Where was einkorn wheat domesticated?

The emergence of agriculture in southwest Asia and its spread to Europe is the key factor in the development of complex civilizations in these regions[1]. One of the earliest domesticates was einkorn wheat (Fig. 1), and other early crops included emmer wheat, barley, pulses such as lentil and pea, and flax. Collaboration between archaeologists and crop scientists over the last 40 years has established that the wild ancestors of these early crops grow mainly in an area known as the 'fertile crescent' (Fig. 2), stretching from the Levant to southeast Turkey and the Zagros mountains of Iran. The earliest Neolithic farming villages known from the Old World that have evidence of these crops appear within the fertile crescent from about 10 000 years ago[2]. However, until now it has been impossible to localize the region in which any of these crops was domesticated more precisely. For einkorn wheat, two particular questions can be framed:

- Where within the area of primary distribution was einkorn taken into domestication?
- As argued by some archaeologists[3], could wild einkorn (*Triticum monococcum* ssp. *boeoticum*) have existed in primary habitats in the Balkans, allowing an independent domestication of einkorn prior to the spread of agriculture into the region from southwest Asia?

Recent work[4] has used DNA finger-printing to pinpoint the area of domestication of einkorn wheat to the Karacadağ mountains of southeast Turkey, with important implications for our understanding of the origin and spread of agriculture.

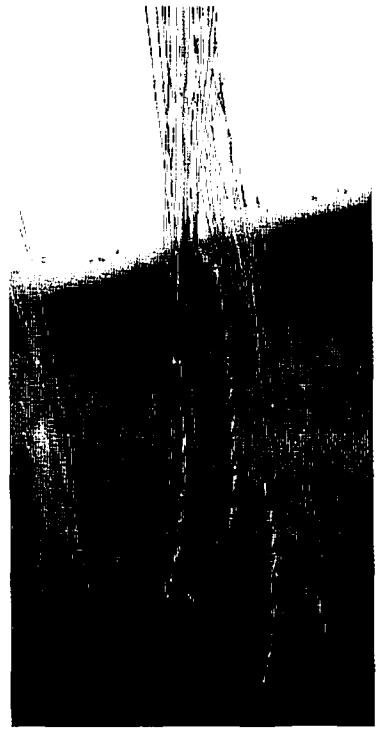

Fig. 1. Spikes of domesticated einkorn, under cultivation in the Pontic mountains of northern Turkey.

Wild and domesticated einkorn

Wild einkorn wheat has long been recognized as the wild ancestor of domesticated einkorn wheat. The two forms are fully interfertile and morphologically very similar. Wild einkorn is widespread in primary, relatively undisturbed habitats in southeast Turkey and northern Iraq, and is present less abundantly in western Turkey and the Zagros mountains of Iran[5]. Wild einkorn is also abundant in secondary, weedy habitats throughout central and western Turkey and much of the Balkans. Wild einkorn probably spread into these secondary habitats as they were created by the spread of agriculture. Domesticated einkorn occurs at several early agricultural sites in southeast Turkey and northern Syria radiocarbon dated to 9500–9700 years ago, including Abu Hureyra, Cafer Höyük, Nevali Çori and Çayönü[6–8]. From the Near East einkorn spread eastwards to become a major crop in central Asia, and an important cereal, although usually secondary to barley and emmer wheat, throughout most of Europe.

New approaches

Heun *et al.* have applied two fresh approaches for investigating the origins of einkorn wheat. First, amplified-fragment length polymorphism (AFLP) DNA finger-printing was used to compare the degree of relationship of 338 lines of wild and domesticated einkorns from different locations. Second, 1362 lines were grown on, ensuring that identification of accessions from genebanks could be checked, and study of morphological traits correlated with genetic characteristics. This is unusual among genetic studies of cereals, both in integrating different types of data and in testing a large number of lines for which the origins are clear. Results from DNA finger-printing show that 19 accessions of wild einkorn from the basalt mountain of Karacadağ in southeast Turkey are distinct from other lines of wild einkorn from within the fertile crescent, and that 11 lines of these are by far the most closely related to domesticated einkorns. Wild einkorn lines from secondary habitats outside the fertile crescent were found to be related to wild einkorn from primary habitats in other fertile-crescent groups, but not to the Karacadağ lines. These weedy einkorns are therefore not feral derivatives of domesticated einkorn, but rather spread with agriculture from different parts of the fertile crescent.

The case of the *aegilopoides* form of weedy wild einkorn is different. The morphological traits of *aegilopoides* – increased number of spikelets per spike, larger seeds and tough rachis – are so similar to those of domesticated einkorn that they probably derive from a feral form of domesticated einkorn or through introgression of weedy wild forms with domesticated einkorn in the region. Nine lines from the Balkans were finger-printed and found to be very closely related to domesticated einkorn. The close genetic relationship is hardly surprising in view of the morphological similarities.

Overall, these results point to a single domestication of wild einkorn, in the Karacadağ region; domesticated einkorn probably spread from here throughout the rest of Eurasia, accompanied by weedy wild einkorns, and with a feral form, *aegilopoides*, evolving after domesticated einkorn reached the Balkans.

Key assumptions

As the authors of this study point out, some assumptions about the stability and survival of populations of wild einkorn are necessary. The distribution of wild cereals today is the result of their expansion during the early Holocene from the refugia in which they survived the last Ice Age, combined with the extinction or depletion of stands of wild and domesticated einkorn caused by increasingly intensive agriculture in the 10 000 years since farming began. For example, archaeobotanical evidence suggests that in the early Neolithic period, stands of wild einkorn may have extended further south than today, to the environs of Abu Hureyra in northern Syria[9]. This is a relatively dry, marginal habitat for wild einkorn, where the pressures of

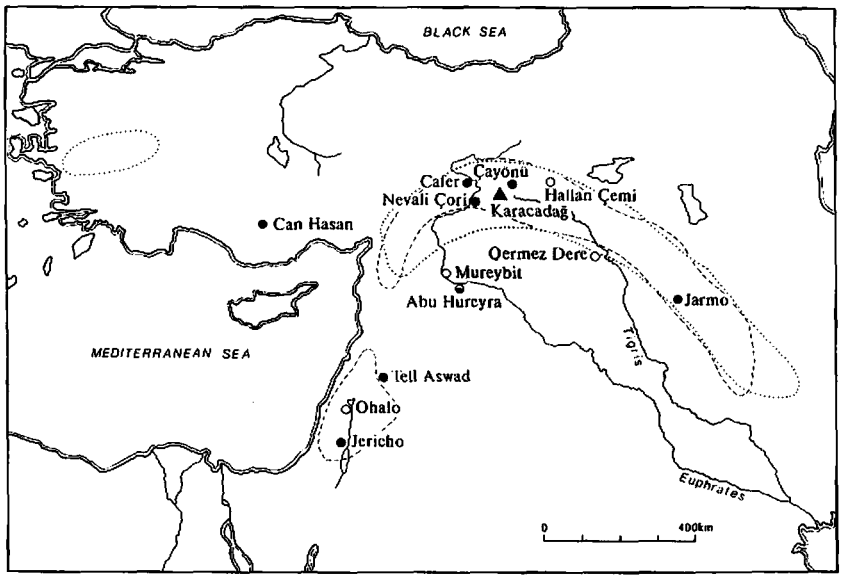

Fig. 2. Early village sites in relation to the distribution of wild wheats. Filled symbols show selected archaeological sites with definite evidence of domesticated crops; open symbols show sites based on hunter-gatherer economies. Dotted lines show the distribution of primary stands of wild einkorn; broken lines show primary stands of wild emmer wheat. The distribution of the two wheats together approximately encompass the fertile crescent.

agriculture and grazing may have led to its early extinction. The Karacadağ forms of wild einkorn may themselves have been more widely distributed in areas adjoining the mountain in the past.

Einkorn domesticated elsewhere in the fertile crescent may have been replaced by the Karacadağ domesticate during the early spread of agriculture. However, the Karacadağ wild einkorn is unique in being closely related to the existing domesticated einkorns, and it is unlikely that more closely related forms could have existed elsewhere. The case of einkorn parallels that for the other Neolithic crops, which also probably derive from a single domestication event[10].

The origins of agriculture

Much attention has been given to the Levant – especially the Jordan valley – as the likely area of the first cultivation and domestication[11]. Until recently, archaeological sites there such as Jericho and Aswad appeared to be the earliest agricultural villages. However, archaeobotanical work on charred plant remains from sites in the northern fertile crescent has established that sites in Turkey and Syria, such as Cafer Höyük and Çayönü, yield better evidence for the earliest domesticated crops by 9500–9800 years ago. The new evidence for the area of domestication of wild einkorn – just a few kilometres from these sites – fits well with this realization that domesticated crops (including einkorn) were present early on at sites in the northern fertile crescent. Harvesting experiments on Karacadağ have shown that enough wild einkorn grain could easily have been harvested to support substantial hunter-gatherer settlements[12]. It is highly likely that pre-Neolithic hunter-gatherer sites exist in the region that have not yet been found by archaeologists, and that these were the precursors to the known agricultural settlements.

Evidence of domestication is not necessarily the same as evidence of agricultural origins, because agriculture may have begun in one area with one set of crops, and then encompassed more domesticates as it spread. Wild ancestors of all the Neolithic founder crops are present in southeast Turkey and could have been domesticated there. However, it is equally possible that agriculture began in the Levant, without einkorn, which is rare in the area, but with emmer wheat and barley. Agriculture may well have begun in different parts of the Near East with different founder crops, blending by the Pre-Pottery Neolithic B period (8000–9500 years ago) of the Neolithic to result in the familiar package of founder crops. As yet, too few Neolithic or pre-Neolithic sites have been excavated to allow us to identify intra-regional patterns of early crop exploitation.

The new insights into einkorn domestication from DNA finger-printing are valuable in their own right, providing a welcome re-emphasis on the importance of the northern fertile crescent in plant domestication, and confirmation of the exclusively southwest Asian origins of European einkorn. If the remarkable power of resolution of AFLP finger-printing is applied to equally large collections of lines of other crop plants and their wild ancestors, significant progress is promised in understanding the location and trajectory of agricultural origins.

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References

1 Diamond, J. (1997) *Guns, Germs and Steel: The Fates of Human Societies*, Jonathan Cape
2 Zohary, D. and Hopf, M. (1993) *Domestication of Plants in the Old World. The Origin and Spread of Cultivated Plants in West Asia, Europe, and the Nile Valley* (2nd edn), Clarendon Press
3 Dennell, R. (1985) *European Economic Prehistory: a New Approach*, Academic Press
4 Heun, M. *et al.* (1997) Site of einkorn wheat domestication identified by DNA fingerprinting, *Science* 278, 1312–1314
5 Harlan, J.R. and Zohary, D. (1966) Distribution of wild wheats and barley, *Science* 153, 1074–1080
6 Nesbitt, M. and Samuel, D. (1996) From staple crop to extinction? The archaeology and history of the hulled wheats, in *Hulled Wheats: Proceedings of the First International Workshop on Hulled Wheats* (Padulosi, S., Hammer, K. and Heller, J., eds), pp. 41–100, International Plant Genetic Resources Institute
7 de Moulins, D. (1993) Les restes de plantes carbonisées de Cafer Höyük, *Cahiers de l'Euphrate* 7, 191–234
8 van Zeist, W. and de Roller, G.J. (1991/1992) The plant husbandry of aceramic Çayönü, SE Turkey, *Palaeohistoria* 33/34, 65–96
9 Hillman, G.C. (1996) Late Pleistocene changes in wild plant-foods available to hunter-gatherers of the northern Fertile Crescent: possible preludes to cereal cultivation, in *The Origins and Spread of Agriculture and Pastoralism in Eurasia* (Harris, D.R., ed.), pp. 159–203, UCL Press
10 Zohary, D. (1996) The mode of domestication of the founder crops of Southwest Asian agriculture, in *The Origins and Spread of Agriculture and Pastoralism in Eurasia* (Harris, D.R., ed.), pp. 142–158, UCL Press
11 Smith, B.D. (1995) *The Emergence of Agriculture*, Scientific American Library
12 Harlan, J.R. (1967) A wild wheat harvest in Turkey, *Archaeology* 20, 197–201