn grain	6995	8700
	E	2	438	Domesticated tetraploid wheat	6419	8230
	E	2	438	Domesticated 6-row barley	6418	8115
	E	2	449	Domesticated hexaploid wheat	5842	8260
Epipalaeolithic: Wild	E	3	405	Wild einkorn grain	170	10600
	E	3	420	Wild einkorn grain	386	10800
	E	2	430	Wild einkorn grain	397	10420
	E	2	457	Wild einkorn grain	171	10600
	E	1	468	Wild einkorn grain	882	6100
	E	1	470	Wild einkorn grain	883	11450

Table 2. Accelerator radiocarbon (AMS) dates for cereal grains from Abu Hureyra (compiled from Moore et al: 527-529). All dates are from the Research Laboratory for Archaeology and History, Oxford University. Early rye grains are indicated by shading. Note that Epipalaeolithic grains should date to between 11500-10000 years BP.

were not distinguished in the original archaeobotanical work, but it is likely that some of the wild einkorn grains are in fact of wild rye. Willcox & Fornite(1999) have identified rye chaff in mudbrick impressions from the site.

Domesticated cereals have been identified at three Epipalaeolithic sites. At Mureybit two grains of domesticated wheat and an emmer spikelet fork were found, but were assumed to be intrusive. The material has not been directly dated. At Iraq ed-Dubb two domesticated-type einkorn or emmer spikelet forks were found in Natufian levels, but have not been directly dated. At both Mureybit and Iraq ed-Dubb some barley grains were considered domesticated in appearance. The three domesticated rye grains from Abu Hureyra are discussed above.

While it is impossible to rule out domestication in the Epipalaeolithic, almost all the wild cereal remains at Epipalaeolithic sites are wild. When domesticates appear, they are in very small quantities, and are either undated or, at Abu Hureyra, mostly date as intrusives from higher levels of the site. Given that intrusion is a well documented archaeological phenomenon, it is likely the best explanation for the presence of domesticates in this period.

The distribution of archaeological wild cereals is consistent with that predicted on palaeoecological grounds, with wild emmer and barley present at Ohalo II, near Lake Galilee, and wild einkorn and wild rye present in the central fertile crescent, at or near Abu Hureyra and Mureybit.

PPNA

As in the Epipalaeolithic, most of the seven PPNA sites from which plant remains have been recovered lack definite evidence of domesticated cereals. At Netiv Hagdud, in Israel, a rich seed assemblage contains abundant grain and chaff of wild barley, and some wild emmer. As at Ohalo II, the proportion of domesticated-type barley

internodes (4.1%) is consistent with the harvest of wild barley. At Jerf al Ahmar all the barley, rye and einkorn chaff is of wild type. At two sites in the central fertile crescent, Qermez Dere and M'lefaat, wild einkorn/rye and wild barley are present, but without remains of chaff. While the status of the barley must be uncertain, there is no reason to believe it is domesticated.

Domesticated plant remains have been identified at three sites. At Iraq ed-Dubb 7 einkorn/emmer spikelet forks are of domesticated type, and together with some large barley grains have been interpreted as evidence of domestication. Otherwise the cereal remains are consistent with wild barley. As explained above, if intrusion can explain the domesticated-type wheat in the Epipalaeolithic levels, it might also explain that in the PPNA levels. The evidence from Jericho is reviewed at length in my appendix, because this site is so often cited as an early agricultural settlement, reflecting the fame of its excavation in the 1960s. In brief, there are but a few grain fragments from high in the PPNA levels, and a single mudbrick impression of domesticated einkorn, the survivor of a group of such impressions that have been reassigned to the Pottery Neolithic. This single impression, perhaps likewise misdated, is a poor foundation for assigning agricultural status to the site.

Tell Aswad offers better evidence for domestication, in the form of domesticated emmer (19 grains, 70 spikelet forks) and barley (30 grains, 17 internodes) from the earliest phase, Ia, of the site (9700-9300 BP). The wheat chaff is not characterised but is probably all of domesticated type - the report refers only to *T. monococcum* and *T. dicoccum* (van Zeist and Bakker-Heeres, 1982: 185-6). Overall at Aswad (all phases) 62% of the barley chaff is wild type, 26% domesticated-type, suggesting that not all barley plants in fields were of domesticated type.

The question that arises with regard to Aswad is probably not of domesticated status (if the above assumption about wheat chaff is correct), but of dating. The dating of the phase Ia samples is crucial to establishing PPNA domestication at the site. The samples were recovered after excavation, by sampling the standing sections. Their provenance is recorded in terms of depth from the surface, and their dating assumes that contexts of the same depth from the surface are of the same date. Direct radiocarbon dating of this material (and re-examination of the disarticulation scars of the cereals from phase Ia) is highly desirable.

The most striking feature of PPNA cereals is that the sites with abundant well-dated, well-documented cereal remains (Netiv Hagdud, Jerf al Ahmar) show no sign of cereal domestication. Only sites that have little material that is also poorly dated, can be interpreted as having domesticates. This may just be coincidence, or it may be that domesticated cereals are not present at PPNA sites. Given the likelihood that wild cereals were being cultivated during this period, domestication would not be surprising. Equally, as Willcox (2000a) argues, cultivation could continue for many hundreds of years without domestication in the presence of certain preconditions. Overall, in terms of domestication, the cereal presence at well-dated PPNA sites is consistent with that at Epipalaeolithic sites, and I agree with Kislev (1992) and Willcox (2000a) in considering plant domestication undemonstrated.

As in the Epipalaeolithic, distribution of wild cereal finds matches the likely distribution of the wild plants. At sites in the central fertile crescent (Qermez Dere, M'lefaat, Jerf al Ahmar) wild einkorn/rye and barley are present. At Netiv Hagdud in the Levant wild emmer accompanies wild barley. This pattern of dominance of the Levant (western fertile crescent) by wild emmer and of the southern fringes of the central fertile crescent by einkorn matches current-day and Epipalaeolithic evidence of distribution. The abundant wild barley from Iraq ed-Dubb is consistent with its location, but the single wild einkorn grain is, if PPNA and if einkorn, possible evidence for cultivation near the site, as it lies outside the distribution area of wild einkorn in primary (i.e. truly wild) habitats (figure 1). The remains of emmer and barley from Jericho, if wild, are unlikely to derive from the desertic surroundings of the site, but grew wild nearby in the Judean hills.

PPNB – early (9500-9200 BP)

The PPNB offers the first unambiguous evidence of plant domestication. In early levels (c. 9200 BP) at Nevali Çori, abundant einkorn and emmer grain and chaff are present, with virtually all the chaff of domesticated-type. Barley chaff is less well-preserved and possibly of wild-type. Also in southeast Turkey, domestication is well-attested at Cafer Höyük, on the basis of domesticated-type grains of einkorn and emmer, and uniformly tough-rachised emmer spikelet forks. Although the quantity of material is small, it is consistent with that from later in the site's occupation. Unfortunately the lowest levels of the site are not directly dated. As discussed in the appendix, the plant remains date to between 9200-9000 BP.

The third site in southeast Turkey, Çayönü, is more problematic, as it was excavated prior to the application of large-scale flotation for plant remains. PPNA plant remains from the round building phase have been excluded from table 1 because identification is limited to cereal grain fragments, and 9 wheat spikelet forks, of domesticated type. Given the small quantity of material and complicated excavation history of the site, this material (which has not been directly dated) is excluded from consideration. The grill building phase spans the transition from PPNA to PPNB periods and is dated 9200-9100 BP. Barley is present, but all barley chaff is

wild-type. In this phase the emmer wheat grains appear wild, but the chaff is all of domesticated-type. Einkorn grains appear domesticated. In view of the substantial number of domesticated-type einkorn and emmer wheat spikelet forks (116) present in this phase, domestication appears well documented.

With domesticated wheat present in southeast Turkey by 9200 BP, what of the Levant? At Dja'de on the Syrian Euphrates, a well-preserved assemblage shows no sign of cereal domestication, beyond a possible increase in barley grain size. The chaff is of wild-type. Although Wadi el-Jilat 7 is sometimes cited as an early agricultural site (Garrard *et al*, 1996: 213), the evidence for domestication is limited to one grain of domesticated two-grained einkorn, and barley grains. Reference to the original publication shows that all the early-PPNB chaff is of wild-type. The material from 'Ain Ghazal contains what is very likely domesticated emmer and barley grains, but until the material is fully published, we will not know which are the earliest levels at the site with evidence for domesticated plants. The Nahal Hemar material, recovered from cave deposits known to contain intrusive seeds (and in any case perhaps as late as 8100 BP) is the best evidence of domesticated cereals in the Levant, apart from Tell Aswad, although it is unclear whether the Aswad phase II plant remains date to the early-PPNB.

Overall the early PPNB offers a surprising perspective on the widely held view that domesticated plants first appear in the Levant in the PPNA. In contrast to the poor quality PPNA evidence, the early PPNB offers three well-dated sites in southeast Turkey with good evidence for domestication, based on chaff.

It is not argued here that domestication first occurred in this region. This early evidence has much to do with the rigorous application of archaeobotanical sampling at two sites, and quite extensive sampling at another. However, it is striking that domesticated cereals are absent at the well-sampled Dja'de, further to the south. This, combined with the lack of a standard package of Neolithic "founder crops" at the sites – note in particular the wild status of barley - suggests that agriculture was still emerging in the early PPNB, and that crops were still in the process of spreading through the fertile crescent at this point. This is consistent with the view that domesticates emerged late in the PPNA, as otherwise this spread should have occurred earlier.

New evidence from Cyprus

Until recently, the earliest domesticated plant remains from outside the fertile crescent were from the Late PPNB and Pottery Neolithic periods (c. 8000 BP), and were thus unhelpful in pinning down a date for domestication of cereals (Hansen, 1992). This has changed following the discovery of early PPNB sites in Cyprus (not included on my map or in table 1), both radiocarbon-dated to 9300-9100 BP. At Shillourokambos grains of barley and einkorn/emmer are present. The material is not well preserved, but the 10 barley internodes are of wild type (Willcox, 2000b). Willcox considers that the site shows pre-agricultural cultivation. In view of the lack of wild wheats on the island, the wild cereals may have been introduced along with the practice of cultivation.

At Mylouthkia both domesticated einkorn and emmer, and barley grains, have been identified on the basis of grain size (Peltenburg *et al.*, 2000; Peltenburg *et al.*, 2001). Chaff is present but not yet characterised as wild or domesticated-type.

Analyses of both sets of material are at an early stage, and the agricultural status of the sites is likely to be clarified in future. However, it is clear from the introduction of wheat (and certain animals) to Cyprus that farming practices (possibly using wild cereals) were being spread in the early PPNB. Given archaeological evidence that these practices came to Cyprus from the Levant, they are evidence for cultivation (and, probably, presence of domesticates) in the Levant that is currently hard-to-find in the Levant itself.

PPNB – middle and late

In these periods domesticated cereals are well documented at a number of sites. Only Ganj Dareh and Dhuweila are of uncertain status, because they lack both chaff and domesticated wheat grains. Ganj Dareh is highly likely to be agricultural, given its character and location as a typical PPNB farming settlement. In contrast, Dhuweila is a campsite in an arid area, where wild cereals may have been occasionally collected.

During the middle-PPNB the Neolithic package of cereals comes together. Domesticated barley is, for the first time, well documented on the basis of chaff characteristics. Naked wheat (both tetraploid and hexaploid) appears at Abu Hureyra in period 2B. Phase B8 contains 1 tetraploid (*Triticum durum*) and 2 hexaploid (*T. aestivum*) rachis segments, and dates to about 8300-8000 BP. At Cafer Höyük hexaploid wheat occurs in level IV, dating to c. 9000-8500 BP, and naked wheats then occur at most sites in these periods. Naked barley, another cereal that only occurs in domesticated form, is also sporadically present in these periods. Six-row hulled barley is not found until the Pottery Neolithic, and domesticated rye only occurs twice, though well documented by chaff.

Implications for current models of agricultural origins

How does this assessment of evidence for early domesticates fit with current views on agricultural origins in the fertile crescent?

The Jordan Valley as hearth
A minority view focuses narrowly on the PPNA of the Jordan Valley of the southern Levant as the single point of origin, perhaps reflecting the rich archaeological record that has resulted from a level of activity in archaeological fieldwork unparalleled elsewhere in the fertile crescent (McCorriston and Hole, 1991). Archaeobotanical evidence for a concentration of PPNA early farming sites in the southern Levant is cited by McCorriston & Hole (1991: 51), listed here with my assessment in brackets: Tell Aswad, 9800 BP (possible); Netiv Hagdud 10,000 BP (not a farming site); Jericho, 10,000 BP (ambiguous; date too early by at least 600 years). Overall, evidence for agriculture in the PPNA is weak, and the well documented use of wild cereals at Netiv Hagdud has close parallels with use of wild cereals at other PPNA sites well outside the PPNA heartland, for example at Mureybit, Jerf al-Ahmar and M'lefaat. Cultivation of wild cereals may have been practised at all of these sites.

The Levant
Perhaps the most widely held view at present is that plant domestication first occurred in the PPNA in the "Levant", using the term very broadly, to refer to the part of the fertile crescent stretching from Israel and Jordan to the Euphrates valley in northern Syria (e.g. (Bar-Yosef and Meadow, 1995: 70; Garrard, 1999: 82; Harris, 1996: 554; Jones *et al.*, 1998). This area corresponds to the Natufian culture area of the later Epipalaeolithic. Domesticated plants are considered to be present at Jericho, Tell Aswad, Iraq ed-Dubb and Abu Hureyra. As in the Jordan Valley model, this view hinges on the weak evidence for domestication at two of these sites, and the stronger evidence from Tell Aswad. The lack of evidence for domestication at Netiv Hagdud is explained (if it is explained at all) in terms of a mixture of sites with different economies.

The fertile crescent as a whole
The third view is that evidence for domesticated plants is not secure until the early PPNB, and that it appears first in the central fertile crescent, well documented by sites in southeast Anatolia and, possibly, in Cyprus. The best evidence for domestication in the Levant during this period may be at Tell Aswad, but it is surprising that the abundant plant remains from Dja'de on the Euphrates show no sign of domestication. It is possible that domesticated plants are not present at the beginning of the early-PPNB, but appear during its course. In this case, the sites dating 9500-9300 BP, such as Dja'de and Wadi el-Jilat 7, might not contain domesticated plants. The absence of domesticated plants in the Levant from 9300-9100 BP may be best explained by the lack of recovered plant remains from this period.

This view, as argued here and by Willcox (1999a; 1999b; 2000a), fits well with some other evidence. As argued by Willcox (this volume), the different distribution of domesticated cereals at farming sites matches well with independent domestication of different crops in different parts of the fertile crescent, rather than the diffusion of all or most crops from a single, small area of domestication. The limitation of cultivation or domestication to a small area would also be surprising in view of evidence from lithics and obsidian for widespread exchange of commodities and ideas within the fertile crescent from the late Epipalaeolithic onwards (Peltenburg *et al.*, 2001).

A note on the eastern fertile crescent
What can we say about the eastern part of the fertile crescent, located on the flanks of the Zagros mountains of Iran. Here archaeological fieldwork ended in 1979. The intervening years have seen excavations that have transformed our understanding of the PPNA period in southeast Turkey and northern Iraq, two areas previously viewed as near-empty prior to the arrival of PPNB cultures. Would something similar have occurred if excavations had continued further east? On the basis of existing knowledge, there is sparse evidence of Epipalaeolithic occupation, then no Aceramic Neolithic sites until middle-PPNB village sites such as Ganj Dareh (Hole 1994: 105).

Palaeoecological evidence does suggest that the increase in wild food resources such as grains and nuts that followed the end of the last Ice Age occurred significantly later in Iran than in the western and central zones of the fertile crescent (Hillman, 1996; van Zeist and Bottema, 1991). It is therefore plausible that the cultivation phase that preceded domestication did not occur in the east, and that this part of the fertile crescent did not participate in early agriculture. However, there is no reason why farming, once developed, should not have spread rapidly towards the east, and it is possible that early PPNB farming villages will be found in this area once fieldwork resumes.

Conclusions

Agriculture and the Neolithic

Does the later date proposed here for first appearance of domesticates (the early PPNB, c. 9300 BP) affect our understanding of the Pre-Pottery Neolithic? If the PPNA is no longer viewed as a farming society (and even if Tell Aswad and other sites are accepted as agricultural sites, it is clear that some PPNA sites such as Netiv Hagdud were not), then the presumed link between the initiation of the Neolithic and the beginning of farming no longer holds good. Shorn of its economic links to the succeeding PPNB cultures, many PPNA sites seem to have far more in common with the preceding Late Epipalaeolithic (Natufian cultures), in terms of house shape and settlement size and organisation. While the PPNA continues to be a useful chronological term, the use of the beginning of the Neolithic as marking a major transformation in human societies may be inappropriate. The question of when farming of crops has a significant impact on human subsistence lies outside the scope of this paper (see Harris chapter); in my view it does by the middle-PPNB period, as marked by the rapid spread of farming across the fertile crescent, and the large size of middle-PPNB sites, presumably reflecting an increase in population (Kuijt, 2000).

Explaining agricultural origins

Does the revised dating of domestication affect explanations of why farming began? Most explanations in the last two decades have invoked the environmental changes consequent on the end of the last Ice Age. Warmer and wetter climate led to a general increase in food resources available to hunter-gatherer populations, and it has been suggested that this enabled sedentism and a subsequent increase in population. However, explanations invoking population increase have become less popular because they are not supported by archaeological fieldwork, which shows no evidence of increase in settlement density in the Late Epipalaeolithic or PPNA periods. Instead, recent explanations have focused on the Younger Dryas, a period of cold and arid climate lasting from about 11,000-10,000 BP (Bar-Yosef, 1998; Harris, 1996; Moore and Hillman, 1992; Moore *et al.*, 2000), although there is disagreement about its impact in southwest Asia (Bottema, 1995; Helmer *et al.*, 1998). If domestication starts 700 (radiocarbon) years later, then the timing of domestication is clearly not linked to the Younger Dryas. Instead, cultivation of wild plants might have been a reaction to the Younger Dryas – and this will be more difficult to identify. The question then arises of why domesticated plants appeared at all, if long-term cultivation of wild plants had been practised for so long without domestication occurring?

Implications for future work

In writing this paper I have encountered many ambiguities in recording and dating of plant remains, which have done much to confuse an already difficult topic. Some changes in practice could help clarify this situation:

- Better dating of plant remains: the availability of accelerator dating (usually available "free" through the Oxford radiocarbon unit) has done much to improve the dating of early sites and plant remains. However, there are too many sites with long sequences of occupation that have not taken advantage of this opportunity. Precise dating of a site may not be important for an excavator, but is of key importance in tracing the origin and spread of crop plants.
- R covery of adequate quantities of seeds: although a few seeds will often be sufficient to demonstrate domestication at a post-Neolithic site, the situation is usually more ambiguous at earlier sites. Reasonable quantities of chaff will be needed to demonstrate domestication, and large numbers of seeds will be needed for the sophisticated statistical techniques that can aid detection of cultivation. In Turkey, Jordan, Syria and Iraq the application of modern flotation techniques has consistently resulted in the recovery of large assemblages of seeds. Given the tiny number of Epipalaeolithic, PPNA and early PPNB sites that have been sampled for plant remains (table 1), it is essential that flotation is carried out at future excavations of this period. Some PPNA sites – notably Jericho and Aswad – could usefully be sampled again.
- A critical approach to domestication: a key argument of this paper is that the quality of evidence for domestication and dating at each site must be evaluated on its own merits. Integration of evidence from one site into overall patterns of evidence from many sites, as advocated by Harlan and de Wet (1973), and practised in my paper, is both a valuable tool and a potential trap. For periods such as the Epipalaeolithic and the middle-late PPNB, claims for domestication can be evaluated against a substantial body of evidence that Epipalaeolithic subsistence is based on wild plants (and that claims for domestication should be treated with scepticism), while in the later PPNB subsistence is based on domesticated plants. Thus at a later PPNB site, even poorly preserved plant remains may be adequate evidence for domestication.

However, in the PPNA and early PPNB periods, there is now no consensus as to the presence of domesticated

plants in different parts of the fertile crescent. In view of different interpretations of archaeobotanical evidence, the small number of sites excavated, and the possibility that differing economies may have existed side-by-side, it seems unlikely that such a consensus will emerge. Strict criteria for domestication must be applied to sites of these periods, and we should accept that some sites domestication status will remain unknown, because the archaeobotanical data is inadequate.

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Appendix. References to sites and supplementary notes

References are limited to those used in compiling table 1; superseded reports are excluded. The basis on which plant remains were identified as domesticated is set out, together with comments on dating.

Abdul Hosein: (Hubbard, 1990). Domestication status uncertain; one tough-type barley rachis segment found. Apparently similar in date to Ganj Dareh, i.e. dating between 9000 and 8400 BP (Hole, 1987).

Abu Hureyra: period 1 (Natufian): (Hillman *et al.*, 2001; Hillman *et al.*, 1989; Moore *et al.*, 2000); period 2 (Neolithic): (de Moulins, 1997; Moore *et al.*, 2000); dating: (Moore, 1986; Moore, 1992; Moore *et al.*, 2000). Abundant radiocarbon dates allow accurate dating of period 1 (11500-10000 BP). Archaeological evidence for occupation at the site began again in about 9000 BP, with phase 2A lasting until 8300 BP (Moore 1992). Moore suggests that there was a hiatus from 10000-9700 BP, then intermittent occupation until 9000 BP. It is not clear to what extent the site was occupied between 10000 and 9000 BP; in the final publication Moore (2000: 492) suggests that occupation was in fact continuous, but that the settlement remains were removed by the occupants of period 2. De Moulins (1997: 91) dates most of the Period 2A samples to 9000-8300 BP, but with two samples dating before 9000 BP.
Evidence for domestication in the lowest Neolithic (phase 2A) samples is from domesticated type einkorn and emmer grains and emmer spikelet forks and the presence of free-threshing wheat grains and rachises. The few barley rachises are of domesticated or uncertain type. Free-threshing wheat rachis segments identifiable to species only appear in period 2B: phase B8 contains 1 tetraploid and 2 hexaploid rachis segments, and dates to about 8300-8000 BP. The numbers are low, but this reflects the general scarcity of cereal remains at the site. Definite evidence of domesticated rye (both grains and rachis fragments) also appears for the first time in period 2B. Identifications of the Natufian cereals are based on grain characteristics as no wheat or rye chaff was found; rye grain was distinguished from wild einkorn grain using morphological criteria (de Moulins 1997: 36). The recent publication of domesticated rye grains from the Epipalaeolithic and PPNA periods (Hillman *et al.*, 2001; Moore *et al.*, 2000) is discussed in the main text of the paper.

Ain Ghazal: (Rollefson *et al.*, 1985: 96-104). Preliminary report with uncertain identifications, but with emmer grain consistent with domesticated form.

Ali Kosh (Bus Mordeh phase): (Helbaek, 1969). Dating uncertain, perhaps contemporary with Jarmo (Hole, 1987). Domesticated status on basis of einkorn and emmer grain shape, and tough-type scars on emmer and barley rachis segments visible in Helbaek's plate 40.

Aşikli Höyük: (van Zeist and de Roller, 1995). Domestication evidenced by einkorn and emmer grains and spikelet forks; barley chaff of mixed wild and domesticated-type. Free-threshing wheat present. Plant remains published so far derive from the upper phases of Level 2, dating to 8800-8500 BP (Esin, 1998: 103).

Atlit-Yam: (Galili *et al.*, 1993). Domesticated status on the basis of free-threshing wheat grains.

Azraq 31: (Colledge, 1994: 89-92, 176-178, tables 4.7, 5.11; 2001: 145, 169). Evidence of domesticates includes 3 tough barley rachises and a free-threshing wheat rachis segment and grain.

Beidha: (Colledge, 1994: 93-98, 178-180, table 5.12, 5.13; 2001: 145-6, 170-1). The domesticated status of the einkorn and emmer chaff is clear from the impressions; naked barley grains were also identified. The status of the barley internodes is uncertain, but photographs of one impression show it to be tough-type

(Colledge 2002: plate 6.3a-c).

Cafer Höyük: (de Moulins, 1993; de Moulins, 1997). A rich and well-analysed set of plant remains with inadequate dating. Cafer is divided into 13 levels, XIII at base, I at top. The earliest naked wheat appears in level IV, hence the division into two groups in my table 1. Reasonable evidence for domesticated cereals is present in level XIII, and its dating is therefore important. Only 6 dependable dates are reported, including 8990 BP at the base of the mound, 9560 in level XII, and 8950 in level XI (Molist and Cauvin, 1991: 110). Published estimates for the beginning of the site vary between 9500 and 9000 BP, the latter clearly discounting the level XII date. De Moulins (1993: 52) suggests 9200 as a plausible date for the earliest occupation, which I have followed. However the earliest date of this site remains uncertain. Levels III-IV are also characterised by inconsistent radiocarbon dates. This is particularly frustrating as level IV contains an early record of free-threshing wheat. The domesticated status of levels XIII-XII is based on einkorn and emmer grains and tough-rachised spikelet forks. The barley grains were apparently identified as wild on the basis of size or shape, though this is not stated.

Can Hasan III: (Hillman, 1972; Hillman, 1978). The largest sample analysed in the preliminary report (48K 860.2) has been shown by radiocarbon dating to be comparatively recent (Gillespie *et al.*, 1985: 244), and its contents have therefore been excluded from this table. Domesticated status is based on einkorn and emmer grain and on chaff of free-threshing wheat and of domesticated rye present from the basal layers onward.

Çayönü: (van Zeist and de Roller, 1991/1992); dating: (Hongo and Meadow, 2000: 126; Özdoğan, 1999: 41), based on extensive but not fully published radiocarbon dates. The earliest, "round building" phase dates to 10200-9200 BP (PPNA) produced cereal grain fragments and nine wheat spikelet forks, of domesticated type (torn rachis). As the plant remains are so few, this phase has been excluded from the table. Although typical emmer grains are not present in quantity until the cell plan phase (8600-8300 BP), grains resembling wild emmer are present from the grill phase onwards. All the associated spikelet forks are of domesticated type throughout the sequence, and I have therefore assumed that this grain type is an early domesticated emmer. All barley chaff at Çayönü is of wild type and the grains are therefore assumed to be wild. Free-threshing wheat does not appear until the Pottery Neolithic period.

Dhuweila: (Colledge, 1994: 85-89, 175-176, table 5.10; 1998; 2001: 145, 168). No chaff present, wild einkorn and barley grains have been identified as wild on the basis of shape. The site was probably used as a temporary hunting camp, hence the few, wild, plant remains.

Dja'de: (Willcox, 1995; Willcox, 1996; Willcox and Roitel, 1998). All barley rachises are of wild type, but it is suggested some of the barley grains appear domesticated.

El Kowm II - Caracol: (de Moulins, 1997; 2000). Domesticated status on the basis of domesticated-type grain and chaff of four cereals.

Ganj Dareh: (van Zeist *et al.*, 1984). The only cereal present at the site is barley. The domestication status remains uncertain; two rachis segments are of wild type; four are of domesticated type. Although van Zeist *et al.* (1984: 202-3) suggest that the site was occupied from c. 9500 BP to c. 8300 BP, Frank Hole considers the early dates anomalous and suggests the site dates from 9000 to 8400 BP (Hole, 1987). I have followed these more conservative dates in the table. In view of its late date, probably an agricultural site.

Ghoraife: (van Zeist and Bakker-Heeres, 1982). Domesticated status is based on domesticated-type grain of four cereals, and free-threshing wheat chaff. The scar-types of the emmer and einkorn spikelet forks are not reported, but 4 barley rachises are brittle and 3 tough. The table thus shows both wild and domesticated barley chaff to be present.

Gritille: (Voigt, 1985) Preliminary report is too brief to determine domesticated status; likely to be agricultural because of its period.

Hacilar: excluded from this table because the Aceramic Neolithic levels at this site appear to contain pottery, and thus to belong to the Pottery Neolithic period (Duru, 1999: 172-3; Özdoğan 1997: 18).

Halula: (Willcox, 1995; Willcox, 1996; Willcox and Roitel, 1998). The site is divided into two phases, Middle PPNB (8700 BP) and Late PPNB (8650-7950 BP). The Late PPNB phase contains free-threshing wheat. Domestication is less certain, though likely, for the Middle PPNB. Grain resembling domesticated einkorn and emmer is accompanied by grain resembling wild emmer, and emmer spikelet forks of both tough and brittle-rachised type. Some barley grains resemble domesticated types, and are accompanied by tough rachises.

Hayonim Cave: (Hopf and Bar-Yosef, 1987). Barley grains with no chaff.

Hayonim Terrace: (Buxó i Capdevila, 1992; Valla *et al.*, 1989). Barley grains with no chaff. Dating of both Hayonim excavation areas is problematic, hence the wide age range assigned in the table (Housley, 1994: 59-60).

Iraq ed-Dubb: (Colledge, 1994: 71-5, 162-5, table 5.4; 2001: 143-4, 153-4). The Late Natufian (below struc-

tures) and PPNA (within structures) samples both contain barley grain (some identified on the basis of size as domesticated) and a large number of wild-type barley rachises (17 in all, with a further 37 of uncertain status (Colledge, 2001:153-4)). Evidence for domestication thus hinges on nine spikelet forks of einkorn or emmer, all of torn (domesticated) type. Two are present in the Late Natufian samples, and seven in the PPNA samples. On the basis of species distribution, Colledge (2001: 143) suggests the spikelet forks are of emmer; this is supported by the presence of a terminal spikelet fork, usually absent in einkorn. The only wheat grain identifiable was wild einkorn. The PPNA layers are overlain by Iron Age and later deposits, from which no archaeobotanical samples were taken.

Jarmo: (Helbaek, 1959; Helbaek, 1966). Radiocarbon dating is problematic, but a date of about 8750 BP has been proposed (Hole, 1987). The plant remains have not been fully published, but domestication is demonstrated by barley and emmer spikelet remains and impressions.

Jerf al Ahmar: (Willcox, 1995; Willcox, 1996; Willcox and Fornite, 1999; Willcox and Roitel, 1998). All barley, rye and einkorn rachises were of wild type, but it is suggested some of the barley grains appear domesticated.

Jericho: (Hopf, 1983). The PPNA finds consist of two groups: charred plant remains, and impressions in mudbrick (p. 608). The charred plant remains consist of 3 distorted grains (and some fragments) resembling emmer, 7 distorted grains (and some fragments) of barley, fig seeds and a few pulse fragments. Both the domesticated status and, as Hopf makes clear with regard to the emmer, the identification of these grains are uncertain. PPNA samples 1019 and 1020 are from stage VIII of Trench I, dating to about 9400 BP, and sample 651 is from stage X, dating to about 9300-9200 BP (Bar-Yosef, 1986). Both sets of samples come from levels at least 3.5 m above the basal PPNA, confirming their late position in the PPNA sequence. The mudbrick impressions are mainly of similarly ambiguous grain fragments. However, one impression of three joined spikelets of tough-rachised einkorn appears to be stronger evidence for domesticated cereals (Hopf 1983: figure 234.7). However, this is the sole survivor of a much larger group of clearly domesticated chaff remains, originally published as PPNA but later recognised on stratigraphic grounds as Pottery Neolithic (Hopf 1983: 610). Given the inherent problems in dating mudbrick, and evident problems in stratigraphy at Jericho, the dating of the remaining impression must be uncertain. If the einkorn impression is correctly dated, it (and the other PPNA impressions from sample 172) date to about 9300-9200 BP.

M'lefaat (Nesbitt, 1998); dating: (Hedges *et al.*, 1996). Barley and wild einkorn grains, but no chaff.

Mureybit: (van Zeist and Bakker-Heeres, 1984b). As at Abu Hureyra, no wheat chaff was found. All six rachis segments of barley were of wild type (van Zeist 1984: 196). The presence of wild rye chaff is recorded by (Willcox, 1996). Very small quantities of domesticated emmer grain and chaff were found, which may derive from later occupation of the site (van Zeist 1984: 186).

Nahal Hemar (3-4): (Kislev, 1988). Domestication status is based on chaff remains of emmer. Kislev suggests there is evidence of intrusion of plant remains from levels 1 and 2. The dating of the cereal remains is therefore uncertain.

Netiv Hagdud: (Kislev, 1997). 4.1% of the 3277 barley rachises are of domesticated type, consistent with use of wild cereals.

Nevali Çori: (Pasternak, 1995; Pasternak, 1999). Almost all of the wheat spikelet forks are of domesticated type; both einkorn and emmer chaff are present (personal observation). The barley chaff is poorly preserved and possibly of wild type. Samples are from the early PPNB levels. Radiocarbon dates from the site range from 9260-9200 BP, consistent with an early PPNB date (Hauptmann, 1999: 78).

Ohalo II: (Kislev *et al.*, 1992). 4 of 30 barley internodes are of non-brittle type, interpreted (as at Netiv Hagdud) as deriving from incomplete natural disarticulation of wild cereal ears.

Qermez Dere: (Watkins, 1995; Watkins *et al.*, 1991); dating: (Hedges *et al.*, 1996). No diagnostic cereal chaff present; grains consistent with wild cereals.

Ras Shamra (Vc): (van Zeist and Bakker-Heeres, 1984a). Domestication status in phase Vc is based on one emmer grain and on emmer spikelet forks of uncertain scar morphology. Probably agricultural because of its period.

Tell Aswad: (van Zeist and Bakker-Heeres, 1982). PPNA Phase I (9700-9300 BP) has the earliest evidence for domesticated cereals in the form of a few emmer and barley grains. Emmer and barley chaff is abundant but its domestication status is not stated for this period. No figures for the wheat internodes are available for Aswad, but 26.6% of barley rachis segments (most of which derive from the later period II) are of domesticated type (van Zeist 1982: 204). In middle-PPNB phase II (8900-8500 BP) very large quantities of domesticated-type grain, as well as smaller amounts of free-threshing wheat grain, are present, and it seems reasonable to assume that the einkorn, emmer and barley are indeed domesticated; this is not clear for Period I.

Tell Bouqras: (van Zeist and Waterbolk- van Rooijen, 1985). Domestication status is based on the presence of free-threshing wheat and naked barley.

Tell Ramad: (van Zeist and Bakker-Heeres, 1982). Domesticated status in phase I is based on domesticated-type grain of five cereals, including free-threshing wheat and naked barley. The scar-types of the emmer and einkorn spikelet forks are not reported, but the barley rachises are about 35% brittle, 50% tough and 15% uncertain. The table thus shows both wild and domesticated barley chaff to be present.

Tell Sabi Abyad II: (van Zeist, 1999). Domestication status is based on einkorn and emmer grains, and grains of free-threshing wheat.

Wadi al-Hammeh 27: (Colledge, 1994: 66-71, 160-161, table 5.3; 2001: 143, 152). Both the size of the barley grains and the disarticulation scars of the poorly preserved barley rachis segments are consistent with wild barley.

Wadi el-Jilat 7: (Colledge, 1994: 75-85, 167-171, tables 5.6, 5.7; 2001: 144-5, 156-62; Garrard *et al.*, 1994; Garrard *et al.*, 1996). The Early PPNB horizon gave two radiocarbon dates, for 8390 BP and 5840 BP. Both dates are regarded as too young, and the excavators have assigned a date range of 9500-9000 BP to this horizon on the basis of the lithic assemblage. The Middle PPNB layers have appropriate radiocarbon dates.

Four early PPNB samples were recovered, from trench A. They contain barley grains, identified as wild and domesticated on the basis of size, and 4 wild barley internodes (and 2 of uncertain status). The early PPNB domesticated-type internodes referred to in Colledge's table 6.5 (2001: 162) are not mentioned in the raw data counts of table 6.4 (2001: 156-62) or the detailed list of barley rachis segments in table 4.5 (2001: 79), and are therefore excluded from my table.

Early PPNB domesticated status thus hinges on one grain of domesticated two-grained einkorn, and two indeterminate wheat grains. The Middle PPNB wild cereals are represented by possible wild emmer grain, wild einkorn grain and wild barley grain and chaff. Domesticated cereals are represented by einkorn and emmer grains and domesticated-type spikelet forks, and barley grains identified as domesticated on the basis of size. Domesticated status for the middle-PPNB is secure because of the wheat grains and chaff.

Wadi Fidan A: (Colledge, 1994:98-101, 180-181, table 5.14; 2001: 146, 171). No radiocarbon dates available. Domesticated status on the basis of domesticated einkorn and emmer grains, and domesticated-type wheat and barley rachis segments.

Wadi Fidan C: (Colledge, 1994: 98-101, 181-182, table 5.15; 2001: 146, 172). No radiocarbon dates available. Domestication status is based on einkorn and free-threshing wheat grains and spikelet forks, and 82 tough barley rachises, as against 8 brittle type.

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