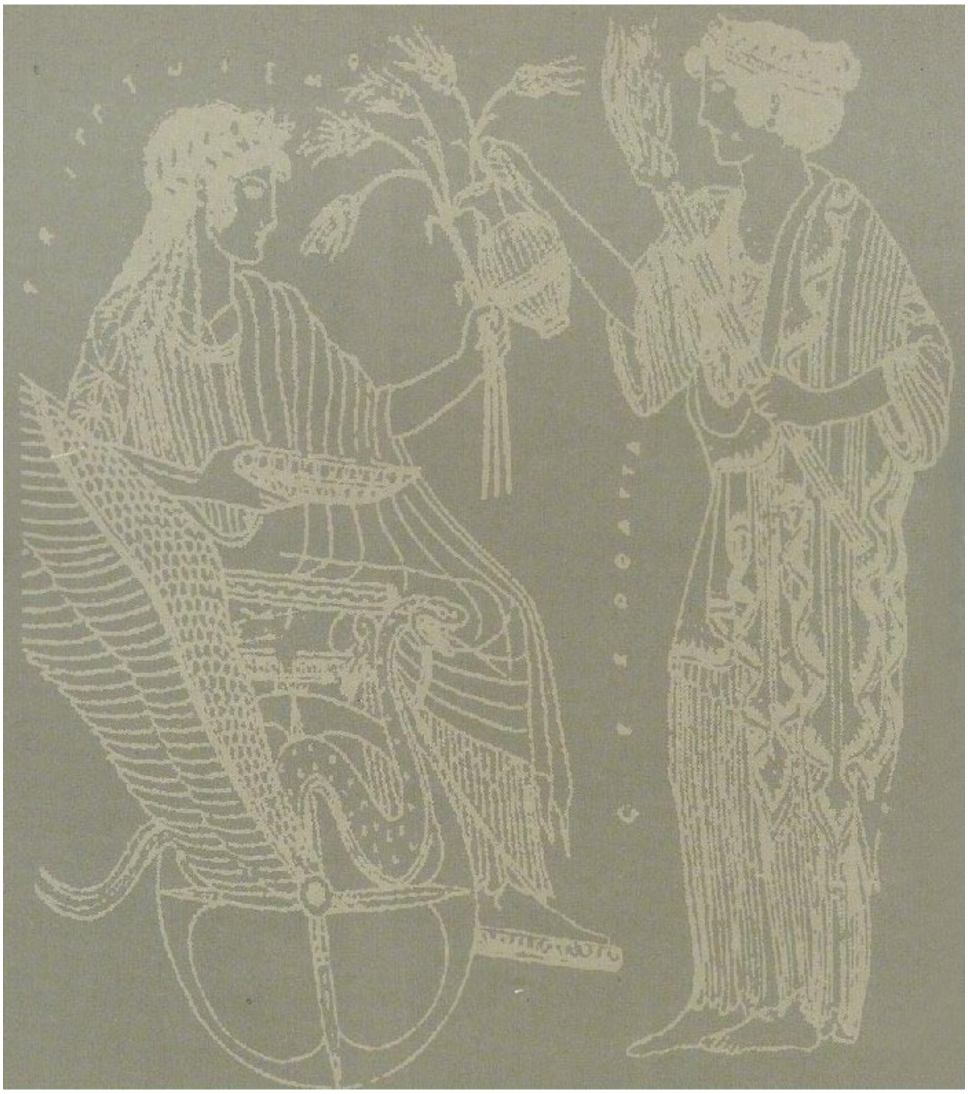
PROMOTING THE CONSERVATION AND USE OF UNDERUTILIZED AND NEGLECTED CROPS. 4.

Hulled Wheat

Proceedings of the First International Workshop on Hulled Wheats
21-22 July 1995
Castelvecchio Pascoli, Tuscany, Italy

S. Padulosi,
K. Hammer
and J. Heller,
editors



VNDER VTILIZED MEDITER RANEAN SPECIES

IPK

International Plant Genetic Resources Institute
IPGRI

The International Plant Genetic Resources Institute (IPGRI) is an autonomous international scientific organization operating under the aegis of the Consultative Group on International Agricultural Research (CGIAR). The international status of IPGRI is conferred under an Establishment Agreement which, by December 1995, had been signed by the Governments of Australia, Belgium, Benin, Bolivia, Burkina Faso, Cameroon, China, Chile, Congo, Costa Rica, Côte d'Ivoire, Cyprus, Czech Republic, Denmark, Ecuador, Egypt, Greece, Guinea, Hungary, India, Iran, Israel, Italy, Jordan, Kenya, Mauritania, Morocco, Pakistan, Panama, Peru, Poland, Portugal, Romania, Russia, Senegal, Slovak Republic, Sudan, Switzerland, Syria, Tunisia, Turkey, Ukraine and Uganda. IPGRI's mandate is to advance the conservation and use of plant genetic resources for the benefit of present and future generations. IPGRI works in partnership with other organizations, undertaking research, training and the provision of scientific and technical advice and information, and has a particularly strong programme link with the Food and Agriculture Organization of the United Nations. Financial support for the agreed research agenda of IPGRI is provided by the Governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Italy, Japan, the Republic of Korea, Mexico, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the USA, and by the Asian Development Bank, IDRC, UNDP and the World Bank.

The Institute of Plant Genetics and Crop Plant Research (IPK) is operated as an independent foundation under public law. The foundation statute assigns to IPK the task of conducting basic research in the area of plant genetics and research on cultivated plants.

Citation:
Padulosi, S., K. Hammer and J. Heller, editors. 1996. Hulled wheats. Promoting the conservation and use of underutilized and neglected crops. 4. Proceedings of the First International Workshop on Hulled Wheats, 21-22 July 1995, Castelvecchio Pascoli, Tuscany, Italy. International Plant Genetic Resources Institute, Rome, Italy.

Cover: Triptolemus and Persephone, from a 5th century BC pot by Ieron of Athens.

ISBN 92-9043-288-8

IPGRI
Via delle Sette Chiese 142
00145 Rome
Italy

IPK
Corrensstraße 3
06466 Gatersleben
Germany

Contents

Preface

Hulled wheat species (einkorn, emmer and spelt) are among the most ancient cereal crops of the Mediterranean region. Here and in the neighbouring Near East, wild ancestors of very unattractive appearance (brittle rachis, small seeds, etc.) were domesticated by farmers who in their simple breeding approaches produced plants possessing more useful agrobotanic traits. These cereals were popular within the region for hundreds of years, and long represented a staple food. At a certain point in history, however, the introduction of higher-yielding, free-threshing wheats caused hulled wheats to fall into a state of neglect, to such an extent that they have become a relic crop (as in the case of einkorn).

For social, cultural or simply economic reasons, hulled wheats are becoming popular once again. Today, they are no longer seen as the 'food of the poor' as they were in the past. On the contrary, they have become an exclusive and fashionable food for which discerning consumers are prepared to pay a higher price than for any other wheat product. In Italy, in particular, the cultivation of these crops which are referred to by the collective name of 'farro', has received increasing interest from farmers, and the area that is now being planted with hulled wheats is expanding rapidly. The 'underutilized' aspect of hulled wheats is being recognized, and this acts as a further incentive for farmers to grow them.

The history of hulled wheats is particularly instructive in understanding the importance of conserving plant genetic resources. There are fashions in the utilization of a particular crop, and one which has been a popular common food in one period can become a neglected species in another. The history of plant genetic resources contains numerous examples of this phenomenon which are even more dire than that of hulled wheats. What we abandon today could be useful tomorrow, and there exists a moral obligation to future generations to preserve the wealth of genetic diversity that has been bequested to us. It is vital that we understand this and ensure that the diversity of our crops is always properly safeguarded, despite the reduced attention a particular crop may receive at a particular time. The knowledge and cultural traditions that are interlinked with our rich agrobotanic legacy should also be a subject of concern.

Awareness is needed of another important aspect of the exploitation of underutilized species: a widespread increase in the cultivation of crops that presently occupy specific market niches, such as hulled wheats, is likely to lead to a market surplus of the product. This may in turn cause a drop in prices, which could have a negative impact on the cultivation of these species, as it will put many farmers out of business. And it is the small farmers, who have been maintaining landraces of hulled wheats in their fields, that are most likely to be affected. The resulting loss of diversity imaginable in such a scenario will clearly be to our detriment.

The increase in popularity of the once-neglected species and of the minor crops in general is relevant to another issue, namely the need for the registration of material in commercial seed catalogues. This is a very sensitive issue for conservationists, as the successful promotion of underutilized species inevitably leads to the registration of those improved varieties bred for increasing yields, and produces higher-quality crops. In a sad paradox of modern agriculture, however, the spread of these improved varieties also leads to the replacement of landraces, and thus to a loss of the very diversity which has been safeguarded by farmers over generations and used to breed the improved types.

What should we be doing to safeguard hulled wheat species such as einkorn (which has almost disappeared from Italy), or to ensure that landraces will still be grown, in spite of the possible spread of new improved types? What is the distribution of these species in the world, and what is the actual situation regarding their use and commercialization? What role could national and international communities be playing to secure the remaining diversity of these species whilst promoting their sustainable use?

These and other issues were addressed in the papers given at the first International Workshop on hulled wheats that took place on 21 July 1995 in Castelvecchio Pascoli, in the region of Tuscany, Italy. The meeting was attended by participants from 12 countries (France, Germany, Greece, Hungary, Italy, Jordan, Spain, Switzerland, Syria, Turkey, UK and the USA) involved in hulled wheat research in various disciplines such as archeobotany, breeding, plant germplasm collecting, genebank management, taxonomy and ethnology. The workshop's audience included extension workers, farmers' associations, cooperatives and users.

Relevant points raised at the workshop were followed up at the first meeting of the Hulled Wheat Genetic Resources Network which took place on the following day. The meeting drew particular attention to the need to establish collaborative efforts in the area of conservation and better utilization of hulled wheat species. The role that the newly established Network will play in achieving these objectives will be an extremely important one. Its Work Plan is provided in Chapter V.

The Workshop in Castelvecchio Pascoli was jointly organized by the BMZ/GTZ-supported German Project on Neglected Species and the Italian-supported Project on Underutilized Mediterranean Species (UMS).

Joachim Heller
Stefano Padulosi
International Plant Genetics Resources Institute

Acknowledgements

IPGRI would like to thank the Comunita' Montana of Garfagnana, Tuscany region, for the warm hospitality in Castelvecchio Pascoli and the Germplasm Institute of the National Research Council for its contribution to the meeting. IPGRI also thanks all those persons who have kindly assisted as referees for the scientific contributions.

I. Taxonomy, Evolution, Distribution and Origin

Notes on the taxonomy of farro: *Triticum monococcum, T. dicoccon* and *T. spelta*

***A.T. Szabó*[1] *and K. Hammer*[2]**

[1] Universities of Western Hungary, Berzsenyi College, Laboratory of Ecological Genetics and Evolution of Crop-Plants, Szombathely, Hungary

[2] Institut für Pflanzengenetik und Kulturpflanzenforschung, Genebank, Gatersleben, Germany

Introduction

The main goal of this paper is to give a broad review of the principles and practices applied in the taxonomy of farro. The work has been motivated by data gathered from ethnobotanical and historical sources indicating the accumulation of ecologically important genetic diversity in neglected wheat species on diploid, tetraploid and hexaploid levels as well. It seemed especially attractive to study the effect of domestication on wheat genetic diversity in diploids. These research possibilities were discussed in the 1970s and 1980s by many colleagues – mostly from Japan, the UK, Italy, Germany, France, Austria, Romania and Hungary – and the time was ripe for a general review. The international IPGRI Project on Farro (Hulled Wheats) as a part of a programme on Underutilized Mediterranean Species marked the start of a new era in the subject.

Wheat, hulled wheat, farro and the *Triticum* species

Systematics and the nomenclature of cultivated and wild wheats is a constant and lasting problem. Divergences in the literature are based mainly on conflicts between:

- ethnobotanical concepts (such as farro) and Linnean taxonomy
- botanical taxonomy and genetic studies
- theoretical requirements and practical needs (reflected also in the level of taxonomic categories accepted).

Wheat (*Triticum s.str.*) as defined here actually is more an ethnobotanical than a taxonomic concept, being applied to any grain furnished by different cultivated *Triticum* populations used mostly for food and feed. In rural territories people are perfectly aware what kinds of wheats are cultivated there. In the Alps – Carpath – Balkan area, for example, we will never meet people calling an *Agropyron*, a *Haynaldia* or an *Aegilops* plant or even a *Triticum monococcum* simply a 'wheat'.

Wheat (*Triticum s.lat.*) as defined by Linnean botany is a taxonomic concept based originally on morphological characters.

In biosystematics (preferred by genetically oriented scientists) emphasis is on crossability. These researchers classify according to crossability criteria the plants belonging traditionally to different genera (e.g. *Agropyron s.l.*, *Aegilops s.l.*, *Haynaldia,* etc.) to the genus *Triticum*, irrespective of their cultivated or spontaneous nature. The biosystematical approach is in contrast to that of classical botany and even more of ethnobotany.

Hulled wheat (in the botanical sense) denotes any wild or cultivated *Triticum* population with nonthreshable grain. From a genetic point of view 'hulled wheats' represents an *ad hoc* group of Triticeae, owning a dominant gene, the Q factor. As threshability is a character selected mostly in cultivation, hulledness is characteristic primarily for neglected, obsolete, spontaneous or wild wheats.

In a genetic sense the hulled wheats comprise taxa belonging to the primary, secondary and even tertiary *Aestivum* wheat genepool *sensu* Harlan and De Wet (1971). In this sense not only the nonthreshable species of *Triticum s.str.* may be regarded as hulled wheats but every species considered by lumpers belonging to *Triticum s.l.* including *Haynaldia, Aegilops, Agropyron*, etc.

Details of the highly complicated and quite controversial biosystematic approaches in the taxonomy and nomenclature of wild and cultivated wheats will be treated elsewhere. Here are mentioned just a few cases to exemplify how complicated some specific situations are.

Farro is a strictly ethnobotanical concept deeply rooted in Italian traditions. The term is reserved for three cultivated hulled wheat species: *Triticum monococcum* (einkorn), *T. dicoccon* (emmer) and *T. spelta* (spelt). In ethnobotanical approaches sometimes (and quite erroneously) hulled wheats and farro are regarded as synonymies (Perrino *et al.,* this volume).

This paper accepted the farro concept for pragmatic reasons, focusing only on the taxonomy of the three cultivated hulled wheat species mentioned in the title. We found that the most convenient word to designate this group of wheats (hulled and neglected as well) is still an ethnobotanical term: the old Italian Latin root 'farro' referring today to einkorn, emmer and spelt wheats altogether. It is worth noting the apparent uniqueness of this collective term farro, with no equivalent found by us in other European Anglo-Saxon, Latin, Slavonic and Finno-Ugric languages.

Accepting the 'farro' concept, some new problems emerged. For example there is a farro species which is not hulled: the recently (1970) isolated 'naked einkorn', *Triticum sinskajae,* collected first in 1926 in Transcaucasia.

Some formal disagreements among the authors occur in the spelling of the scientific name of different farro taxa, as for example:

1. ***Triticum boeoticum***: in spite of the general agreement in spelling of the name of wild einkorn as *T. boeoticum* Boiss. 1854 em. Schiemann 1943 (Schultze-Motel 1986; Soó 1973; Terrell *et al.* 1986, etc.), in *Flora Europeae* C.J. Humphries (1980) adopted the form *T. baeoticum* Boiss. 1853 syn. *T. monococcum* subsp. *baeoticum* (Boiss.) Hayek. Here we spell the name according to the general usage which is worth conserving.
2. ***Triticum dicoccon*** Schrank 1789 is generally accepted as a valid name for emmer, but *T. dicoccum* Schübler 1819 [syn. *T. vulgare* subsp. *dicoccum* Körn. 1885, *T. sativum* subsp. *dicoccum* Aschers. et Graebn. 1901, *T. turgidum* subsp. *dicoccum* (Schrank) Thell. 1918] is also frequently used for scientific denomination of emmer.
3. ***Triticum spelta*** L. 1753 [syn. *T. vulgare* var. *spelta* Alef. 1866, Körn. 1885 pro subsp., *T. sativum* subsp. *spelta* Aschers et Graebn. 1901, Thell. 1918], the spelt wheat, is problematic on an ethnobotanical level, not really being a farro in Italian, but 'faricello' or 'spelta' (Schultze-Motel 1986:1462).

Lumpers and splitters in wheat taxonomy

The main boundary line between the different approaches accepted in wheat taxonomy runs between splitters and lumpers. The situation is often reflected in personal discussions and correspondence: "When publishing in a good journal, editors tend to impose their nomenclature, ...so for instance in my papers... I was forced to use a different nomenclature in each publication ...". (V. Vallega, July 1995, pers. comm.). This seems to be not only a formal but also a real problem: the problem of genus and species concept in modern crop plant biology, and especially in the taxonomy of the tribe Triticeae.

The situation requires a solution, because interest in hulled wheat species is traditional and is growing steadily (cf. Annex 1. List of some keywords in farro research). This growing interest needs a common taxonomic symbolism, or at least clear conventions regarding the content and utilization of different botanical names.

In the tribe Triticeae, generic delimitation is somehow heavily contested (Clayton and Renvoize 1989; Watson and Dallwitz 1992). On the genus level, for example, the names *Aegilops* and *Triticum* are used with quite different meanings by different authors (*Triticum tauschii*: Bates and Killeen 1980; *Triticum* x *boeoticotauschichicum*: Galstyan-Avanesyan 1986; *Aegilops*: Hammer 1980; Tanaka 1983; Witcombe 1983; Van Slageren 1994, etc.). Even more controversial is the situation with other genera such as *Dasypyrum* (syn. *Haynaldia*, a name worth being proposed as *nomen conservandum*!) or *Agropyron s.l.* Both genera have species belonging to the primary or secondary *Triticum* genepool.

Splitters belong mostly to traditional botanical schools. Classical representatives in farro systematics are many botanists from the Komarov Institute, the All Russian Institute of Plant Industry and of course many other scientists throughout the world (e.g. Wagoner in Williams 1995 for *Thinopyrum* syn. *Agropyron intermedium* complex).

Askel Löve, for example, followed J.H.F. Link (1767-1851) and separated einkorn on the genus level from other wheats by including it in the genus *Crithodium* under the name *Crithodium monococcum* (L.) Á.Löve: *T. thaoudar* Reut. was classified as *Crithodium monococcum* (L.) Á. Löve subsp. *aegilopoides* (Link) Á.Löve. This tendency of splitting is further complicated in the case of *T. dicoccon* classified by Löve as *Giachilon polonicum* (L.) Seidl. subsp. *dicoccum* (Schrank) Á. Löve, or *T. turgidum* L. classified as *Giachilon polonicum* (L.) Seidl subsp. *turgidum* (L.) Á. Löve (see also D. Löve 1992 for further examples).

Dorofeev *et al.* (1979, 1980) divided somewhat similarly the genus *Triticum* in two subgenera: *Triticum* L. and *Boeoticum* Migush. et Dorof. The diploid wheat ancestors have been included in both subgenera: *T. urartu* Thum. ex Gandil. as a monospecific section in subgen. *Triticum* Sect. *Urartu* Dorof. et A. Filat. (genome Au), *T. boeoticum* Boiss., *T. monococcum* L. and *T. sinskajae* A. Filat. et Kurk. in sect. *Monococcum* Dum. (genome Ab).

Molecular biologists generally classify these wheats as different subspecies of *T. monococcum* (Sharma and Waines 1981; Waines 1983).

The most comprehensive botanical survey of wheats (including the hulled ones) on specific and infraspecific levels is that of Dorefeev *et al.* (1979). Other authors, as for example Miller (1990) or Mac Key (1966), prefer a more simple 'lumping nomenclature'. A generally accepted practical scheme is still strongly needed in which **wild taxa are consequently treated on the subspecies and variety levels, and cultivated taxa on the convariety and (pro)variety levels**, in accordance with the International Code of Botanical Nomenclature for Cultivated Plants.

Geneticists are generally lumpers in theory and splitters in practice; advocates for large collective species with many subspecies and varieties, but who generally use (for reason of convenience and/or prestige) instead of the subspecies and botanical variety names the species name when performing new interspecific or intergeneric crosses. Kimber and Feldman (1987) consider, for example, vars. *urartu* and *boeoticum* as subspecies belonging to *T. monococcum*. Others subdivide *T. boeoticum* – accepted as a separate species – into subsp. *aegilopoides* and subsp. *thaoudar*. Opposed to this opinion, Dorofeev *et al.* (1979), Lelley and Mándy (1963) or Zhukovski. (1971) accept *T. monococcum, T. boeoticum* and *T. urartu* as separate species with several further subspecies; still on this it seems rather acceptable that *T. urartu* be a separate species according also to crossability data and electrophoretic banding patterns (it can be crossed in fact with *T. monococcum* only if *T. urartu* is the male parent; F_1 is normally self-fertile).

On the species level the nomenclature of both diploid and tetraploid taxa is quite controversial, just to mention the use of *T. boeoticum* and *T. monococcum* in different senses (Neumann *et al.* 1985; Pistrick *et al.* 1995; Waines 1983), or the controversial usage of the names regarding wild and cultivated durum wheats and its hybrids (*Triticum turgidum* var. *dicoccoides* – Anikster 1988; *Triticum dicoccoides* – Kuzmenko *et al.* 1990; *Triticum turgidum* – Kerby and Kuspira 1987; *Triticum dicoccon* – Borojevic 1956, Schiemann 1956; amphidiploids with *Dasypyrum* – Friebe *et al.* 1986, Kawahara 1988, Kuzmenko *et al.* 1990; *Triticum spelta* x *T. durum* – Lapochkina and Pukhalskii 1983; *Aegilops squarrosa* x *Triticum boeoticum* – Gill *et al.* 1981; *Triticum* x *boeoticotauschicum* – Galstyan-Avanesyan 1986; *Triticum sharonensis* x *T. monococcum* – Kushnir and Halloran 1982, etc.)

Names are used with different meanings in the Triticinae section in different papers dealing with, for example, intergeneric amphiploids (Miller 1981), gene symbols (Kimber and Sears 1983), seed coat morphology (Banerjee and Chauchan 1981), crossability (Belea 1992 and the bibliography cited there), taxonomy (Dorofeev *et al.* 1979, 1980; Schultze-Motel 1986), evolution (Dorofeev 1969, 1969a, 1971; Sakamoto 1987, 1991), classification by DNA hybridization (El-Sharkaway *et al.* 1977), ear morphology (Foltyn 1990), C-banding (Friebe *et al.* 1986) and cold hardiness (Galiba 1994).

Hulled wheats are treated taxonomically differently by different authors (Hegi 1908, Kuckuck 1970, Harlan 1981, Hammer and Perrino 1984, Kimber and Feldman 1987, van Slageren 1994; cultivation and conservation: D'Antuono and Pavoni 1993; 'no chemicals' biofarming: Gyulai 1995; in monographical works: Lelley and Mándy 1963; genetic resources: Croston and Williams 1981, Sharma *et al.* 1981, Sakamoto and Kobayashi 1982, Hodgkin *et al.* 1992, Furuta and Ohta 1993, Merezhko 1994, Pannu *et al.* 1994; useful characters: Tanaka 1983; morphophysiological traits: Al-Hakimi and Monneveux 1993).

Looking at what happens in the everyday practice of different authors and/or journals we are inclined towards liberal nomenclatural solutions used in accordance with the scope of a given publication. But it is important to indicate in every paper precisely which nomenclatural approach and/or principle is followed by the author (*Triticum sensu lato/sensu stricto, s.l./s.s.*).

In the botanical taxonomy of the farro genepool the taxonomic solutions accepted by Schultze-Motel (1986) and Dorefeev *et al.* (1979) served as a baseline for our proposals.

Infraspecific classification

The taxonomic treatment of infraspecific variability in wild and cultivated taxa is still based on the Linnean tradition but a classification supported also by taxonomically relevant, identified marker genes seems to be a growing necessity.

There is no general agreement in taxonomic categories accepted for infraspecific classification of all cultivated plants. In our view the taxonomy applied for the classification of plant populations resulting from human selection should express consequently (even in the taxon level abbreviations) the difference between natural and artificial selection: subsp**.** for spontaneus and (supra)convar. for cultivated larger groups, var. for spontaneous and provar. for cultivated smaller ones. For the smallest spontaneous taxonomic categories the f. (forma) and for cultivated one the cv. (cultivar) is accepted.

This system (if used consequently) **carries information not only about common characters, but also regarding the spontaneous or cultivated nature of the group concerned, about the mode of selection under which a taxon actually evolves.** Unfortunately there is no general agreement among agrobotanists on the consequent and coherent application of different infraspecific taxonomical categories, especially on the provariety level. The difference of opinions is reflected also by the solutions accepted in this paper (subsp., var., supraconvar., convar., provar., -var).

Botanical nomenclature vs. gene and genome nomenclature

Botanical nomenclature

The botanical nomenclature has almost a tricentennial tradition. The nomenclature of *Triticum* genomes and genes has a history of just some decades. Accordingly the botanical nomenclature of different taxa is more complicated. For example, many journals accept only reports in which *Aegilops* is treated as *Triticum*. Moreover there are problems of priority. For example, to Witcombe (1983), *Aegilops speltoides* Tausch has a priority as opposed to *A. aucheri* Boiss. and A. *squarrosa* L. as opposed to *A. tauschii* Coss. which is a name of doubtful validity. The opinion of Hammer (1980) is widely accepted: *A. squarrosa* L. is considered by Hammer as an invalid name; genebank accessions held in Gatersleben are being identified as *A. tauschii* Coss. *A. sharonensis* Eig and *A. searsii* Feld. et Kis. have been lumped into *A. longissima* Schweinf. et Muschl., as well as *A. ligustica* (Savign.) Coss. in *A. speltoides* Tausch (Witcombe 1983). For more details on the subject see Van Slageren (1994:326-328). Some generic names used in the taxonomy of *Aegilops* and *Triticum* species are shown in Table 1.

At the species level, the taxonomic problems are even more complicated. Looking for example at the donors of the quite controversial B hoeomologous group of the bread wheat (*Triticum aestivum* L.), the situation of valid names and their synonymies looks rather confused (Table 2.).

Table 1. Examples of generic names used for *Aegilops* and *Triticum*.

Year	Author	Name
Aegilops		
1753	Linné	*Aegilops*
1846	Savigny	*Agropyron*
1959	Bowden	*Triticum*
Triticum		
1753	Linné	*Triticum*
1777	Scopoli	*Bromus*
1834	Link	*Crithodium*
1836	Seidl	*Gigachilon*
1836	Endlicher	*Spelta*
1837	Koch	*Cerealia*
1841	Seringe	*Nivieria*
1846	Heynhold	*Cryptopyrum*
1856	Godron	*Eutriticum*
1866	Alefeld	*Deina*
1887	Hackel	*Sitopyros*
1887	Krause	*Frumentum*
1925	Philiptshenko	*Monococcum*

Notes:

1. In genus *Agropyron* 23 authors indicated about 30 different genetic names, including *Triticum* (hulled).
2. In genus *Haynaldia/Dasypyrum* the two known species have been classified in genera *Hordeum* (auct. dif.), *Secale* (Linné 1753), *Triticum* (Marshall de Bieberstein 1808, Link 1827?, Ascherson et Graebner 1901, Szabó n.publ.), *Agropyrum* (auct dif. non Link 1827), *Haynaldia* (Schur 1866), *Pseudosecale* (Borbás 1897), *Dasypyrum* (Candargy 1901, Maire 1942, Humphries 1980).

Table 2. The nomenclature of the species considered as possible donors of B genome of emmer, spelt (*Triticum dicoccon*, *T. spelta*) and bread wheat (*T. aestivum*).

Year	Author(s)	Species names	Genome (n)
1775	Forsskal	*Triticum bicorne*	B (Sears 1956)
1850	Jaubert et Spach	*Aegilops bicorne*	
1912	Schweinfurth et Muschler	*Aegilops longissima*	B1, S1
1928	Eig	*Aegilops sharonensis*	
1959	Bowden	*Triticum longissimum*	
1977	Feldman et Kislev	*Triticum searsii*	
1980	Feldman et Kislev ex Hammer	*Aegilops searsii*	B1, S1
1837	Tausch	*Aegilops speltoides*	Bsp, Ssp
1844	Boissier	*Aegilops aucheri*	Bsp, Ssp
1857	Grenier	*Triticum speltoides*	
1847	Savigny	*Agropyron ligusticum*	
1864	Cosson	*Aegilops ligustica*	

In the genetic analysis of different crops, taxonomic problems do occur frequently. These are often related to new taxonomic discoveries, with changes regarding *inter alia* the biological content of the taxa considered. Geneticists are often confused in deciding the level of a newly created hybrid: would that be an infraspecific, interspecific, intergeneric or distant hybrid?

The standardization of Kimber and Sears (1983) for genomes (Table 3), and that of McIntosh (1983) for genes (Table 4, and Annex 2-4 for further excerpts) has been accepted here with some minor modification, e.g. for the Ab genome of *T. monococcum* and *T. sinskajae*, as well as in the case of the designation of the *Glu* allelic system. The gene nomenclature in farro is important not just for practical, but also for theoretical, evolutionary reasons (Payne and Lawrence 1983). It would be desirable to use a coherent system in which, for example, *Glu-1 1A5* means actually the gene product of the 5th allelic sequence expressed by the *glu-1* gene on the 1st chromosome from the *A* genome. However, a generally accepted solution is to talk about the '*Glu*' genes, meaning a DNS sequence (*glu*) and a protein product (*Glu*) as well.

Genome compatibility and homoeologous chromosome pairing ability are also important factors in hulled wheat evolution (Kimber 1993).

These evolutionary factors were studied in many quite controversial cases, as in *Triticum araraticum* (Badeeva *et al.* 1994); infraspecific divergence (Badeeva *et al.* 1994); *Triticum turgidum* var. *dicoccoides* (Anikster 1988); *Triticum dicoccoides* – chromosomes (Kuzmenko *et al.* 1990); *Triticum turgidum* – resistance genes (Kerby and Kuspira 1987); *Triticum dicoccum* – cultivation in former Yugoslavia (Borojevic 1956, Schiemann 1956); amphidiploids with *Dasypyrum* (Friebe *et al.* 1986); chromosomes (Kuzmenko *et al.* 1990); *Triticum tauschii* (Bates and Killeen 1980); *Triticum macha* (Dekaprelevich 1961); *Triticum sinskajae* (Filatenko and Kurkiev 1975); *Triticum vavilovii* – resynthesis, *Triticum timopheevii* – hybrids, mutations (Kawahara 1985); *Triticum spelta* – ethnobotany (Sakamoto 1993).

Genome nomenclature

Some taxonomically relevant genomes in genus *Triticum* are listed in Table 3.

Nomenclature of taxonomically relevant genes

Populations characterized by gene blocks of different allelic composition fitted for different ecogeographic conditions have been generally classified in different taxa by traditional systematics (cf. van Slageren 1990).

A fairly good example for that is the border line between wild and cultivated einkorn taxa: the hairiness and the fragility of the rachis. These are expressed even in identification keys in quantitative terms, in terms of allelic frequencies and expressivity.

The taxonomic situation is much more confused on the infraspecific level in the case of the wild and the cultivated groups. Here the populations are generally very variable, intermixed, and differences in allelic frequencies (and consequently in taxonomy) are less evident.

Table 3. Some taxonomically relevant genomes in genus *Triticum* (*s. lat.*). Genome names according to Kimber and Sears (1983), slightly modified.

Symbol	Genome (synonyms in parentheses)
Ab	** *T. monococcum* (*T. boeoticum*)
Au	* *T. urartu*
S	* *T. speltoides*
Sb	* *T. bicorne* (*A. bicornis*)
Sl	* *T. longissimum* (*A. longissima, A. sharonensis*)
Ss	* *T. searsii* (*A. searsii*)
Mt	* *T. tripsacoides* (*A. mutica*)
D	* *T. tauschii* (*A. squarrosa*)
M	* *T. comosum* (*A. comosa, A. heldreichii*)
Un	* *T. uniaristatum* (*A. uniaristata*)
C	* *T. dichasians* (*A. caudata, A. markgrafii*)
U	* *T. umbellulatum* (*A. umbellulata*)
AB	** *T. turgidum* (*T. dicoccoides, T. dicoccon, T. durum*, etc.)
AG	* *T. timopheevii* (*T. araraticum*)
AAG	* *T. zhukovskyi* (*T. timopheevii* var.)
ABD	** *T. aestivum (T. compactum, T. macha, T. spelta,* etc.)
DUn	* *T. ventricosum* (*A. ventricosa*)
DM,DDM	* *T. crassum* (4x, 6x) (*A. crassa*)
DMS	* *T. syriacum* (*A. crassa* subsp. *vavilovii, A. vavilovii*)
DMU	* *T. juvenale* (*A. juvenalis*)
US	* *T. kotschyi* (*A. kotschyi, A. peregrina, A. variabilis*)
UM	* *T. ovatum* (*A. ovata*)
UM, UMUn	* *T. triaristatum* (4x, 6x) (*A. triaristata*)
UM	* *T. macrochaetum* (*A. biuncinalis, A. lorentii*)
UM	* *T. columnare* (*A. columnaris)*
UC	* *T. triuncinalis* (*A. triuncinalis*)
CD	* *T. cylindricum* (*A. cylindrica*)

* only hulled taxa (species, subspecies, etc.) known.
** hulled and naked taxa (species, subspecies, etc.) known.
T. = Triticum; *A. = Aegilops.*

There is a large quantity of allelic differences between populations, which remained undetected by taxonomists, but were recognized in practice and expressed in ethnobotanical terms (e.g. by landrace names, or in the "know how" regarding the proper use of a landrace product, etc.).

To such allelic differences belong, for example, characters connected with feeding and/or bread-making quality of the wheats (as reflected by the high molecular weight HMW-glutenin and low molecular weight LMW-gliadin fraction of the endosperm proteins) or the varying carotene content of the kernels.

There is sometimes a striking parallelism between morphologically relevant genetic markers and botanical classifications. An interesting example in this respect has been provided by Blixt and Williams (1982) for peas. Our concept coincides with theirs in some respects:

1. The attempt to identify the characters used in infraspecific classifications based on morphology with the phenotypic manifestation of known genes could demonstrate a high degree of conformity between botanically and genetically defined characters.

2. There is evidence that for plants with less elaborated genetic knowledge a good infraspecific botanical classification with carefully defined key characters can be extremely useful even in searching for marker genes.
3. Genetic knowledge of the characters used can lead to a more reliable and objective classification.

Table 4. Examples of some taxonomically relevant genes in hulled wheats. Symbols according to McIntosh 1983, slightly modified (genes of central taxonomical importance in bold).

Gene symbol	Character name	Notes
B	Inhibitor of awns	
Bg	Black glume colour	
Bs	Inhibitor of basal sterility in speltoids	*
C	Club spike shape	*
Ch	Hybrid chlorosis	*
cn	Chlorina	*
Ha	Grain hardness	
Hd	Hooded (awns)	
Hg	Hairy glumes	
Hl	Hairy leaf	
Hn	Hairy node	
Hr[1]	**Hairy rachis**	
lg	Liguleless	*
ms	Male sterility	*
Ne	Hybrid necrosis	*
Ng[1]	**Naked grain**	
Pbc	Pseudo-black chaff	
Pc	Purple culm	
Rf[1]	**Rachis fragility**	
Ppd	Response to photoperiod	*
q/Q[1]	**Spelt factor**	
R	Red grain colour	
Ra	Red auricles	*
Rc	Red coleoptile	*
Rg	Red glume colour	
Rht	Reduced height	
s	Sphaerococcum factor	*
Tg	Tenacious glumes	*
Us	Uniculm stunt	*
v	Virescent	*
Vrn	Response to vernalization	*
W	Waxiness	*

[1] Taxonomically very important gene complex (wild, hulled).

* Not really explored until now in farro taxonomy.

Taxonomy (nomenclature and systematics) of farro

Botanical identification and basic nomenclature of farro species

Variability reflected in taxonomy of noncultivated (wild and weedy) populations is not treated here in detail. Only the basic nomenclature and identification key are presented for the main taxa (Humphries 1980) in order to help identification. The botanical identification key may be summarized as follows:

1a. Rachis fragile, disarticulating at maturity (farro species)
2a. Spikelets with 2 florets, usually one fertile
3a. Glumes strongly attached to caryopses
4a. Rachis densely hairy, disarticulating readily at maturity — **1**. *T. boeoticum*
4b. Rachis sparsely ciliate, disarticulating only with pressure at maturity — **2**. *T. monococcum*
3b. Glumes sparsely attached to caryopses (free threshing) — **3**. *T. sinskajae*
2b. Spikelets usually with 3-5 florets, usually 2 fertile
5a. Rachis disarticulating above the spikelet — **4**. *T. dicoccon*
5b. Rachis disarticulating below the spikelet — **5**. *T. spelta*
1b. Rachis tough, not disarticulating at maturity (non farro species)
6a. Glumes strongly keeled throughout
7a. Glumes nearly as long as the lowest floret, spike compressed — **6**. *T. durum*
7b. Glumes about 2/3 as long as lowest floret, spike square in section — **7**. *T. turgidum*
6b. Only the upper half of the glumes are keeled — **8**. *T. aestivum*

Among the diploid hulled wheats probably einkorn (*Triticum monococcum* L.) has received the largest attention by taxonomists (cf. Stranski 1934; Dorofeev *et al.* 1979; Schultze-Motel 1986), and by ethnobotanists (Borza 1945; Péntek and Szabó 1981, 1985; Pistrick *et al.* 1995).

In the case of einkorn the infraspecific variability may be identified at different levels. Relatively recent works have revealed new morpho-anatomical variability in the vegetative part and in the ear morphology (Castagna *et al.* 1993), endosperm composition (Kanzaki and Noda 1988), phytoliths, i.e. the variability of silica bodies formed in the epidermis (Ball *et al.* 1993), and even in *in vitro* cultivated cell lines (Erdei *et al.* 1982).

Biochemical, molecular and genetic variability (Smith-Huerta *et al.* 1989) along with resistance traits are generally not reflected in taxonomic nomenclature, but are important for grouping germplasm into different categories. So, for example, variability on economically important gene products such as some isoenzymes (Nishikawa *et al.* 1992) or proteins is important for flour quality (Payne *et al.* 1987; Waines and Payne 1987; D'Egidio *et al.* 1991; Lelley and Gröger 1993/94). Variability and possible use of einkorn resistance/tolerance genes for wheat breeding has been studied by Corazza *et al.* (1986), Mcintosh *et al.* (1984), Multani *et al.* (1989) and Rubies *et al.* (1992). To identify those genes responsible for this resistance and presence of genetic relationship among various taxa, variability at the DNA level has also been studied (e.g. RFLP polymorphism, Castagna *et al.* 1994).

Variability in chromosome and/or genome level, in chromosome structure and karyotype has been studied by many scientists such as Claesson *et al.* (1990, crossability and chromosome pairing), Li *et al.* (1986), Miller *et al.* (1981, A4 chromosome), DubCovsky and Dvorak (1993, linkage map), Dean and Leech (1982, leaf development and ploidy), etc. This variability may also be of taxonomic significance.

Taxonomically difficult, and insufficiently explored, are the results of different hybridization experiments performed for example within the einkorn genepool at intergeneric and interspecific levels. We can recall here those of Bates and Killeen (1980, interspecific crosses with *Secale*), Chelak (1980, interspecific crosses with tetraploid wheats), Claesson *et al.* (1990, crossability, chromosome pairing), Cox *et al.* (1991, hybridization attempts and reproductive behaviour), Kison and Neumann (1993, *T. monococcum* x *S. cereale*), Gerechter-Amitai *et al.* (1971, hybrid bridge), Sharma and Waines (1981, male and female fertility in hybrids), etc.

Other investigations have been made on the origin, distribution, domestication, evolution and potential agronomic value of diploid wheats as botanical entities in the works of Dhaliwal (1977), Kishitani and Tsunoda (1981), Pavicevic (1971, 1972), Szabó (1983, 1994) or as genetic resources (Neumann *et al.* 1985; Pistrick *et al.* 1995; Szabó 1981; Vallega 1991, 1992; Waines 1983).

Variability in cultivated hulled wheats as reflected in taxonomy

Farro wheats are marked with bold.

T. monococcum L. convar. (subsp.) ***monococcum***	Ab(m)	**cultivated Einkorn**
T. monococcum convar. (subsp.) ***sinskajae*** (F. et D.) em. h.l.	As	**Sinskaja Einkorn**
T. timopheevii Zhuk.	AbG	Timofeev Emmer
* *T. ispahanicum* Heslot	AuB	Ispahanic Emmer
T. dicoccon Schrank	AuB	**Palestine Emmer**
* *T. karamyschevii* Nevski	AuB	Karamyschev wheat, Kolchic Emmer
T. zhukovskyi Men. et Er.	AbAbG	Zhukovsky Dinkel
T. macha Dek. et Men.	AuBD	Macha Dinkel
T. vavilovii (Thum.)Jakubz.	AuBD	Vavilov Dinkel
T. spelta L.	AuBD	**Spelta Dinkel, Spelt**

The cultivated diploid farro – Triticum monococcum

T. monococcum L. convar (subsp.). *monococcum*: cultivated Einkorn (mostly hulled)
T. monococcum L. convar. (subsp.) *sinskajae* (F. et D.): Sinskaja Einkorn (not hulled)

T. monococcum L. 1753.
[Syn.: *T. pubescens* Bieb. 1800; *T. hornemannii* Clementi 1818, *Nivieria monococcum* Ser. 1841; *T. vulgare monococcum* Alef. 1866; *T. monococcum* b.) *cereale* (A. et G.) Thell. 1918; *T. monococcum* subsp. *monococcum* A. et D. Löve 1961](cf. page 4, this paper)
English: einkorn, French: engrain, German: Einkorn, Hungarian: alakor, Italian: farro, Romanian: alac.

A. Geographical provenance groups ('races')

1. *Helotinum* Flaksb. (Asia Minor, Transcaucasia, Crimea)
2. *Alemanum* Flaksb. (Germany, Switzerland)
3. *Ibericum* Flaksb. (Spain, S. France, Morocco)
4. *Transsylvanicum* h.l. (Eastern Carpathians, Balkan Peninsula ?)

B. Agrobotanical classification.

Spontaneous subspecies and variety groups:

subsp. *boeoticum* (Boiss. 1853 pro sp.) Hayek et Markg. 1932, Mac Key 1966
syn. *Crithodium aegilopoides* Link. 1834.
T. boeoticum Boiss. subsp. *boeoticum* - wild einkorn. In: Terrell *et al.* 1986.

subsp. *thaoudar* (Reut. ex. Bourgeau 1860 pro sp.) Grossh. 1939
syn. *T. spontaneum* subsp. *thaoudar* (Reut.) Flaksb. 1935.
T. boeoticum Boiss. subsp. *thaoudar* (Reuter ex Hausskn.) Schiem. In: Terrell *et al.* 1986.

Note: var. *reuteri* (Flaksb.) Hammer et Szabó n. comb. cf. **basionym**: *T. thaoudar* var. *reuteri* Flaksb., Kult. Fl. SSSR 1 (1935, 345). *T. baeoticum* var. *thaoudar* Dorof. *et al.* Kult. Fl. SSSR 1 (1979, 293), nom. illeg.

Cultivated variety groups (convarieties, provarieties):

convar. (subsp.) *monococcum*

– provar. *atriaristatum* Flaksb. [syn. var. *nigroatrum* Flaksb.]
Distribution: France, Bulgaria, Asia Minor

– provar. *flavescens* Koern. in Koern.
Distribution: Asia Minor, Balkan, Alps, Germany, France, Spain, Morocco

– provar. *hohensteinii* Flaksb.
[syn. var. *tataricum* Kovarsk., var. *ratschinicum* Dekapr. et Menabde] .
Distribution: Germany, Georgia, Crimea

– provar. *hornemanii* (Clem.) Koern. in Koern. et Wern. 1885.
[Syn.: T. hornemannii Clem., *T. pubescens* Bieb., var. *pubescens* (Bieb.) Koern., *T. monococcum* var. *sangesuri* Thum.]
Distribution: Spain, Germany, Switzerland, Austria, Balkan, Caucasus, Crimea

– provar. *macedonicum* Papag. 1919.
[Syn.: *T. monococcum* var. *eredvianum* Zhuk., f. *punctatum* Stransk.]
Distribution: Balkan, Asia Minor, Georgia, Crimea

– provar. *monococcum* [syn. var. *laetissimum* Koern.].
Distribution: Asia Minor, Balkan /Bulgaria, former Yugoslavia/, Spain, France, Morocco

– provar. *nigricultum* Flaksb.
Distribution: Asia Minor, Balkan, Italy, Germany, Crimea

– provar. *pseudoflavescens* Flaksb.
Distribution: Germany, Spain, former Yugoslavia, Asia Minor

– provar. *pseudohornemannii* Dakapr. et Menabde.
Distribution: Georgia, Crimea, Germany

– provar. *pseudomacedonicum* Flaksb. [syn. *pseudoerdevianum* Zhuk.].
Distribution: Turkey, Bulgaria, Crimea

– provar. *sofianum* Stransk.
Distribution: Bulgaria

– provar. *symphaeropolitanum* Drosd.
Distribution: Asia Minor, Balkan, Crimea

– provar. *tauricum* Drosd.
Distribution: Asia Minor, Crimea, Balkan, Italy, Spain, Morocco

– provar. *vulgare* Koern.
Distribution: Asia Minor, Balkan, Crimea, Austria, Germany, France, Spain, Transcaucasia

–**provar. *clusii* Szabó et Hammer h.l.**: a convar. monococco *spiculae partim biflorifertilae, cariopsae partim nudae* differt. Typus: Transsylvania 1977 / 1990, Leg. A.T. Szabó. Holotype: in Herbarium Lab. Ecol. Genet. Evol. Crop., No. 3547RG, UWH, BDTF, Szombathely, Hungary.

This group of landraces collected in Transylvania differs from *T. monococcum* convar. *monococcum* by a higher frequency of free threshing and from *T. monococcum* (supra)convar. (subsp.) *sinskajae* by a much lower percentage of nakedness of grains and a different spike morphology. It seems to represent local selections developed perhaps during the 16th - 19th centuries, but arrested in evolution due to the dramatic genetic erosion characteristic for the second half of the 20th century.

– **convar. et provar. *sinskajae*** (A. Filat. et Kurk. pro sp. 1975, as basionym) em. h.l. Syn.: *T. monococcum* subsp. *sinskajae* auct. dif.

An apparently monotypic convariety isolated in 1970 from a sample collected by Zhukovskii in 1926 in Transcaucasia.

Table 5. Character matrix of infraspecific variability in *Triticum monococcum* convar. *monococcum*.

1	2	3	4	5	6	7	8	9	
x				x		x			var. *monococcum*
x					x	x			var. *tauricum*
	x			x		x			var. *flavescens*
	x				x	x			var. *pseudoflavescens*
			x		x	x			var. *sofianum*
x				x			x		var. *macedonicum*
x					x		x		var. *pseudomacedonicum*
	x			x			x		var. *vulgare*
	x				x		x		var. *atriaristatum*
		x			x		x		var. *symphaeropolitanum*
			x		x		x		var. *nigricultum*
x				x				x	var. *hohensteinii*
	x			x				x	var. *hornemannii*
	x				x			x	var. *pseudohornemannii*

1 = glumes white; 2 = glumes brown; 3 = glumes black, basis white; 4 = glumes black, basis brown; 5 = awns of the same colour as glumes; 6 = awns black; 7 = glumes dull; 8 = glumes shining; 9 = glumes hairy.

As this paper does not intend to describe in detail the new group of Transylvanian landraces, we would like to state only that the main characteristics of this variety group (difficult to differentiate from other groups cultivated in Alps - Balkan - Carpath area) rest on the presence of Ng factor and second flower fertility factor with different frequencies in different local populations.

As in all similar cases it should be considered that classification at the botanical variety and lower levels is predominantly artificial (Hammer 1981). But the presence or absence of character states shows that there is no equal distribution and not all character states combine freely within the material described so far. From the 24 character combinations theoretically possible, only 14 are realized within the classification (see above) so far. Provar. *clusii* and two new character combinations with green grains found recently are not yet included. They are still to be described.

Their discovery proves the law of homologous series of Vavilov (see Hammer and Schubert 1994), because in other hulled wheats this character state is also present (*T. spelta*). Infraspecific classifications are useful for collecting plant genetic resources (Hanelt and Hammer 1995), for conservation practices and of course, for taxonomic work. They include a number of morphological characters which are necessary for the characterization of the material.

The cultivated tetraploid farro – Triticum dicoccon

T. dicoccon Schrank 1789. [Syn.: *T. turgidum* subsp. *dicoccum* (Schrank) Thell. 1918].
English: emmer, Palestine: emmer, German: emmer, Hungarian: tönke, Romanian: ghireá.

There is a tendency among the lumpers to unify almost the whole tetraploid wheat variability under the common name *Triticum turgidum* L. *s.l.*, including *T. durum* Desf. syn. *T. turgidum* subsp. *turgidum* convar. *durum* (Desf.) Mac Key 1966 (English: durum wheat, macaroni wheat, Italian: grano duro, French: blé dur) and *T. turgidum* L. syn. *T. durum* subsp. *turgidum* (L.) V. Dorof. This approach does not allow a clear taxonomic differentiation between hulled (farro) and naked wheat taxa and is not considered here, accordingly.

Similar to the infraspecific classification of einkorn, the agrobotanical classification of emmer presented here is also predominantly artificial. Some of the described cultivated varieties have a very limited agricultural significance, e.g. on agricultural test fields, and reflect only the documented existence of specific character combinations that emerged during farro evolution.

– subsp. (supraconvar.) et convar. *dicoccon*

(pro)var. *albiramosum* Körn.
-var. *atratum* (Host) Körn.
-var. *bauhinii* (Alef.) Körn.
-var. *bispiculatum* Körn.
-var. *cladurum* (Alef.) Körn.
-var. *decussatum* Körn.
-var. *dicoccon*
-var. *diploleucum* Körn.
-var. *dodonaei* Körn.
-var. *erythrurum* Körn.
-var. *fictesemicanum* Flaksb.
-var. *fuchsii* (Alef.) Körn.
-var. *hybridum* Körn.
-var. *italicum* Hammer
-var. *krausei* Körn.
-var. *leucocladum* (Alef.) Körn.
-var. *liguliforme* Körn.
-var. *macratherum* Körn.
-var. *mazzucattii* Körn.
-var. *melanocladum* Körn.
-var. *melanurum* (Alef.) Körn.
-var. *metzgeri* (Alef.) Körn.
-var. *muticum* (Bayle-Barelle) Körn.
-var. *novicium* Körn.
-var. *pseudoerythrurum* Must.
-var. *pseudokrausei* Flaksb.
-var. *pseudomacratherum* Flaksb.
-var. *pseudorubriramosum* Flaksb.
-var. *pseudorufum* Flaksb.
-var. *rubriramosum* Körn.
-var. *rufum* Schübl.
-var. *schuebleri* Körn.
-var. *semicanum* Körn.
-var. *subatratum* Körn.
-var. *subcladurum* Körn.
-var. *subliguliforme* Flaksb.
-var. *submajus* Körn.
-var. *tashkentum* Udacz.
-var. *tragii* Körn.
-var. *tricoccon* (Schübl.) Körn.

– convar. *euscaldunense* Flaksb.

-var. *vasconicum* (Stolet.) Flaksb.

– subsp. (supraconvar) *maroccanum* Flaksb.
-var. *unimiegei* A. Filat. et Migusch.
-var. *compactomiegei* Flaksb.
-var. *miegei* Flaksb.

– subsp. (supraconvar.) *asiaticum* Vav.

– convar. *serbicum (*A. Schulz) Flaksb.
-var. *serbicum* A. Schulz
-var. *volgense* (Flaksb.) Flaksb.

– convar. *transcaucasicum* Flaksb.
-var. *aeruginosum* Flaksb.
-var. *arpurunial* Gandil.
-var. *chevsuricum* Dekapr.
-var. *flaksbergeri* Dekapr.
-var. *gunbadi* Palm.
-var. *haussknechtianum* A. Schulz
-var. *jakubzineri* Udacz.
-var. *rubrogunbadi* Palm.
-var. *uniaeruginosum* Dorof.
-var. *uniluteotinctum* Dorof.

– subsp. (supracovar). *abyssinicum* Vav.
-var. *arras (*Hochst.) Körn.
-var. *nigroajar* Perciv.
-var. *nigrum* Stolet.
-var. *praecox* (Stolet.) Flaksb.
-var. *pseudoarras* Flaksb.
-var. *pseudopraecox* Palm. et Jakubz.
-var. *pubescens* Jakubz.
-var. *violaceoarras* Jakubz.

The infraspecific classification of *T. dicoccon* is rather complex (Dorofeev *et al.* 1979). The classification shows that there are additional infraspecific categories apart from the basic varietal unit. A cultivated subspecies (supraconvar.) is a category closely related to geographical distribution. Four subspecies are being used for *T. dicoccon*: subsp. *dicoccon* (European material), subsp. *marocanum* (material from Morocco), subsp. *asiaticum* (Asiatic material) and subsp. *abyssinicum* (Ethiopian material). Convariety is a category in use for cultivated plants indicating groups of botanical varieties. This category is useful to indicate some well-defined groups within the high infraspecific variation of crop plants. Thus, within subsp. *dicoccon*, material from the Western Pyrénées is treated under convar. *euscaldunense*, whereas the rest of the European material is grouped under convar. *dicoccon*. Within subsp. *asiaticum*, two convars. are accepted, i.e. convar. *serbicum*, reaching southeastern parts of Europe, and even the relic emmer of Slovakia belongs to this group (Kühn *et al.* 1976), and convar. *transcaucasicum* from the Caucasus area. In comparison with *T. monococcum*, emmer has a much higher infraspecific variation, as can be seen easily

Table 6. Character matrix of infraspecific variability in *Triticum dicoccon* convar. *dicoccon*.

1	2	3	4	5	6	7	8	9	10	11	12	13	
x			x		x			x			x		var. *dicoccon*
x				x	x			x			x		var. *liguliforme*
	x		x		x			x			x		var. *rufum*
	x			x	x			x			x		var. *pseudorufum*
x			x		x			x			x		var. *tashkentum*
x			x		x			x				x	var. *fictesemicanum*
x				x	x			x				x	var. *semicanum*
	x		x		x			x				x	var. *macratherum*
	x			x	x			x				x	var. *pseudomacratherum*
		x		x	x			x				x	var. *atratum*
x				x	x			x			x		var. *diploleucum* *white kernels
x			x		x				x		x		var. *tricoccum*
x				x	x				x		x		var. *subliguliforme*
	x		x		x				x			x	var. *fuchsii*
x				x	x				x			x	var. *submajus*
	x		x		x				x			x	var. *bauhinii*
				x	x				x				var. *subatratum*
	x				x					x	x		var. *novicium*
x					x					x	x		var. *italicum*
x					x					x		x	var. *muticum*
	x				x					x		x	var. *hybridum*
		x			x					x		x	var. *decussatum*
	x		x			x		x			x		var. *schübleri*
x			x			x		x				x	var. *mazzucattii*
	x		x			x			x		x		var. *dodonaei*
	x		x			x			x			x	var. *tragii*
x						x				x	x		var. *bispiculatum*
x			x				x	x			x		var. *albiramosum*
	x		x				x	x			x		var. *erythrurum*
	x			x			x	x			x		var. *pseudoerythrurum*
	x		x				x	x				x	var. *rubriramosum*
	x			x			x	x				x	var. *pseudorubriramosum*
		x		x			x	x				x	var. *melanurum*
	x		x				x		x		x		var. *cladurum*
	x		x				x		x			x	var. *krausei*
	x			x			x		x			x	var. *pseudokrausei*
x							x			x	x		var. *leucocladum*
	x						x			x	x		var. *subcladurum*
x		x					x			x		x	var. *metzgeri*
							x			x		x	var. *melanocladum*

1 = glumes white
2 = glumes brown
3 = glumes black
4 = awns of the same colour as glumes
5 = awns black
6 = spikes simple
7 = spikes with double spikelets
8 = spikes branched
9 = awns long
10 = awns short
11 = awns absent
12 = glumes naked
13 = glumes hairy (pubescent)

from the large amount of infraspecific taxa. Only convar. *dicoccon*, comprising the typical European emmers, has been selected for demonstrating characters and character states used for the determination of botanical varieties. Theoretically 108 varieties are possible, considering all the combinations of morphologically detectable characters and character states used. From this number, 40 varieties have been actually realized. One new variety has been found recently in Italy and its formal description according to the International Code of Botanical Nomenclature for cultivated plants is:

Triticum dicoccon Schrank var. *italicum* Hammer, var. *nov*.
A *T. dicocco* var. *novicium* Koern. *spica alba differt*.
Typus: Italia 1989; leg. K. Hammer, TRI 1687 - Institut für Pflanzengenetik und Kulturpflanzenforschung Gatersleben (GAT 1), 27.7.92.
The new var. differs from var. *novicium* by white glumes.

This example indicates that genetic diversity for this cereal still can be found today in our fields, despite the worrying trend of genetic erosion that is being observed in European crops.

The cultivated hexaploid farro – Triticum spelta

T. spelta L. 1753.
[Syn.: *T. aestivum* subsp. *spelta* (L.) Thell. 1918].
English: spelt, French: spelta, German: Spelz, Spelta Dinkel, Italian: spelta, faricello, Hungarian: tönköly, Romanian: alac, tenchiu.

Within the Dinkel group *T. spelta* is the most important species.

Table 7. Character matrix of infraspecific variability in *Triticum spelta* subsp. *spelta*..

1	2	3	4	5	6	7	8	9	10	11	
x						x	x		x		var. *album*
	x					x	x		x		var. *duhamelianum*
		x				x	x		x		var. *amissum*
x						x	x			x	var. *viridialbispicatum*
x						x		x	x		var. *recens*
	x					x		x	x		var. *neglectum*
		x				x		x	x		var. *alefeldii*
x			x		x		x		x		var. *arduinii*
	x		x		x		x		x		var. *vulpinum*
		x		x	x		x		x		var. *schenkii*
x			x		x		x			x	var. *viridiarduinii*
x			x		x			x	x		var. *albivelutinum*
	x		x		x			x	x		var. *rubrivelutinum*
	x			x	x			x	x		var. *caeruleum*

1 = glumes white
2 = glumes brown
3 = glumes gray or black
4 = awns of the same colour as glumes
5 = awns black
6 = awns present
7 = awns absent
8 = glumes glabrous
9 = glumes pubescent
10 = grains brown
11 = grains green

– subsp. (supraconvar.) *spelta*

(pro)var. *albivelutinum* Körn.
var. *album* (Alef.) Körn.
var. *alefeldii* Körn.
var. *amissum* Körn.
var. *arduini* (Mazz.) Körn.
var. *caeruleum* (Alef.) Körn.
var. *duhamelianum* (Mazz.) Koern.
var. *neglectum* Körn.
var. *recens* Körn.
var. *rubrivelutinum* Körn.
var. *schenkii* Körn.
var. *viridialbispicatum* Jakubz.
var. *viridiarduini* Jakubz. et Puchalski
var. *vulpinum* (Alef.) Körn.

– subsp. (supraconvar.) *kuckuckianum* Gökg. ex Dorof. *et al.*

– subsp. *kuckuckianum* Gökg. ex Dorof. *et al.*

convar. *kuckuckianum* A. Filat. et Dorof.

(pro)var. *albiduhamelianum* Dorof.
var. *arpurual* Gandil.
var. *asialbispicatum* Dorof.
var. *asialbivelutinum* Dorof.
var. *asiamissum* Dorof.
var. *asicaeruleum* Dorof.
var. *asiduhamelianum* Dorof.
var. *asineglectum* Dorof.
var. *asirecens* Dorof.
var. *asirubrivelutinum* Dorof.
var. *dekaprelevichii* Dorof.
var. *dorofeevii* Udacz.
var. *flaksbergeri* Dorof.
var. *griseoturanorecens* Udacz.
var. *ispharalbispicatum* Udacz.
var. *ispharaecum* Udacz.
var. *ispharobaktiaricum* Udacz.
var. *jakubzineri* Dorof.
var. *karabachicum* Dorof.
var. *marinae* Dorof.
var. *menabdii* Dorof.
var. *mupulumiru* Gandil.
var. *mupural* Gandil.
var. *mustaphaevii* Dorof.
var. *pseudobaktiaricum* Dorof.
var. *pseudobuldojii* Dorof.
var. *pseudosharkordii* Dorof.
var. *samuricum* Dorof.
var. *schaartusicum* Udacz.
var. *shemachinicum* Dorof.
var. *sinskajae* Dorof.
var. *subbaktiaricum* Dorof.
var. *subbuldojii* Udacz.
var. *subsharkordii* Dorof.
var. *tashausicum* Udacz.
var. *thumanianii* Dorof.
var. *turanoalborecens*
var. *turanoalefeldii* Udacz.
var. *vavilovii* Dorof.
var. *zhukovskij* Dorof.

convar. *tarakanovii* A. Filat. et Dorof.

var. *tarakanovii* Udacz.

The infraspecific classification *of T. spelta* is also complex (Dorofeev *et al.* 1979). Two larger geographical groups are present, subsp. *spelta* from Europe and subsp. *kuckuckianum* from the Asiatic area. The latter subspecies was detected only in the 1950s (Kuckuck and Schiemann 1957), but displays an astonishing variation including the very variable convar. *kuckuckianum* and the liguleless convar. *tarakanovii* from the Pamir area. The European subsp. *spelta* has been chosen for demonstrating characters and character states. Forty-eight botanical varieties are theoretically possible. Only 14 have been realized, indicating the rather restricted variability within the relic European material.

Conclusions

1. **Farro** is an Italian ethnobotanical category covering the cultivated *Triticum monococcum* (einkorn), *T. dicoccon* (dinkel) and *T. spelta* (spelt) altogether. The concept was accepted here for pragmatic (ecological, economical and historical) reasons.
2. **Hulled wheats** represent another essentially ethnobotanical category which unites cultivated and wild grain Triticeae lacking the free-threshing factor.
3. **Triticum (wheat)** in the broad biosystematic sense (*Triticum s.l.*) is a name in which the lumpers include all *Triticeae* grasses hybridizing more or less spontaneously and belonging to a comon genepool.
4. *Triticum sensu strictissimo,* according to splitters, does not include for example the cultivated diploid **farro** (*Crithodium monococcum* syn. *Triticum monococcum*) which is reproductively quite isolated from the rest of the Triticeae.
5. A synthesis of botanical and genetical knowledge in the farro systematics would be both desirable and welcome.
6. The taxonomy of einkorn (the diploid '*farro*') includes about **16 cultivated** taxa (convar., provar.):

   ***Triticum monococcum* L.**

   subsp. *boeoticum* (Boiss.) Hayek et Markg. – spontaneous ancestor
   subsp. *thaoudar* (Reut.) Grossh. – spontaneous ancestor
   convar. *monococcum*, including 14 provarieties
   convar. *sinskajae* (Filat. et Kurk.) Szabó et Hammer
7. The taxonomy of emmer (the tetraploid farro) includes about **67 cultivated taxa** (convar., provar.):

   ***Triticum dicoccon* Schrank**

   supraconvar. (subsp.) et convar. *dicoccon* including 40 provarieties
   convar. *euscaldunense* Flaksb. with one provariety
   supraconvar. (subsp.) et convar. *moroccanum* Flaksb. with 3 provarieties
   supraconvar. (subsp.) *asiaticum* Vav.
   convar. *serbicum* (A. Schulz)Flaksb. with 2 provarieties
   convar. *transcaucasicum* Flaksb. with 11 provarieties
   supraconvar. (subsp.) *abyssinicum* Vav. with 8 provarieties.
8. The taxonomy of spelt (the hexaploid farro) includes about **60 cultivated taxa** (convar., provar.):

   ***Triticum spelta* L.**

   supraconvar. (subsp.) *spelta* with 14 provarieties
   supraconvar. (subsp.) *kuckuckianum* Gögk.
   convar. *kuckuckianum* Filat. et Dorof. with 40 provarieties
   convar. *tarakanovii* Filat. et Dorof. with one provariety.

Acknowledgements

This investigation has been supported by MKM, OTKA (grant NR. 3173) and the Italian-funded project coordinated by IPGRI on the Underutilized Mediterranean Species. The authors acknowledge here the reprints received from different colleagues in the subject.

References

Al-Hakimi, A. and P. Monneveux. 1993. Morphophysiological traits related to drought tolerance in primitive wheat species. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). ICARDA, Aleppo, Syria.

Anikster, Y. 1988. The biological structure of native populations of wild emmer wheat (*Triticum turgidum* var. *dicoccoides*) in Israel. Final Report 1984-1987. Part 1-2., USDA, ARS, Oregon State Univ., Corvallis, USA and The Nat. Cons. for Res. Develop. Ministr. Sci. Develop. Israel.

Badeeva, E.D., N.S. Badeev, B.S. Gill and A.A. Filatenko. 1994. Intraspecific karyotype divergence in *Triticum araraticum* (Poaceae). Plant Syst. Evol. 192:117-145.

Ball, T.B., D.J. Brotherson and S.J. Gardner. 1993. A typological and morphometric study of variation in phytoliths from einkorn wheat (*Triticum monococcum*). Can. J. Bot. 71:1182-1192.

Banerjee, S.K. and K.P.S. Chauchan. 1981. Studies on the evolution of seed coat pattern in wheat by scanning electron microscopy. Seed Sci. Technol. 9(3):819-822.

Bates, L.S. and T.J. Killeen. 1980. Effects of maternal and paternal genotypes on direct *Triticum* diploid species crosses with *Secale* species: *Triticum monococcum* L., *T. tauschii* (Coss.) Schmal., *Secale cereale* L. cv. Prolific, *S. cereale* cv. *Petkus*, *S. cereale* cv. *Snoopy* and *S. montanum* L. Cereal Res. Commun. 8(4):593-597.

Belea, A. 1992. Interspecific and Intergeneric Crosses in Cultivated Plants. Akadémiai Kiadó, Budapest. Cf. also Szabó (ed.) 1995.

Blixt, S. and J.T. Williams. 1982. Documentation of Genetic Resources. A Model. Pp. 1-24, 29-84. Nordic Gene Bank / IPGRI, Rome.

Borojevic, S. 1956. A note about the "New data for recent cultivation *of Triticum monococcum* and *Triticum dicoccum* in Yugoslavia". Wheat Inf. Serv. 4:1.

Borza, A.L. 1945. L'alac (Engrain, *Triticum monococcum*) chez les Roumains. Étude botanique et d'histoire culturelle. Bibl. Rer. Transs. 16., Sibiu.

Castagna, R. 1991. Induced chlorophyll mutations in *Triticum monococcum* L. J. Genet. Breed. 45:373-376.

Castagna, R., B. Borghi, G. Bassinger and F. Salamini. 1993. Induction and characterisation of *Triticum monococcum* mutants affecting plant and ear morphology. J. Genet. Breed. 47:127-138.

Castagna, R., G. Magaga, M. Perenzin, M. Heun and F. Salamini. 1994. RFLP-based genetic relationships of Einkorn wheats. Theor. Appl. Genet. 88:818-823.

Chelak, V.R. 1980. Cytogenetic investigation of hybrids of certain tetraploid wheat species with cultivated einkorn wheat (*Triticum monococcum* L. var. *flavescens*). Cytol. and Genet. 14(2):11-16.

Chizaki, Y. 1934. Another new haploid plant in *Triticum monococcum* L. The Botanical Magazine 48, 573:621-628.

Claesson, L., M. Kotimaeki and R.V. Bothmer. 1990. Crossability and chromosome pairing in some interspecific *Triticum* hybrids. Hereditas (Landskrona) 112(1):49-55.

Corazza, L., M. Pasquini and P. Perrino. 1986. Resistance to rust and powdery mildew in some strains of *Triticum monococcum* L. and *Triticum dicoccum* Schubler cultivated in Italy. Genet. Agric. 40(2):243-253.

Cox, T.S., L.G. Harrel, P. Chen and B.S. Gill. 1991. Reproductive behavior of hexaploid / diploid wheat hybrids. Plant Breeding 107:105-118.

Croston, R.P. and J.T. Williams. 1981. A World Survey of Wheat Genetic Resources. IBPGR, Rome.

Damania, A.B. (editor). 1993. Biodiversity and Wheat Improvement. John Wiley and Sons, Chichester, New York.

D'Antuono, L.F. 1994. Obsolete wheats in Italy: an overview on cultivation, use and perspectives for their conservation. Pp. 41-48 *in* Report of the IPGRI Workshop on Conservation and Use of Underutilized Mediterranean Species (S. Padulosi *et al.*, eds.). IPGRI, Rome, Italy.

D'Antuono, L.F. and A. Pavoni. 1993. Technology and grain growth of *Triticum dicoccum* and *T. monococcum* from Italy. Pp. 273-286 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). ICARDA, Aleppo, Syria.

De Pace, C., R. Paolini, G.T. Scarascia Mungozza, C.O. Qualset and V. Delre. 1990. Evaluation and utilization of *Dasypyrum villosum* as a genetic resource for wheat improvement. *In* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). A Wiley-Sayce Publication. J. Wiley and Sons, Chichester.

Dean, C. and R.M. Leech. 1982. Genome expression during normal leaf development. 2. Direct correlation between ribulose biphosphate carboxylase content and nuclear ploidy in a polyploid series of wheat (*Triticum monococcum*, *Triticum dicoccum*, *Triticum aestivum*). Plant Physiol. 70(6):1605-1608.

D'Egidio, M.G., S. Nardi and V. Vallega. 1991. Quality of diploid wheat, *Triticum monococcum* L. Pp. 205-208 *in* Cereals International (D.J. Martin and C.W. Wrigley, eds.). Proceedings of the International Conference, Brisbane, Australia, 9-13 Sept. 1991.

Dekaprelevich, L.L. 1961. Die Art *Triticum macha* Dek. et Men. im Lichte neuster Untersuchungen über die Herkunft der hexaploiden Weizen. Z. für Pflanzenzücht. 45:17-30.

Dhaliwal, H.S. 1977. Origin of *Triticum monococcum* L. Wheat Inf. Serv. 44:14-17.

Dorofeev, V.F., A.A. Filatenko and E.F. Migushova. 1980. Identification of Wheats. Methodological Guide. [In Russian]. VIR. Leningrad, Russia.

Dorofeev, V.F., A.A. Filatenko, E.F. Migushova, R.A. Udashin and R.R. Iacubziner. 1979. Wheat. Flora of Cultivated Plants I (V.F. Dorofeev and O.N. Korovina, eds.). Leningrad, Kolos, Russia.

Dorofeev, V.F. 1969, 1969a, 1971. Die Weizen Transkaukasiens und ihre Bedeutung in der Evolution der Gattung *Triticum* L. 1., 2., 3. Z. für Pflanzenzücht. 61(1):1-28, 62(3):201-230, 66:335-360.

Dubcovsky, J. and J. Dvorak. 1993. Comparison of *Triticum monococcum* and *Triticum aestivum* 1A linkage maps based on homologous and homoeologous recombination. Pp. 115-116 *in* Progress in Genome Mapping of Wheat and Related Species. Proc. Of the 3rd Public Workshop of the Int. Triticaea Mapping Initiative, 22-26 September 1992. (D. Hoisington, ed.). CIMMYT, Mexico.

El-Sharkaway, A.M.A., A.M.A. Ali and M.M. Abd-el-halim. 1977. Classification of some *Triticum* spp. (*T. aestivum*, *T. pyramidale*, *T. durum*, *T. dicoccum* and *T. monococcum*) on biochemical level. 3. DNA / DNA hybridisation. Egypt. J. Bot. 20(3):153-158.

Erdei, L., L. Vigh and D. Dudits. 1982. Isolation of a wheat (*Triticum monococcum*) cell line with altered membrane properties. Plant Physiol. 69(3):572-574.

Filatenko, A.A. and U.K. Kurkiev. 1975. A new species - *Triticum sinskajae* A. Filat. et Kurk. [In Russian]. Trudi po Prikladnoj Bot. Genet. Sel. 54:239-241.

Foltyn, J. 1990. Homology of evolutionary ear forms of cultivated wheat (genus *Triticum*): traits of homogeneity and heterogeneity. [In Russian]. Sborn. Uvt. Genet. Slecht. 26,1:13-22.

Friebe, B., M.C. Cermeno and F.J. Zeller. 1986. C-banding polymorphism and the analysis of nucleolar activity in *Dasypyrum villosum* (L.) Candargy, its added chromosomes to hexaploid wheat and the amphidiploid *Triticum dicoccum* - *D. villosum*. Theor. Appl. Genet. 73(3):337-342.

Furuta J. and S. Ohta. 1993. A preliminary Report of "The Botanical Exploration in Southeastern Europe by GIFU University (SEEG) in 1990 and 1991. Plant Germ-Plasm Inst. Univ. Kyoto, Japan.

Galiba, G. 1994. *In vitro* adaptation for drought and cold hardiness in wheat. Plant Breed. Rev. 12:115-162.

Galstyan-Avanesyan, S.K. 1986. Parallel resynthesis of the wheat *Triticum vavilovii* (Thum.) Jakubz. (2n = 42) and new botanical varieties of it. Biol. Zhurn. Armen. 39(6):520-522.

Gandylan, P.A. and Z.O. Shakaryan. 1992. Cytological study of the amphidiploid *Triticum boeoticum* Boiss. x *Aegilops tauschii* Coss (*T. boeoticotauschichum* Gandil.). Tsitol. Genet. 26(2):3-11.

Gerechter-Amitai, Z.K., I. Wahl, A. Vardi and D. Zohary. 1971. Transfer of stem rust seedling resistance from wild diploid einkorn to tetraploid durum wheat by means of a triploid hybrid bridge. Euphytica 20:281-285.

Gill, B.S., J.G. Waines and H.C. Sharma. 1981. Endosperm abortion and the production of viable *Aegilops squarrosa x Triticum boeoticum* hybrids by embryo culture. Plant Sci. Lett. 23(2):181-187.

Gill, B.S., L.E. Browder, J.H. Hachett, T.R. Harvey, T.J. Martin, W.J. Rupp, H.C. Sharma and J.G. Waines. 1983. Disease and insect resistance in wild wheats. Pp. 785-792 *in* Proc. of the 6th Int. Wheat Genet. Symp. (S. Sakamoto. ed.). Kyoto, Japan.

Gyulai, F. 1995. The Biohistorical Farm. A Project on Biological Farming and Nature Protection. Budapest, Hungary. (Unpublished manuscript).

Hammer, K. 1980. Vorarbeiten zur monographischen Darstellung von Wildpflanzen-sortimenten: *Aegilops* L. Kulturpflanze 28:33-180.

Hammer, K. 1981. Problems of *Papaver somniferum* classification and some remarks on recently collected European poppy land-races. Kulturpflanze 29:287-296.

Hammer, K. and I. Schubert. 1994. Are Vavilov's law of homologous series and synteny related? Genet. Resources and Crop Evolution 41:123-124.

Hammer, K. and P. Perrino. 1984. Further information on farro *(Triticum monococcum* L. *and T. dicoccon* Schrank) in South Italy. Kulturpflanze 32:143-151.

Hanelt, P. and K. Hammer. 1985. Classification of intraspecific variation in crop plants. Pp. 113-120 *in* Collecting Plant Genetic Diversity (L. Guarino, V. Ramanatha Rao and R. Reid, eds.). CAB International, Wallingford, UK.

Harlan, J.R. 1981. The early history of wheat: Earliest traces to the sack of Rome. Pp. 1-19 *in* Wheat Science Today and Tomorrow (L.T. Evans and W.J. Peacock, eds.). Cambridge Univ. Press, Cambridge.

Harlan, J.R. and J.M.J. De Wet. 1971. Toward a rational classification of cultivated plants. Taxon 20:509-514.

Hegi, G. 1908. Illustrierte Flora von Mitteleuropa. I. Verlag von J.F. Lehmann. München.

Heyne, E.G. (editor). 1987. Wheat and Wheat Improvement. Agronomy Number 13. ASA, SCSA, SSSA Publ., Madison, Wisconsin.

Hodgkin, T., Y.J. Adham and K.S. Powell. 1992. A preliminary survey of wild *Triticum* and *Aegilops* species in the world's genebanks. Hereditas 116:155-162.

Humphries, C.J. 1980. *Triticum* L. Pp. 202-203 *in* Flora Europaea. Volume 5. Alismataceae to Orchidaceae (T.G. Tutin, V.H. Heywood, N.A. Burgess, D.M. Moore, D.H. Valentine, S.M. Walters and D.A. Webb, eds.). Cambridge Univ. Press, Cambridge.

Kanzaki, K. and K. Noda. 1988. Glutinous (waxy) endosperm starch mutant of *Triticum monococcum* L. Jpn. J. Breed. 38:423-427.

Katayama, Y. 1934. Haploid formation by X-rays in *Triticum monococcum*. Cytologia 5(2):235-237.

Katayama, Y. 1935a. On chromosomal variant induced by X-ray treatment in *Triticum monococcum*. Proc. Imp. Acad. XI, 3:110-111.

Katayama, Y. 1935b. Karyogenetic studies on X-rayed sex cells and their derivatives in *Triticum monococcum*. J. Coll. Agric. Tokyo Imp. Univ. 8(4):333-365.

Kawahara, T. 1985. New types of Cs chlorosis found in hybrids between the Emmer and *Timopheevii* group of the tertaploid wheats. Wheat Inf. Serv. 60:38-39.

Kazanaki, K. and K. Noda. 1988. Glutinous (waxy) endosperm starch mutant of *Triticum monococcum* L. Jpn. J. Breed. 38(4):423-427.

Kerber, E.R. and P.L. Dyck. 1973. Inheritance of stem rust resistance transferred from diploid wheat (*Triticum monococcum*) to tetraploid and hexaploid wheat and chromosome location of the gene involved. Can. J. Genet. Cytol. 15:397-409.

Kerby, K. and J. Kuspira. 1987. The phylogeny of the polyploid wheats *Triticum aestivum* (bread wheat) and *Triticum turgidum* (macaroni wheat). Genome 29:722-737.

Kihara, H. and E. Kishimoto. 1942. Embryologische Studien über die Entstehung der Haploiden durch verspätete Bestäubung *bei Triticum monococcum* var. *vulgare*. [In Japanese, with German summary]. Seiken Zeiho 1:3-9.

Kihara, H. and K. Yamashita. 1947a. Genetic studies on mutations induced by X-ray in Einkorn wheat I. Seiken Ziho 3:29-39.

Kihara, H. and K. Yamashita. 1947b. Five linkage groups of Einkorn wheat. Jpn. J. Genet. 22:15-16.

Kihara, H., M. Kimura and H. Ono. 1951. Studies on the right- and left-handedness of spikelets in einkorn wheats. Proc. Jpn. Acad. 27(10):678-683.

Kimber, G. and E.R. Sears. 1983. Assignment of genome symbols in the Triticea. Pp. 1195-1196 *in* Proc. of the 6th Int. Wheat Genet. Symp. (S. Sakamoto, ed.). Kyoto, Japan.

Kimber, G. and E.R. Sears. 1987. Evolution in the genus *Triticum* and the origin of cultivated wheat. *In* Wheat and Wheat Improvement (E.G. Heyne, ed.). Agronomy Number 13. ASA, SCSA, SSSA Publ., Madison, Wisconsin.

Kimber, G. and M. Feldman. 1987. Wild Wheat: an introduction. Special Reports 353, Univ. of Missouri, Columbia, Mo., USA.

Kimura, M. 1947. Meiosis of haploids in Einkorn wheat. Jpn. J. Genet. 24:17-18.

Kishitani, S. and S. Tsunoda. 1981. Physiological aspects of domestication in diploid wheat. Euphytica 30(2):247-252.

Kison, H.U. and M. Neumann. 1993. The introgression of genetic information *from Triticum monococcum* L. into hexaploid triticale by hybridisation with a *T. monococcum* x *S. cereale* amphiploid. 2. Stabilizing basic material after passing an intermediuate octoploid stage. Plant Breed. 110(4):283-289.

Kuckuck, H. 1970. Primitive wheats. Pp. 249-266 *in* Genetic Resources in Plants, their Exploration and Conservation (O.H. Frankel and E. Bennet, eds.). IBP Handbooks no. 11.

Kuckuck, H. und E. Schiemann. 1957. Über das Vorkommen von Spelz und Emmer (*Triticum spelta* L. und *T. dicoccum* Schuebl.) im Iran. Z. für Pflanzenzüchtg. 38:383-396.

Kühn, F., K. Hammer and P. Hanelt. 1976. Botanische Ergebnisse einer Reise in die CSSR 1974 zur Sammlung autochthoner Landsorten von Kulturpflanzen. Kulturpflanze 24:283-347.

Kuzmenko, S.P., D.M. Ataeva and P.A. Gandilyan. 1990. Comparative study of the chromosomes of *Triticum dicoccoides* and *Triticum dicoccum* by the differential staining method. Cytol. Genet. 24(2):15-19.

Kushnir, U. and G.M. Halloran. 1982. Quantitative studies of the amphidiploid (*Aegilops sharonensis x Triticum monococcum*) and the origin of the B genome of wheat. Wheat Inf. Serv. 54:12-16.

Lafiandra, D., M. Ciaffi and S. Benedettelli. 1993. Seed storage proteins of wild wheat progenitors. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, Chichester, New York.

Lapochkina, I.F. and V.A. Pukhalskii. 1983. Study of meiosis in the interspecific hybrids *Triticum spelta* L. x *Triticum durum* Desf. Cytol. Genet. 17(5):1-5.

Lelley, J. and Gy. Mándy. 1963. The wheat (*Triticum aestivum* L.). [In Hungarian]. Kultúrflora 19, Akadémiai Kiadó, Budapest, Hungary.

Lelley, T. and S. Gröger. 1993/94. Einfluss der HMW-, und LMW-Glutenin, der Gliadine und der 1BL/1RS Translokation auf die Backqualität des Weizens. Bericht ueber die 44. Arbeitstagung der Arbeitsgemeinschaft der Saatzuchtleiter, Gumpenstein 13-19. (Report on the 44. Meeting of Plant Breeders, Gumpenstein, Austria).

Li Guo-Zheng, Wang-Xiao-Fan and Wang Shi-Jin. 1986. The karyotype analysis *of Triticum monococcum*. Acta Phytotaxonomica Sinica 24(2):161-164.

Löschenberger, F., H. Hämsel and E. Heberle-Bors. 1993. Plant formation from pollen of tetraploid wheat species and *Triticum tauschii*. Cereal Res. Commun. 21(2-3):133-137.

Löve, D. (translator). 1992. N.I. Vavilov: Origin and Geography of Cultivated Plants. Cambridge Univ. Press.

Maan, S.S. 1987. Interspecific and Intergeneric Hybridisation in Wheat. *In* Wheat and Wheat Improvement (E.G. Heyne, ed.). Agronomy Number 13. ASA, SCSA, SSSA Publ., Madison, Wisconsin.

Mac Key, J. 1966. Species relationship in *Triticum*. *In* Proc. of the Second International Wheat Genetics Symposium. Hereditas Suppl. 2: 237-276.

Matsamura, S. 1946. Chromosomal aberrations in Einkorn wheat induced by X-ray treatment. Jpn. J. Genet. 21:91-92.

Matsamura, S. 1951. Radiation genetics in wheat: I. Chromosome aberrations in einkorn wheat induced by irradiation. Cytologia 16(3):201-211.

May, C.E. and R. Apples. 1987. The molecular genetics of wheat: Toward an understanding of 16 billion base pairs of DNA. *In* Wheat and Wheat Improvement (E.G. Heyne, ed.). Agronomy Number 13. ASA, SCSA, SSSA Publ., Madison, Wisconsin.

McIntosh, R.A. 1983. A catalogue of gene symbols for wheat. Pp. 1197-1254 *in* Proc. 6th Internat. Wheat Genet. Symp. (S. Sakamoto, ed.). Kyoto, Japan.

McIntosh, R.A., P.L. Dyck, T.T. The, J. Cusick and D.L. Milne. 1984. Cytogenetical studies in wheat XIII.: Sr35 - a third gene from *Triticum monococcum* for resistance to *Puccinia graminis tritici*. Z. für Pflanzenzüchtg. 92:1-14.

Merezhko, A.F. 1994. The Problem of Donors in Plant Breeding. The Russian Academy of Agricultural Sciences. The N.I. Vavilov Institute of Plant Industry (VIR) (Red. resp. N.A. Slepenkova). St. Petersburg, Russia, pp. 1-128

Metakovsky, E.V. and S.K. Baboev. 1992. Polymorphism and inheritance of gliadin polypeptides in *T. monococcum* L. Theor. Appl. Genet. 84(7-8):971-978.

Miller, T.E. 1981. Chromosome pairing of intergeneric amphiploids as a means of assessing genome relationships in the Triticeae. Z. für Pflanzenzüchtung 87:69-78.

Miller, T.E. 1990. Systematics and Evolution. Pp. 1-30 *in* Wheat Breeding. Its Scientific Basis (F.G.H. Lupton, ed.). Chapman and Hall, London, New York.

Miller, T.E., K.W. Shepherd and R. Riley. 1981. Relationship of chromosome 4A of diploid wheat to that of hexaploid wheat: a clarification of an earlier study. Cereal Res. Commun. 9(4):327-329.

Morrison, L.A. 1993. *Triticum - Aegilops* systematics: Taking an integrative approach. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, Chichester, New York.

Multani, D.S., H.S. Dhaliwal, S.K. Sharma and K.S. Gill. 1989. Inheritance of isoproturon tolerance in durum wheat transferred from *Triticum monococcum*. Plant Breed. 102:166-168.

Murashev, V.V. and F.M. Kupferman. 1976. Morphophysiological analysis of potential and real production of *Triticum monococcum* L. and *T. aestivum* L. [In Russian]. Nauchn. Dokl. Vyssh. Shk. 5:86-89.

Neumann, M., W. Sodkiewicz and K. Skiebbe. 1985. On possibilities of genetic information transfer from *Triticum monococcum* to Triticale. Genet. Polon. 26(2):209-215.

Nishikawa, K., Y. Furuta, T. Yamada and S. Kudo. 1992. Genetic studies of α-amylase isozymes in wheat. VII. Variation in diploid ancestral species and phylogeny of tetraploid wheat. Jpn. J. Genet. 67:1-15.

Nyárády, E.I., Al. Beldie, I. Morariu and A. Nyárády, editors. 1972. Flora Republicae Socialisticae Romania. XII. Ed. Acad. R.S. Romabia, Bucuresti. Cf. Velican V. 1972, *Triticum* L. pg. 624-639.

Ohta, S. and Y. Furuta. 1993. A report of the wheat field research in Yugoslavia. Wheat Inf. Serv. 76:39-42.

Padulosi, S. (compiler). 1995. Hulled Wheats Species: A reference list of publications. Manuscript. IPGRI, Rome, Italy.

Pannu, P.P.S., H. Singh, R. Datta and H.S. Dhaliwal. 1994. Screening of wild *Triticum* and *Aegilops* species for resistance to Karnal bunt disease of wheat. Plant Genet. Resour. Newsl. 97:47-51.

Pavicevic, L. 1971. Sur la phylogenese et l'evolution de *Tr. monococcum* L. Poljopr. i sum. 17(4):1-23.

Pavicevic, L. 1972. *Triticum monococcum* L. Jug. Akad. Zn. i Um., Poseban otisak iz knjige Rad 364. Zagreb.

Payne, P.I. and G.J. Lawrence. 1983. Catalogue of alleles for the complex gene loci, Glu-A1, Glu-B1, and Glu-D1 which code for high-molecular-weight subunits of glutenin in hexaploid wheat. Cereal Res. Commun. 11:29-35.

Payne, P.I., L.M. Holt, K. Harinder, D.P. Macartney and G.J. Lawrence. 1987. The use of near-isogenic lines with different HMW glutenin subunits in studying bread-making quality and glutenin structure. In: Proc. 3rd Int. Wheat Gluten Symp. Budapest, Hungary.

Péntek, J. and T.A. Szabó. 1981. Das Einkorn (*Triticum monococcum* L.) in Siebenbürgen (Transylvania). Ethnographia 112)2-3):259-277.

Péntek, J. and T.A. Szabó. 1985. Plant Kingdom and Human Life in Kalotaszeg (the Calata Area, Transylvania, Romania). [In Hungarian]. Kriterion, Bucharest. 116-123, 298.

Perrino, P. 1982. Nomenclatura relativa a *Triticum monococcum* L. e *Triticum dicoccum* Schuebler (syn. di *T. dicoccon* Schrank) ancora coltivata in Italia. Rivista di Agronomia 16(2):134-137.

Perrino, P. and E. Porceddu. 1990. Wheat Genetic Resources in Ethiopia and the Mediterranean Region. *In* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). A Wiley-Sayce Publication. J. Wiley and Sons, Chichester.

Perrino, P. and K. Hammer. 1982. *Triticum monococcum* L. and *T. dicoccum* Schuebler (syn. of *T. dicoccon* Schrank) are still cultivated in italy. Presence, collecting and action. Genetica Agraria 36(3-4):343-351.

Perrino, P., D. Semeraro and E.G. Laghetti. s.a. Il farro. Un cereale della salute. Bari.

Perrino, P., G. Laghetti and K. Hammer. 1988. Collection of plant genetic resources in Italy. Kulturpflanze 36:377-390.

Perrino, P., G. Laghetti, S. Cifarelli, N. Volpe and P.L. Spagnoletti-Zeuli. 1993. Wild wheats in southern Italy. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, Chichester, New York.

Person-Dedryver, F. and J. Jahier. 1985. Cereals as hosts of Meloidogyne naasi Franklin. 3. Investigations into the level of resistance of wheat relatives (resistance genes, introgression, *Triticum monococcum* subsp. *boeoticium*, *Triticum urartu*, diploid and tetraploid *Aegilops* species. [In French]. Agronomie 5(7):573-578.

Pistrick, K., M. Avramiuc, V. Chereches and N. Friesen. 1995. Collecting plant genetic resources in Romania (Eastern Carpathians, Maramures, Muntii Apuseni) 1994. (in press.)

Potgieter, G.F., G.F. Marais and F.D. Torr. 1991. The transfer of resistance to the Russian wheat aphid from *Triticum monococcum* L. to common wheat. Plant Breed. 106(1):48-72.

Powell, M.A. 1985. Salt, seed, and yields in Summerian agriculture. A critique of the theory of progressive salinisation. Z. Assyr. u. Vorderas. Arch. 75(1):7-38.

Prilyuk, L.V. 1984. Hybridisation between einkorn wheat and rye. Soviet Genetics. 20(8):1085-1088.

Prilyuk, L.V. and U.K. Kurkiev. 1988. Allotetraploid *Triticum monococcum* x *Secale cereale*. [In Russian]. Nauch. tekhn. byul. VIR 174:69-72.

Ramey, T.B., J.G. Waines and J.A. Mosjidis. 1988. Detection of repeated genotypes among 93 diploid wheat accessions. Euphytica 37(3):283-287.

Rigin, B.V. and T.S. Repina. 1988. Inheritance of the type of development in *Triticum monococcum*. [In Russian]. Nauch. tekh. byul. VIR 174:21-23.

Rubies, S., C. Autonell and V. Vallega. 1992. Reactions of diploid wheat, *Triticum monococcum,* to soilborne wheat mosaic virus and wheat spindle streak mosaic virus. Petria 2:64.

Ryan, G.S., E.F. Antonelli and R.M. Solari. 1976. Variabilidad intraspecifica *en Triticum monococcum* L. Boletino Genetico 9:31-34.

Sakamoto, S. (editor). 1986. A preliminary Report of Kyoto University Ethnobotanical Exploration to Greece and Turkey in 1982. Rep. Pl. Germpl. Inst. Fac. Agr. Kyoto Univ.

Sakamoto, S. 1987. Origin and phylogenetic differentiation of cereals in Southwest Eurasia. Pp. 1-45 *in* Domesticated Plants and Animals of the Southwest Eurasian Agro-Pastoral Complex. I. Cereals (S. Sakamoto, ed.). Kyoto Univ.

Sakamoto, S. 1991. The cytogenetic evolution of Triticeae grasses. Pp. 469-481 *in* Chromosome Engineering in Plants: Genetics, Breeding, Evolution, Part A (P.K. Gupta and T. Tsuchya, eds.). Elsevier, Amsterdam, The Netherlands.

Sakamoto, S. 1993. Discussion on the harvesting method of *Triticum spelta*. Pp 100-117 *in* Technologies and Culture in Farming (K. Sasaki, ed.). Shueisha, Tokyo, Japan.

Sakamoto, S. and H. Kobayashi. 1982. Variation and geographical distribution of cultivated plants, their wild relatives and weeds native to Turkey, Greece and Romania. Pp. 41-104 *in* Preliminary Report of Comparative Studies on the Agrico-Pastoral Peoples in Southwestern Eurasia. II. (Z. Tani, ed.). Kyoto Univ.

Schiemann, E. 1956. New data for recent cultivation of *Triticum monococcum and Triticum dicoccum* in Yugoslavia. Wheat Inf. Serv. 3:1-3.

Schneider, D.M. and M. Heun. 1988. Neue Mehltauresistenzgene in diploiden und tetraploiden Triticum Arten. Mitteil. Biol. Bundesanst. f. Land u. Forstw. Berlin-Dahlem. 245:311.

Schultze-Motel, J. 1986. *Triticum*. *In* Rudolf Mansfelds Verzeichnis der landwirtschaftlich und gärtnerisch kultivierten Pflanzen (ohne Zierpflanzen) (J. Schultze-Motel, ed.). Akademie Verl. Berlin, Germany.

Schultze-Motel, J. 1992, 1993, 1994. Literature on archeological remains of cultivated plants 1989/1990 1990/1991 1991/1992. Veget. Hist. Archeobot. 1:53-62, 2:47-59, 3:33-61.

Schumann, G. 1986. Experiments for producing introgression lines of soft wheat by the help of *Triticum monococcum* as donor. Cereal Res. Commun. 14(1):61-67.

Sharma, H.C. and J.G. Waines. 1980. Inheritance of tough rachis in crosses of *Triticum monococcum* and *Triticum boeoticum*. J. Heredity 71(3):214-216.

Sharma, H.C. and J.G. Waines. 1981. The relationship between male and female fertility and among taxa in diploid wheats. Am. J. Bot. 68:449- 451.

Sharma, H.C., J.G. Waines and K.W. Foster. 1981. Variability in primitive and wild wheats for useful genetic characters. Crop Sci. 21:555-559.

Skiebe, K. and M. Neumann. 1984. Untersuchungen zur Kreuzbarkeit von 6x-Triticale-Formen mit 2x-*Triticum monococcum*. Arch. Züchtungsf. 14(2):145-149.

Skiebe, K., H. Wolfram and M. Neumann. 1982. Rekombinanten nach Kreuzung von Weizen/Roggen-Allopolyploiden mit *Triticum monococcum* und ihr Verhalten gegenüber Mehltau. Arch. Züchtungsf. 12(2):79-85.

Smith-Huerta, N.L., A.J. Huerta, Arth K. Barn and J.G. Waines. 1989. Genetic diversity in wild diploid wheats *T. monococcum* var. *boeoticum* and *T. urartu* (Poaceae). Theor. Appl. Genet. 78:260-264.

Sodkiewicz, W. 1985. Probleme und Möglichkeiten der Übertragung genetischer Information *von Triticum monococcum* auf Triticale unter Verwendung von Alloploiden aus diploidem Weizen und Roggen. Arch. Züchtungsf. 15(2):79-82.

Sodkiewicz, W. 1988. Hybrids between diploid wheat and rye. Pt. 2. Amphiploid *Triticum monococcum* L. x *Secale cereale* L. Morphology of plants, fertility and functionality of gamets. Genetica Polonica 29(3-4):237-248.

Sodkiewicz, W. 1992a. Attempts of the transfer of diploid wheat genes onto triticale at application of amphiploid of *Triticum monococcum* x *Secale cereale*. In Polish. Biul. Inst. Hod. Akl. Rosl. 183:99-106.

Sodkiewicz, W. 1992b. Introgression of genetic information from *Triticum monococcum* L. into hexaploid triticale by hybridisation with *T. monococcum* x *S. cereale* amphiploid. 1. Development of introgressive hexaploid lines by increasing the chromosome numbers of hypoploid BC(1)-plants. Plant Breed. 109(4):287-295.

Soó, R. 1973. Synopsis systematico-geobotanica florae vegetationsquae Hungariae V., Akadémiai Kiadó, Budapest.

Srivastava, J.P. and A.B. Damania (editors). 1990. Wheat Genetic Resources: Meeting Diverse Needs. A Wiley-Sayce Publication. J. Wiley and Sons, Chichester.

Stranski, I.T. 1934. Die varietätsmässige Zusammensetzung von *Triticum monococcum* L. Landw. Jahrb. 80:883-907.

Sutka, J. and O. Veisz. 1988. Reversal of dominance in a gene on chromosome 5A controlling frost resistance in wheat. Genome 30(3):313-317.

Szabó, T.A. (editor). 1994. Vavilov Lectures 1994. BIO TÁR, Coll. Clus. 4:101-113.

Szabó, T.A. 1981. Problems of genetic erosion in Transylvania, Romania. Kulturpflanze 29:47-62.

Szabó, T.A. 1983. Applied biology in the evolution of cultivated plants. [in Hungarian]. Ceres, Bucharest 122, 143-150.

Szabó, T.A. 1995a. Historical, ethnobotanical and genetic resources research regarding the evolution of cultivated plants and their wild relatives in the Carpathian Basin. DrSci Thesis. [In Hungarian]. Budapest - Szombathely, Hungary.

Szabó, T.A. 1995b. Studies on Einkorn *(Triticum monococcum s.l.*) in Hungary, based on the publications of Dr. Adonis Belea. Haynaldia Bio Tár Electr. 5.1:1-12.

Szabó, T.A. 1995c. The history and present situation of einkorn (*Triticum monococcum* L.) genetic resources in Transylvania. [Abstract in Hungarian]. Pp. 2-3 *in* Proceedings of the Memorial "Barabás Zoltán" Cereal Breeding Session. 2-3 March 1995 Szeged. Full version in English prepared for publication in Haynaldia Bio Tár Electr.

Szabó, T.A. and A. Màrton. 1980. The traces of the einkorn. An ancient wheat species in the light of modern research. [In Hungarian]. Müvelödés, Bucharest 33(1):35-44, 2:45-46.

Szabó, T.A. senior. 1976. Wortgeschichtlicher Thesaurus der siebenbürgisch-ungarischen Sprache. Bd. I. A-C. Kriterion Verlag, Bucuresti. 1-1225 (203-204).

Tanaka, M. 1983. Catalogue of *Aegilops - Triticum* Germplasm Preserved in Kyoto University. Pl. Germpl. Inst. Fac. Agr. Kyoto Univerity, Japan,

Terrell, E.E., S.R. Hill, J.H. Wiersema and W.E. Rice. 1986. A Checklist of Names for 3,000 Vascular Plants of Economic Importance. Agriculture Handbook Number 505. USDA, ARS, Government Printing Office, Washington, DC.

The, T.T. 1976. Variability and inheritance studies in *Triticum monococcum* for reaction *to Puccinia graminis* f. sp. *tritici* and *P. recondita.* Z. für Pflanzenzücht. 76(4):287-298.

The, T.T. and E.P. Baker. 1975. Basic studies relating to the transference of genetic characters from *Triticum monococcum* L. to hexaploid wheat. Aust. J. Biol. Sci. 28:189-199.

Tsunewaki, K. 1991. RFLP analysis of common wheat and its ancestors. Wheat Inf. Serv. 72:67-69.

Valkoun, J. and O.F. Mamluk. 1993. Disease resistance and agronomic performance of durum and bread wheat lines derived from crosses with *Triticum monococcum*. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, Chichester, New York.

Valkoun, J., D. Kucerova and P. Bartos. 1986. Transfer of leaf rust resistance from *Triticum monococcum* L. to hexaploid wheat. Z. für Pflanzenzücht. 96:271-278.

Valkoun, J., D. Kucerova and P. Bartos. 1989. Transfer of a new gene for stem rust resistance from *Triticum monococcum* to hexaploid wheat, *Triticum aestivum*. Genet. Slecht. Uv. 25(3):209-214.

Vallega, V. 1977. Validità del *Triticum monococcum* nel miglioramento genetico del frumento. Sementi Elette 23(1):3-8.

Vallega, V. 1978. Search for useful genetic characters in diploid *Triticum* spp. Pp 156-162 *in* Proc. 5th. Int. Wheat Genet. Symp., New Delhi, India.

Vallega, V. 1979. Field performance of varieties of *Triticum monococcum*, *T. durum*, and *Hordeum vulgare* grown at two locations. Genet. Agric. 33:363-370.

Vallega, V. 1988. Comparative analysis of high-molecular-weight glutenin-subunit composition in various *Triticum* species. Plant Breed. 100:241-246.

Vallega, V. 1991. *Triticum monococcum* as a source of genes. Annual Wheat N.37:74-77.

Vallega, V. 1992. Agronomical performance and breeding value of selected strains of diploid wheat, *Triticum monococcum*. Euphytica 61:13-23.

Vallega, V. 1994. *Triticum monococcum* amino acid composition. Annual Wheat N.40:154-156.

Vallega, V. and T. Mello-Sampayo. 1987. Variation of high molecular-weight glutenin subunits amongst cultivars of *Triticum turgidum* L. from Portugal. Euphytica 36(3):755-762.

Van der Veen, M. 1992. Crop husbandry regimes: an archaeobotanical study of farming in northern England 1000 BC - AD 500. Sheffield Archeological Monographs, vol. 3. J.R. Collins, Sheffield, 1-227.

Van Slageren, M. 1990. The significance of taxonomic methods in handling genetic diversity. *In In* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). A Wiley-Sayce Publication. J. Wiley and Sons, Chichester.

Van Slageren, M.W. 1994. Wild wheats: a monograph of *Aegilops* L. and *Amblyopyrum* (Jaub. et Sp.) Eig (Poaceae). Wageningen Agr. Univ. Papers 94-7, 513 pp.

Verzea, M. 1989. Crossability of diploid wheat (*Triticum monococcum* L.) with diploid rye (*Secale cereale* L.). [In Romanian]. Probl. genet. teor. apl. 21(1):15-22.

Vierling, R.A. and H.T. Nguyen. 1992a. Heat-shock protein genetic expression in diploid wheat genotypes differing in thermal tolerance. Crop Sci. 32(2):370-377.

Vierling, R.A. and H.T. Nguyen. 1992b. Use of RAPD markers to determine the genetic diversity of diploid wheat genotypes. Theor. Appl. Genet. 84(7-8):835-838.

Vodenitsharova, M.S. 1989. Izoenzyme variation in ploidy distinguishable species of subtribe Triticina. Cereal Res. Commun. 17(1):11-18.

Wagoner, P. 1995. Intermediate wheatgrass (*Thynopyrum intermedium*). Development of a perennial grain crop. *In* Cereals and Pseudocereals (J.T. Williams, ed.). Chapman and Hall, London.

Waines, J.G. 1983. Genetic resources in diploid wheats: the case for diploid commercial wheats. Pp. 115-122 *in* Proc. 6th Int. Wheat. Symp. (S. Sakamoto, ed.). Kyoto, Japan.

Waines, J.G. and P.I. Payne. 1987. Electrophoretic analysis of the high-molecular-weight glutenin subunits of *Triticum monococcum*, *T. urartu*, and the A genome of bread wheat (*T. aestivum*). Theor. Appl. Genet. 74:71-76.

Waines, J.G., M.M. Rafi and B. Ehdaie. 1993. Yield components and transpiration efficiency in wild wheats. *In* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, Chichester, New York.

Watson, L. and M.J. Dallwitz. 1992. The Grass Genera of the World. University Press, Cambridge.

Williams, J.T. (editor). 1995. Cereals and Pseudocereals. Chapman and Hall. London.

Witcombe, J.R. 1983. A Guide to the Species of *Aegilops* L. Their taxonomy, morphology and distribution. IBPGR Secretariat, Rome, Italy.

Yakovleva, G.M. and D. Dudich. 1993a. Differences in metabolism of polyamines and effect of 1-aminoxy-3-aminopropane in wheat cells (*Triticum monococcum* L.) growing on agar or liquid medium. [In Russian]. Fiziol. Rast. 40(5):791-796.

Yakovleva, G.M. and D. Dudich. 1993b. Effects of an aminooxy analogue of putrescein on wheat cell cultures (*Triticum monococcum* L.). J. Plant. Physiol. 142(2):218-221.

Yamashita, K. 1947. Analysis of translocations induced by X-ray in Einkorn wheat. [In Japanese]. Jpn. J. Genet 22:34-37.

Yamashita, K. 1949. Studies on reciprocal translocations in Einkorn wheat. [In Japanese]. Jpn. J. Genet. 24:110-112.

Yamashita, K. 1950a. A synthetic complex heterozygote in Einkorn wheats: *aegilopoides* x *monococcum*. Proc. Jpn. Acad. 26(9):66-71.

Yamashita, K. 1950b. Studies on X-ray induced reciprocal translocations in Einkorn wheat. I. Analysis of some new RT types. [In Japanese with English summary]. Rep. Kihara Inst. Biol. Res. (Seiken Ziho) 4:102-110.

Yamashita, K. 1951. Studies on X-ray induced reciprocal translocations in Einkorn wheats. III. A newly synthesized ring of 14 chromosomes in a complex heterozygote, *aegilopoides* x *monococcum*. Cytologia 16:164-176.

Yamashita, K. 1952. Studies on X-ray induced reciprocal translocations in Einkorn wheats. II. [In Japanese with English summary]. Rep. Kihara Inst. Biol. Res. (Seiken Ziho) 5(5):1-41.

Yurkova, G.N., A.M. Bielka and L.V. Sirant. 1988. Screening various wheat species for regenerative ability. Biol. kult. klet. biotekhn. 1:118-119.

Zeven, A.C. and T.J.L.V. Hintum. 1992. Classification of landraces and improved cultivars of hexaploid wheats (*Triticum aestivum*, *T. compactum* and *T. spelta*) grown in the USA and described in 1922. Euphytica 59(1):33-47.

Zhukovski, P.M. 1971. Kulturnie rastenia i ik sorodichi [Cultivated Plants and their Relatives, in Russian]. Kolos, Leningrad, Russia.

Zwingelberg, H. 1993. Dehulling and cleaning of spelt wheat (dinkel and gruenkern). In German. Mühle u. Mischfuttertechn. 130(36):445-447.

Annex 1

Index of some keywords related to hulled wheat research (farros). References are listed in the Reference section of this paper.

General

Keyword	Reference
A genome, frost resistance	Sutka and Veisz 1988
adaptations, cold hardiness	Galiba 1994
Aegilops	Hammer 1980; van Slageren 1994; Witcombe 1983; Morrison 1993
archeobotany	Schultze-Motel 1992, 1993, 1994; van der Veen 1992
bibliography	Belea 1992; Padulosi 1995; Szabó 1995b
biohistory	Gyulai 1995; Harlan 1981; Hegi 1908
C-banding	Friebe *et al.* 1986, and further titles not cited here
crosses, general references	Belea 1992
crosses with *Secale*	Bates and Killeen 1980
crossability	Claesson *et al.* 1990
cultivation, Transylvania	Borza 1945; Pistrick *et al.* 1995; Szabó sr. 1976; Szabo 1981
cultivation, Italy	D'Antuono 1994; Hammer and Perrino 1984; Perrino *et al.* 1988
cultivation, former Yugoslavia	Borojevic 1956; Pavicevic 1972; Schiemann 1956
cytogenetics	Chelak 1980
dehulling	Zwingelberg 1993
DNA	El-Sharkaway *et al.* 1977; May and Apples 1987
domestication	Kishitani and Tsunoda 1981
ecogeography	Perrino *et al.* (this volume)
ethnobiodiversity, Transcaucasia	Dorofeev 1969, 1969a, 1971
ethnobotany	Péntek and Szabó 1981, 1985; Szabó and Màrton 1980; Szabó 1995a
gene donors	Merezhko 1994; Schumann 1986
genebanks	Hodgkin *et al.* 1992; Tanaka 1983
genetic resources	Croston and Williams 1981; Furuta and Ohta 1993; Ohta and Furuta 1993; De Pace *et al.* 1990
gene transfer	Gerechter-Amitai *et al.* 1971
genome symbols	Kimber and Sears 1983
genome expression	Dean and Leech 1982
haploids, X-rays	Katayama 1934, 1935a,b
hybrids	Cox *et al.* 1991; Maan 1987
identification	Dorofeev *et al.* 1979, 1980
izozymes	Vodenitsharova 1989
karyotype divergence, *T. araraticum*	Badeeva *et al.* 1994

T. monococcum

Keyword	Reference
amino acids	Vallega 1994
breeding value	Vallega 1977, 1978, 1979, 1991, 1992
chlorophyll mutations	Castagna 1991
chromosmal aberrations	Matsamura 1946, 1951
cytology	Belea 1992; Friebe *et al.* 1986; Kuzmenko *et al.* 1990
development type	Rigin and Repina 1988
gene transfer, triticale	Neumann *et al.* 1985
genetic resources	Perrino and Hammer 1982; Perrino *et al.* this volume; Sakamoto 1986, 1987; Szabó and Màrton 1980; Szabó 1995c; Waines 1983
genetic erosion	Szabó 1981
genetic diversity	Smith-Huerta *et al.* 1989
genotypes	Ramey *et al.* 1988
gliadins	Metakovsky and Baboev 1992
glutenins	Lelley and Göger 1993/94; Vallega 1988; Vallega and Mello-Sampayo 1987; Waines and Payne 1987
glutinous endosperm	Kanzaki and Noda 1988
haploids	Chizaki 1934; Kihara and Kishimoto 1942
infraspecific variability	Ryan *et al.* 1976; Sakamoto and Kobayashi 1982; Sharma *et al.* 1981
insect resistance	Person-Dedryver and Jahier 1985; Potgieter *et al.* 1991
karyotype	Li *et al.* 1986
linkage maps	Dubcovsky and Dvorak 1993; Kihara *et al.* 1947
meiosis	Kimura 1947
origin	Dhaliwal 1977; Nishikawa 1992; Pavicevici 1971; Sakamoto 1987, 1991; Kimber and Yamashita 1987a, b
polyamines	Yakovleva and Dudich 1993a, b
production potential	Murashev and Kupferman 1976
protoplasts	Erdei *et al.* 1982
rachis	Sharma and Waines 1980
RAPD	Vierling and Nguyen 1992b
resistance genes	McIntosh *et al.* 1984
resistance to *Puccinia*	The and Baker 1975; The 1976; Valkoun *et al.* 1986, 1989
righthandedness, spiklets	Kihara *et al.* 1951
taxonomy	Dorofeev *et al.* 1979; Stranski 1934; Schultze-Motel 1986; Nyárády *et al.* 1972; Perrino 1982; Soó 1973; Terrell *et al.* 1986
thermal tolerance, heat shock	Vierling and Nguyen 1992a
tolerance	Multani *et al.* 1989
translocations	Yamashita 1949
virus resistance	Rubies *et al.* 1992
x *aegilopoides* complex heterozygote	Yamashita 1950a
x *T. durum*	Valkoun and Mamlouk 1993

Keyword	Reference
x *Secale*	Kison and Neumann 1993; Prilyuk 1984; Prilyuk and Kurkiev 1988; Skiebe and Neumann 1984; Verzea 1989
x *T. sharonensis*	Kushnir and Halloran 1982
x *Triticale*	Sodkiewicz 1985, 1988, 1992a,b
X-rays	Katamaya 1935a, b; Kihara and Yamashita 1947a; Yamashita 1947, 1950b, 1951, 1952

Farros (*Triticum* spp.)

Keyword	Reference
classification of landraces	Zeven and Hintum1992
genetic resources	Perrino and Porceddu 1990; Srivastava and Damania 1990
mutations, chlorophyll	Castagna *et al.* 1993; Kawahara 1985
paleoethnobotany	Powell 1985
phylogeny	Kerby and Kuspira 1987
phytolits	Ball *et al.* 1993
pollen culture	Löschenberger *et al.* 1993
primitive wheats	Al-Hakimi and Monneveux 1993; Kuckuck 1970; Lafiandra *et al.* 1993
quality, proteins	D'Egidio *et al.* 1991
regenerative ability	Yurkova *et al.* 1988
resistance, general	Gill *et al.* 1983; Pannu *et al.* 1994
resistance, fugi	Corazza *et al.* 1986; Kerber and Dyck 1973; Schneider and Heun 1988; Skiebe *et al.* 1982
resynthesis of polyploids	Galstyan-Avanesyan 1986
RFLP	Castagna *et al.* 1994; Tsunewaki 1991
seed charcters	Banerjee and Chauchan1981
systematics, evolution	Miller 1990; Szabó 1983, 1994, 1995a; Morrison 1993
taxonomy	Dorofeev *et al.* 1979; Schultze-Motel 1986
technology	D'Antuono and Pavoni 1993
Triticum, monograph	Lelley and Mándy 1963; Damania 1993; Heyne 1987
Triticum, homogeneity of characters	Foltyn 1990
Triticum glutenins	Lelley and Gröger 1993/94; Payne and Lawrence 1983; Payne *et al.* 1987
T. boeoticum hybrids	Gill *et al.* 1981
T. boetotauschicum	Gandlyan and Shakaryan1992
T. macha	Dekaprelevich 1961
T. spelta x *durum*	Lapochkina and Pukhalskii 1983
T. sinskajae	Filatenko and Kurkiev 1975
T. turgidum, *T. dicoccoides*	Anikster 1988
wild wheats	Kimber and Sears 1987; Perrino *et al.* 1993; Waines *et al.* 1993

Annex 2

Some characters and genes relevant for the taxonomy of hulled wheats (according to McIntosh 1983, modified).

Explanations: i = nearly isogenic stock; s = chromosome substitution stock; v = cultivar stock. All indicated only if data regarding a hulled species are available

1. Major gene groups used in classification and/or grouping

Taxonomic character	Gene symbol	Gene position	Taxon
Spelt group characters	q c	S1	*T. spelta, T. vavilovii*
Macha etc. wheats	q	K	Idem
Wild wheat character	rf	Rf	*T. boeoticum* vs. *T. monococcum*, etc.

2. Single genes used mostly in microtaxonomy (subsp., convar., provar., and cultivar identification)

Taxonomic character	Gene symbol	Gene position	Taxon
1. Anthocyanin pigments			
1.1. Purple anthers	Pa	?	?
1.2. Red auricles	Ra	?	?
1.3. Red coleoptiles	Rc3	7DS	Miranovskaya 808 *T. dicoc.; Ae. squarrosa*
		7A	*T. spelta* var.
		Rc+Su; 2A,6A etc. Rc4,2A,6A etc.	?
1.4. Purple/red culm	Pc	7BS	?
1.5. Purple grain	Pg h.l.	?	?
	Pg 2-x	3A,7B pleio-tropic, same as Pc,Rc	?
2. Awnedness			
2.1. Hooded	Hd	4Bs	?
2.2. Tipped 1	B1	AL	?
2.3. Tipped 2	B2	6Bl	?
	b1a	?	? half awned
3. Smooth awns	?	?	?
4. Basal sterility (spelt)	Bs	D	? compl. to Q
4. Chlorophyll abnormalities			
4.1. Virescent	v1,2,a,b	3A	?
4.2. Chlorina	cn	A1,B1	?
5. Corroded	co	6B,6D	?
	i(co)	6A	?
6. Crossability (*Secale*)	kr1-x	4A,5B,1D,7D dif.genes	?
7. Gibberrellic acid response	Gai1-3	4A	?

Taxonomic character	Gene symbol	Gene position	Taxon
8. Glume colour			
8.1. Red	Rg1-2	1BS, 1DL	?
8.2. Black	Bg	1A	
8.3. Pseudo-black	Pbc	3B	
8.4. Black-striped	?	?	*T. dicoccon*
8.5. Inhibitor	i(Rg?,)	3A	?
8.6. Hulledness (threshing fact.)	q	/ Q	in hulled wheats
9. Awn colour	?	?	? (bibl. not clear)
10. Grain hardness	Ha	?	?
11. Dwarfness (grass-clump)	D1-4	a,B,D1-3...	?
12. Hairy glume	Hg	1AS	dominant, widespread in *T. monococcum*, *T. aestivum*, etc.
13. Hairy leaf	Hl	4A	*T. aestivum*
14. Hairy peduncule	Hp	4Aß / 5R, 5BS, 6D	?
15. Hairy node	Hn	5AL, B1	?single dominant gene; (*T. monococcum*)
16. Height	Ht	? polygenic	?
16.1. Reduced height	Rht1-8	4A,4DS	additive effects, recessive, semi-dom.
17. Hybrid weakness			
17.1. Necrosis	Ne1-2,m,s,w	2BS,5BL	?
17.2. Chlorosis	Ch1-2	2A,3Da,	*T. macha* var.dif.; *T. dicoccoides* var.; *T. vavilovii; T. elongatum* (almost in every stock)
18. Lack of ligules	lg1-2	2B,2D	?
19. Male sterility	ms1a-c	4A	?
20. Meiotic characters			
20.1. Low-temp. pairing	ltp	5D(+12 / -20o)	?
	Ltp	normal on low temp.	in *T. dicoccon*
20.2. Pairing homoeologous	ph1-2,a-b	5BL,3DS	Chinese Spr. Ph1 Ph2
21. Pollen killer	ki / Ki	6BL	?
22. Proteins			
22.1. Seed protein	Pro1-2	6BL	?
22.2. Alcohol-dehydrogenase	AdhA,B,D,1	4Aa,4BL,4DS no variability in 6x	
	Adh-A1 (AdhA)	?	*T. turgidum* !
	Adh-B1 (AdhB)	?	*T. timopheevii*, variable
22.3. Aminopeptidase	AmpA1-D1	6Aa,6BS,6Da	?
22.4. Glut. oxal. transaminase	GotA1-D1 etc	?	?
2.2.5. Endopeptidase	Ep-A1-D1	7Al,7BL,7DL	?
22.6. Lipoxygenase	Lpx-A,B,D,	1-2 4A-D,5A-D	?
22.7. Phosphodiesterase	Pde-A,B,D,	1 3A-D	?
22.8. Gluc. phosph. isomerase	Gpi-A-D	1AS-DS	?
	Gpi-R1,U1,Ag1, Hch1	?	*T. umbellul.*, *T. elong.*

Taxonomic character	Gene symbol	Gene position	Taxon
22.9. Shikiminate dehydrog.	SkdhA1-D1	5AS-DS, 5U	?
22.10. Glutenins	Glu-A1a-c	1AL	*T. monococcum*
	Glu-B1a-k	1BL	(cf. Table 3.)
	Glu-d1a-f	1DL	?
22.11. Gliadins	Gli-A,B,D1	1AS,1BS,1DS	*T. monococcum*
22.12. Lipopurothionin	Pur-A1	1AL,BL,DL	?
22.13. Nitrate reductase	Nra / nra	?	?
23. Red grain colour	R1	3Da	dominant
	R2	3Aa	?
	R3	3B	?
	R?	3Ag	*T. elongatum* (transferred)
24. Photoperiod	ppd1	2D	?
	ppd2	2BS	?
	ppd3	2A	also in *T. turgidum*
25. Vernalization	Vrn1	5AL	insens. (*T. monococcum*)
	Vrn2	Ss	?
	Vrn3	5DL	?
	Vrn4	?	?
	Vrn5	eiH	winter cultivars; recessive alleles
27. Restorers of fertility	Rf1	1A	*T. timopheevi* / *T. sq.*
	Rf2	7D	Idem / *T. aestivum*
	Rf3	1B	*T. spelta*
	Rf4	6B	*T. timoph./T. squar.*
	Rf5	6D	Idem
28. Palmitate + lineolate	Pln	7DS	*T. aest.* cv. Aradi
29. Tenacious glumes	Tg	2Da	*T. tauschii*, dominant
30. Uniculm stunt	Us / us1-2	?	Us normal, us stunt
31. Waxiness	w	2BS	not glaucous
	W1I(inhib.)	2BS	*T. dicoccoides*
	W2a	?	*T. tauschii*
	W2b	?	*T. aest.*, dosage effects
	W2I(inhib.)	2Da	non-glaucous *T. tauschii*
32. Pathogenic reaction			
32.1. *Cochliobolus sativus*	Crr	5BL	rec. Root Rot
32.2. *Erysiphe graminis*	Pm1	7AL	? Powd. Mild.
	Pm3a	1AS	?
	Pm3b-c	1A	?
	Pm4a	2AL	?
	Pm4b	2AL	?
	Pm5	7BL	?
	Pm6	2B	?
	Pm7	4Aß	?
	Pm8	1R(1B)	?
	Pm9	7A	?
32.3. *Heterodera avenae,* cereal cyst nematode	Cre	2B	?
32.4. *Puccinia graminis,* stem rust			
	Sr2	3BS	?
	Sr3-4	?	?
	Sr5	D6	?
	Sr6	2Da	?
	Sr7a,b	4B,4BL	?

Taxonomic character	Gene symbol	Gene position	Taxon
	Sr8	6Aa	?
	Sr9a,b,d	2BL	?
	Sr9e	2BL	*T. turg.* cv. Vernal
	Sr11	6BL	?
	Sr12	3BS	?
	Sr13	6Aß	?
	Sr14	1BL	?
	Sr15	7AL	?
	Sr16	2BL	?
	Sr17	7BL	?
	Sr18	1D	?
	Sr19	2BS	?
	Sr20	2BL	?
	Sr21	2AL	?
	Sr22	7AL	?
	Sr23	4A	?
	Sr24	3DL	?
	Sr25	7DL	?
	Sr26	6Aß	?
	Sr27	3A	?
	Sr28	2BL	?
	Sr29	6Dß,a	?
	Sr30	5DL	
	Sr31	1R/1B	?
	Sr32	2A,B,D	?
	Sr33	1DL	?
	Sr34	2A,D,M	?
	Sr35	3AL	*T. monoc.* C6969
	Sr36	2BS	*T. timoph.* deriv.
	Sr37	4Aß	*T. timoph.* deriv.
32.5. *Puccinia recondita,* (brown) leaf rust			
	Lr1	5DL	?
	Lr2a	5Da	?
	Lr3	6BL	?
	Lr4-8	?	?
	Lr9	6BL	?
	Lr10	1AS	?
	Lr11	2A	?
	Lr12	4A	?
	Lr13	2BS	?
	Lr14a,b	2BS	?
	Lr15	2Da	?
	Lr16	4A	?
	Lr17	2AS	?
	Lr18	5BL	?
	Lr19	7DL	?
	Lr20	7AL	?
	Lr21	1DL	*T. squar.* var. *meyeri*
	Lr22	2Da	*T. squar.* var. *strang.*
	Lr23	2BS	?
	Lr24	3DL	"linked" to Sr24
	Lr25	4Aß	"linked" to PM7
	Lr26	1RS-1BL	?
	Lr27	3BS (compl.	?

Taxonomic character	Gene symbol	Gene position	Taxon
		on 4A)	
	Lr28	4BL	?
	Lr29	7DS	?
	Lr30	4BL	?
32.6. *Puccinia striiformis*, yellow / stripe rust			
	Yr1	2A	?
	Yr2	7B	?
	Yr3-4	?	?
	Yr5	2BL	*T. spelta album*
	Yr6	7BS	?
	Yr7	2BL	?
	Yr8	2D	?
	Yr9	1R(1B)	?
	Yr10	1BS	?
32.7. *Tilletia* spp., bunt, dwarf smut			
	Bt1	2B	?
	Bt2-3	?	?
	Bt4-6	1B	?
	Bt7	2D	?
	Bt8-10	?	?
32.8. *Mayetiola / Phytophaga destructor*, Hessian / sawfly			
	H1-2	?	?
	H3	5A	?, recessive
	H4	?	idem
	H5	?	temp. sens.,
	H6	5A	?
	H7-8	?	duplicate factors
	H9	5A	?
	H10	5A	?
	H11-12	?	*T. turgidum*
	H13	?	*T. turg./T. tausch.*
32.9. *Toxoptera/Schizaphis graminum*, greenbug	Gb	?	rec.
32.10. *Ustilago tritici*, loose smut	Ut1-4	?	?
Other characters:			
33. Rachis fragile	Rf	?	
34. Rachis hairy	Rh	?	

a - first identified arm on metacentric chromosomes; ß - second identified arm on metacentrics; A,B, etc. - genome symbols; e - enhancer; i - inhibitor; L - long arm; S - short arm; Su - suppressors.

Annex 3

Examples of endosperm storage protein gene nomenclature (McIntosh 1983).

Gene symbols	Gene position	Cultivar stock	Frequency
Glutenins			
Glu-A1a	1AL	cv. Hope	28%
-A1b	1AL	cv. Bezostaya-1	28%
-A1c	1AL	cv. Chinese Spring	44%
Glu-B1a	1BL	cv. Flinor	19%
-B1b	1BL	cv. Chinese Spring	25%
-B1c	1BL	cv. Bezostaya-1	30%
-B1d	1BL	cv. Hope	18%
-B1e	1BL	cv. Federation	3%
-B1f	1BL	cv. Lancota	rare
-B1g	1BL	cv. NS335	rare
-B1h	1BL	cv. Sappo	rare
-B1i	1BL	cv. Gabo	4%
-B1j	1BL	cv. Dunav	rare
-B1k	1BL	cv. Serbian	rare
Glu-D1a	1DL	cv. Chinese Spring	56%
-D1b	1DL	cv. Hobbit	3%
-D1c	1DL	cv. Champlein	5%
-D1d	1DL	cv. Hope	35%
-D1e	1DL	cv. Flinor	rare
-D1f	1DL	cv. Daneli	rare
Gliadins			
Gli-A1	1AS	?	?
Gli-B1	1BS	?	?
Gli-D1	1DS	?	?

Annex 4

Some genetic linkages in the A genome of different *Triticum* species.

Chromos.	Genes	Linked to	%	Notes
1AS	Hg	centromere	–	independent
	Pm3a	centromere	–	independent
	Hg	Pm3a	1-5%	–
	Hg	Bg	0-16%	in *T. monoc.*
		–	0-2%	in *T. turgidum*
		–	12%	in *T. aestivum*
	Gli-A1	Glu-A1	66%	–
1AL	Glu-A1	centromere	8%	–
2AS	Lr17	centromere	–	independent
	Lr17	Lr11	–	independent
2AL	Sr21	centromere	2%	–
	Pm4b	Sr21	38%	–
	Pm4b	centromere	–	independent
3Aa	Sr35	centromere	0.3%	–
	Sr35	R2	1%	–
3Aß	?	?	?	–
4Aa	Rht1 / Gai1	centromere	15%	–
	Gai1	Gai3	0%	–
4Aß	Lr25 / Pm7	centromere	1%	–
	Lr25	Pm7	0%	–
	ms1b	centromere	–	independent
	ms1c	centromere	–	independent
	ms1b	Lr25	34 c.o. units	–
	ms1c	Lr25	20 c.o. units	–
	Hp	centromere	30%	–
5AL	Vrn1	centromere	–	independent
	q	B1 (n)	30%	–
	q (S)	B1 (N)	33%	–
	q (S)	B1 (B)	37%	–
	q (K)	B1	41%	–
	q (S)	Hn	35%	–
	B1	Hn	5%	–
5AS	?	?	?	–
Unresolved:				
	H3	H6	9%	
	H3	H9	16%	
	H6	H9	2%	
	H9	H10	36%	gene order:3-6-9
6Aa	Sr8	centromere	44%	–
	Sr8	Sr13	–	independent
6Aß	Sr13	centromere	–	independent
7AL	Sr22	centromere	27%	–
	Sr22	Rc1	42%	in *T. monococcum*
	Sr22	Cn-A1	2%	–
	Sr22	Pm1 / Lr20 / Sr15	41%	–
	Cn-A1a	centromere	–	independent
	cn-A1b	centromere	34%	–
	cn-A1a	Pm1 / Lr20 / Sr15	40%	
	Pm1	centromere	–	independent
	Pm1	Pm9	–	linked

From staple crop to extinction? The archaeology and history of the hulled wheats

M. Nesbitt[1] *and D. Samuel*[2]

[1] Institute of Archaeology, University College London, London, England
[2] McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, England

General aspects

Introduction

The importance of the hulled wheats in past societies is hardly reflected in their current status as minor, ever-declining crops in isolated, marginal areas. Yet the hulled wheats were among the earliest domesticated plants, spread over Eurasia from the British Isles to central Asia, and were staple crops for many millennia. Our aim is to outline the history of the hulled wheats from domestication to classical antiquity, focusing on some key research questions. We will concentrate on the evidence of archaeobotany – the study of plant remains from archaeological excavations – because this is direct evidence for the presence and use of hulled wheats in the past. Textual evidence – whether from clay tablets or medieval manuscripts – presents major difficulties in interpretation, some of which are discussed later on.

The history of the hulled wheats is to a considerable extent the history of agriculture. Inevitably we have had to be highly selective in what we cover, and have relied mainly on secondary sources. We hope at least to offer a reasonably comprehensive guide to the general literature, to discuss critical issues in some detail, and to offer some thoughts on how to tackle some of the major problem areas in the history of hulled wheats. Special acknowledgements are due to van Zeist *et al.* (1991) and Zohary and Hopf (1993), on whom we have drawn heavily.

Areas that we have covered in detail include evidence for the domestication of hulled wheats, their spread in all directions from the Near East, and their role in the ancient civilizations of Egypt and Mesopotamia. We end with a brief survey of the place of hulled wheats in the classical world, and their decline in western Europe. Before tackling these topics, we thought it useful to survey some more general areas. Since much confusion has arisen about how the hulled wheats are processed, we discuss this topic at some length, and in particular whether parching is necessary for dehusking. Nomenclature and archaeobotanical identification criteria are also briefly discussed.

The archaeological chronology for Europe and the Near East draws on two sources. Texts provide enough information to allow us to assign approximate calendar dates back to the Early Bronze Age in the Near East and the Classical period in Europe. Before that, most dates depend on radiocarbon dating, which systematically underestimates the ages of ancient objects: for example, a seed radiocarbon dated to about 4500 years ago would in fact be about 5200 calendar years old. Until recently, radiocarbon dates earlier than about 5000 years ago could not be calibrated, but calibrated dates are constantly being pushed back by tree-ring dating. In the archaeological literature there is therefore a (usually unspoken) divide in precision of dates, around 3000 BC. In this paper we show calendar year or calibrated radiocarbon dates as BC/AD, and uncalibrated radiocarbon dates as bc/ad.

Numerous references to the scarcity of archaeobotanical data will be made in this paper; these do not reflect any lack of plant remains at archaeological sites, but rather the very uneven application of the highly effective flotation techniques developed since the 1960s (Nesbitt 1995b). In general, more effort has been made to recover plant remains from early sites (Neolithic or pre-Neolithic), and from sites in the Near East and Britain, the Netherlands, Switzerland and Germany. Recovery of plant remains in other areas is still limited and rarely employs large-scale flotation techniques. It is thus problematical to compare sites, both on a local scale and on a broad geographical scale. This in turn means that patterns of use for hulled wheats over time and in different regions are sometimes difficult or impossible to trace on current evidence.

Nomenclature

The wheat genus (*Triticum* L.) has been subjected to a confusing array of taxonomic treatments (Morrison 1993; van Slageren 1994). Perhaps the only area of general agreement is that none of the existing treatments satisfactorily combines phylogenetic realities with ease of use.

In this paper we will refer to the three main domesticated hulled wheats by their common names: einkorn, emmer and spelt. When wild einkorn is referred to, it usually includes *T. urartu* and *T. boeoticum*; similarly, wild emmer refers to both *T. dicoccoides* and *T. araraticum*. The rarer cultivated species and the other wild wheats will be referred to by their botanical names, following for convenience the traditional concept of wheat species as outlined by Dorofeev and Migushova (1979). Botanical names and common names of hulled wheats are shown in Table 1. We use macaroni wheat to refer to tetraploid free-threshing wheat *(T. durum* Desf. /*T. turgidum* L.) and bread wheat to refer to hexaploid free-threshing wheat *(T. aestivum* L. in the widest sense). Common names for hulled wheats have led to a great deal of confusion in past literature, particularly through the use of ‘spelt’ as an all-inclusive term. Our terminology, as outlined above and in Table 1, represents standard use of these common names today.

The names used for different parts of the spike of hulled wheats are shown in Figures 1 and 2; see also Charles (1984).

What is distinctive about the hulled wheats?

As the name suggests, the main character that separates the hulled wheats from the free-threshing wheats is the persistent enclosing hull. When a spike of hulled wheat is threshed, it breaks up into its component spikelets, each consisting of tough glumes attached to a rachis segment. Each spikelet encloses one or more grains. When a free-threshing wheat – for example, macaroni or bread wheat – is threshed, the rachis segments stay attached to each other, while the glumes and other chaff break, releasing the free grain (Fig. 1). The hulled character is the result of two differences in the structure of the spike: the semi-brittle joints between the rachis internodes, and the toughened glumes. This has major implications for crop processing, discussed in the following two sections.

Hulledness in wheat involves other important characteristics. The thick, tough glumes of hulled wheats give excellent protection to the grains in the field and in storage. The fact that hulled wheats are mainly grown in mountainous areas today is not simply a result of their isolation; hulled wheats do seem especially resistant to poor soil conditions and a range of fungal diseases.

Table 1. Common and botanical names of wild and domesticated hulled wheats, arranged by genetic characteristics. Botanical names are according to Dorofeev and Migushova (1979).

Ploidy level	Common name	Botanical name	Wild or domesticate	Genome formula
Diploid	Wild einkorn	*T. boeoticum* Boiss.	Wild	A
		T. urartu Thum. ex Gandil.	Wild	A
	Einkorn	*T. monococcum* L.	Domesticate	A
Tetraploid	Wild emmer	*T. dicoccoides* (Körn. ex Aschers. et Gräbn.) Schweinf.	Wild	AB
		T. araraticum Jakubz.	Wild	AG
	Emmer	*T. dicoccum* (Schrank) Schübl.	Domesticate	AB
		T. palaeocolchicum Menabde	Domesticate	AB
		T. ispahanicum Heslot	Domesticate	AB
		T. timopheevi (Zhuk.) Zhuk.	Domesticate	AG
Hexaploid	Spelt	*T. spelta* L.	Domesticate	ABD
		T. macha Dekapr. et Menabde	Domesticate	ABD
		T. vavilovii (Thum.) Jakubz.	Domesticate	ABD
		T. zhukovskyi Menabde et Ericzjan	Domesticate	AAG

Even discounting the hulled character, these wheats differ significantly from their free-threshing counterparts. For example, the flour and dough properties of einkorn and emmer are very different from those of macaroni wheat and bread wheat. The hulled wheats also have a thinner pericarp – a property drawn to our attention by Turkish millers, and mentioned by Küster (1985). We have not found any mention of this difference in some standard accounts of food-plant anatomy (e.g. Winton and Winton 1932), but it is real and deserves further study. Since the hulled wheats are clearly separated from the free-threshing wheats by more than just the hulled character, it is appropriate to consider the hulled wheats as a distinctive group.

Parching of hulled wheats

The literature on hulled wheats often refers to the necessity of parching spikelets to render the chaff brittle, in order to free the enclosed grain (for example, Moritz 1955:129; Spurr 1986:11, note 30; Sallares 1995:95 and see references in Meurers-Balke and Lüning 1992:357). As Leonor Peña-Chocarro describes (this volume), this idea may ultimately be based on descriptions in classical texts, such as that in Pliny (1950):97: "...Etruria pounds the ears of emmer, after it has been roasted, with a pestle shod with iron at the end...".

The ethnographic record for cereals in general demonstrates that there are a number of possible reasons for the use of heat, which have nothing to do with dehusking (Hillman 1982; van der Veen 1989; L. Peña-Chocarro, this volume). Fenton (1978:37), for example, lists three reasons for drying grain in Orkney and Shetland: to dry a crop which was harvested slightly unripe; to make malt for brewing; or to harden grain for milling in rotary querns. The classical references to heating of hulled wheats need not therefore refer to parching as an aid to dehusking.

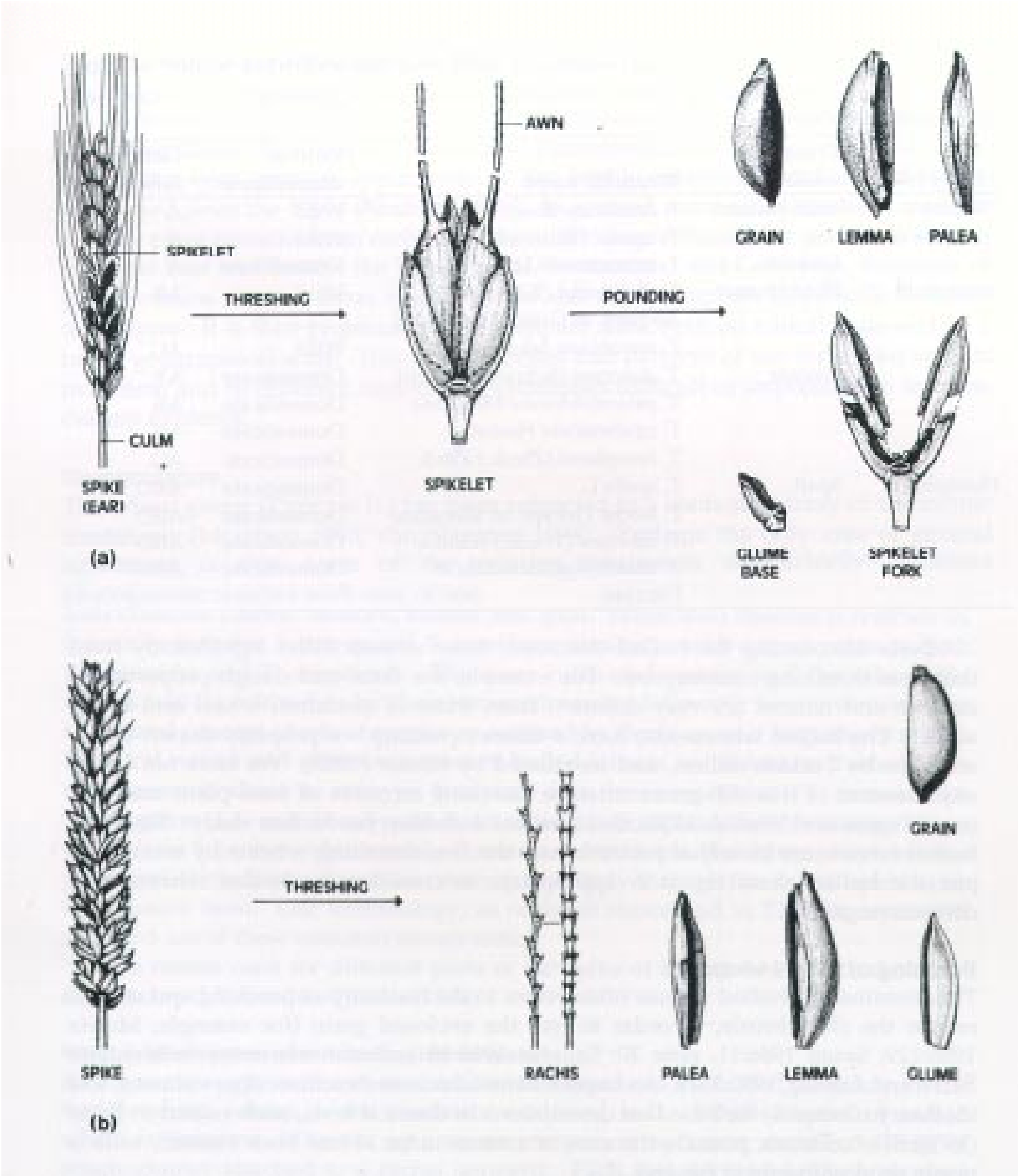


Fig. 1. The anatomy of hulled and free-threshing wheat.

a. Hulled wheat. Upon threshing, the spike breaks up into individual spikelets which must be further vigorously processed to free the grain from the tough chaff.

b. Free-threshing wheat. When threshed, the central rachis remains whole or nearly so. The chaff surrounding the grain separates easily from the rachis and the grain falls out freely.

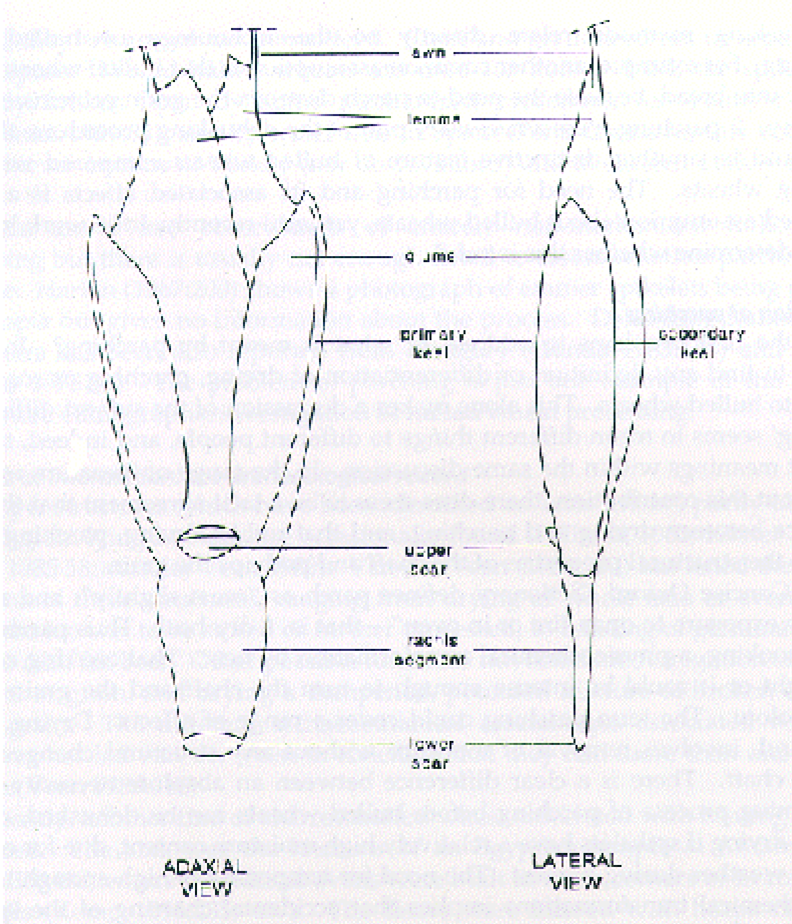


Fig. 2. Schematic diagram of a typical hulled wheat spikelet, showing the constituent parts.

Without detailed descriptions in ethnographic accounts or general discussions, it can be very difficult to distinguish precisely at what stage and why heat is applied to cereals. Vagueness is one reason why most ethnohistorical accounts of hulled wheat processing are not reliable. Since there are a number of reasons why heating might be involved, the attempt to determine whether parching is an integral part of non-mechanized hulled wheat processing using incomplete descriptions is likely to prove misleading, if not impossible.

Recently, a number of archaeobotanists have begun to question the view that it is obligatory to parch hulled wheats before they can be husked. This is an important question for several reasons. If parching was commonly used for dehusking, it would be a potentially important source of charred cereal in the archaeological record. These cereals would be produced at a clearly definable stage in the processing sequence with distinctive results: whole charred spikelets. This in turn would have a direct effect on the interpretation of archaeological contexts. A common assumption is that hulled wheats are over-represented in the archaeobotanical record because the need to parch means they were accidentally charred more frequently than free-threshing wheats.

Dehusking methods relate directly to the technology of hulled wheat processing. For example, another common assumption is that hulled wheats cannot be made into bread, because the need to parch destroys the grain proteins essential for bakery. If parching were a necessary part of the dehusking procedure, then this step would be another distinctive feature of hulled wheats compared with free-threshing wheats. The need for parching and its associated effects is a deeply embedded assumption about hulled wheats, yet until recently, little work has been done to determine whether this is valid.

A definition of parching

One of the first problems to address is: what is meant by parching? It is very difficult to find any definition or differentiation of drying, parching or roasting as applied to hulled wheats. This alone makes a discussion of the subject difficult, for ‘parching’ seems to mean different things to different people, and indeed, takes on different meanings within the same discussion. In the range of literature we quote throughout this contribution, there does seem to be a tacit agreement that there is a difference between drying and parching, and that unlike drying, parching has an effect on the structural properties of the chaff and perhaps the grain.

The Concise Oxford Dictionary defines parch as “roast slightly”, and roast as “cook by exposure to open fire or in oven” – that is, a dry heat. Thus parching is a type of cooking, a physicochemical transformation by heat. That cooking could be very slight or it could be intense enough to turn the chaff and the grain a deep brown colour. The term parching could cover a range of effects. Drying, on the other hand, involves removal of moisture without any structural changes in the grain or chaff. There is a clear difference between an absolute necessity for the transforming process of parching before hulled wheats can be dehusked, and the need for drying if spikelets have a relatively high moisture content, due for example to damp weather during harvest. The need for temperatures high enough to cause physicochemical transformations implies that accidental charring of the spikelets would be more likely for parching than drying.

There are few experiments on how temperature affects the grain and chaff of the hulled wheats. One exception is the work by Lüning and Meurers-Balke (1980:338-339). They found that at 50ºC and 100ºC, no change was discernible. At 150ºC, spelt was unaffected while einkorn and emmer chaff became somewhat brittle. Not until 200ºC was reached did einkorn and emmer chaff become significantly affected, while the more robust spelt chaff started to become brittle.

No work has been done on how length of time affects spikelets during exposure to low temperatures (about 100ºC) but it is possible to hypothesise that physicochemical changes require a threshold energy input before they will occur; that is, they are temperature-dependent (e.g. French 1973:1055). Thus, long exposures to low temperatures are likely to make spikelets very dry, but unlikely to cause any significant structural change which causes the chaff to become brittle and easily shattered. More work is needed to test this.

On the basis of the work done by Lüning and Meurers-Balke (1980), a reasonable distinction is that drying involves temperatures up to about 100ºC, while parching takes place at temperatures above about 150ºC, irrespective of exposure time.

Sources of information: the ethnographic record

One of the greatest barriers to the investigation of hulled wheat parching is the lack of ethnographic information. This stems from the rarity of modern hulled wheat cultivation. Often, in the few areas where hulled wheats still survive and have been studied, they are grown for animal feed. Chaff and grain need not be separated for this purpose. Where hulled wheats are used for human food, the spikelets are generally broken open by some mechanized procedure, for example in Italy (D'Antuono 1989:55), and by water mill in Spain (Peña-Chocarro, this volume), in the Pontic mountains of Turkey (our observations) and in eastern Turkey (Hillman 1984b).

There are a few observations of entirely non-mechanized hulled wheat processing but there is usually not enough detail to assess whether parching plays any role. Harlan (1967:200) shows a photograph of emmer spikelets being pounded in Ethiopia but gives no information about the process. Dehusking hulled wheats in mortars has been also reported from Hungary (Gunda 1983:155) and Slovakia (Markus 1975:35). The problem of parching is just one example of the need for much more ethnographic investigation of hulled wheat processing.

Sources of information: the archaeological record

In Europe, structures which have been identified as ‘corn driers’, partly because of charred grain lying in them, are occasionally found (Hillman 1982; Küster 1984:310; Küster 1985:58; van der Veen 1989). Van der Veen (1989:303) has listed the possible functions of these structures, ranging from drying of whole ears or even sheaves which are too wet to be stored or further processed, to roasting of germinated grain to make malt for beer. Other possible functions not listed are fumigation of infested spikelets or grain, and drying a dampened, pounded mixture of broken chaff and whole grain. The different archaeobotanical assemblages associated with these structures has led van der Veen to conclude that they had more than one function (van der Veen 1989:316).

Recently, another find of charred hulled wheat associated with heating has been excavated. The area was the kitchens of an Egyptian temple at Amarna, dated about 1350 BC, where cylindrical ovens were built in room corners or in rows along the walls (Kemp 1995:435, 437). The floors were littered with heaps of charred emmer grain and chaff (D. Samuel, unpublished data). Although this and the European finds show that hulled wheats were associated in some way or in several ways with heating, we are faced with problems of interpretation which again are due to lack of ethnographic evidence. In the case of the Egyptian temple kitchens, substantial quantities of barley were also recovered, suggesting the use of processes which were not unique to hulled wheats.

The archaeological record offers a further enigma if parching is a necessity for hulled wheat processing. Küster (1984:310) states that the type of kiln found at Erberdingen-Hochdorf, with charred einkorn spikelets – and apple halves – has rarely been found in Neolithic settlements. Van der Veen (1989:302) points out that British ‘corn-driers’ are restricted geographically – southern and eastern Britain – and in time – to the Roman period, with the majority of such constructions dating to the 3rd and 4th centuries AD. As Braun (1995:36) points out, emmer was an important crop in Roman Italy, but there are no large kilns or ovens associated with spikelet parching. If parching was an essential processing step, why are apparent parching installations so uncommon?

Sources of evidence: experimental work

Before going on to discuss the experimental evidence, another problem with terminology needs to be clarified. There is frequent confusion between pounding and milling. These terms are not interchangeable, although they are often used as if they were. They describe specific actions which are carried out with specific tools.

Pounding involves an up and down motion applied with some force. It is usually done with a pestle in a mortar. Both these tools may be made of stone or wood and may vary in size.

Milling is the equivalent of grinding. This means using friction, which may include the application of pressure, to break up material between two surfaces. Querns are the tools used for milling cereals and there are two types. The saddle quern is a flat slab, often made of stone, which lies unmoving on the ground or in an emplacement, or may even be a hollowed area in a much bigger rock. The grinding action is done with a smaller hand stone rubbed back and forth along the long axis of the saddle quern surface. Pounding up and down on the saddle quern would be likely to gouge the surface heavily but effective grinding requires a reasonably flat surface. This is the reason that pounding would not be done on a saddle quern. There has been relatively little investigation of these tools (Moritz 1958:18-41; Sumner 1967; Wright 1992).

The rotary quern is made up of a pair of disks, usually of stone. There is a very wide range of shapes, particularly among those from the Roman period (Curwen 1937, 1941; Moritz 1958). The basic form is a pair of disks, one of which rotates above the other around a common axle (Moritz 1958:xxvii). Milling is done by the friction between the flat inner surfaces which fit closely together. Rotary querns were not invented until the Classical period, probably in Italy in early Roman times (Moritz 1958:60-61). All cereal processing before this time was done with mortars and saddle querns.

Irrespective of the terms actually employed in the literature, when pestles and mortars are used, the action is pounding, and when querns of whatever type are used, the action is milling or grinding.

There have been few hulled wheat processing experiments, and of these, not all have aimed to investigate the effect on the spikelets and grains (e.g. Bower 1992). Some work has been done on dehusking with a saddle quern; other work concentrates on the use of mortar and pestle.

Beranová (1986:323), Küster (1984:310-311, 1985:59-50) and Meurers-Balke and Lüning (1992:350) examined hulled wheat dehusking on saddle querns. In all series of experiments, heating did improve the proportion of dehusked spikelets obtained by milling. The optimal temperature for the latter two cases was about 100ºC – a drying rather than a parching temperature. Beranová (1986:323), however, found that dehusking this way was slow and yielded a poor product. Likewise, Meurers-Balke and Lüning (1992:350) concluded that in comparison to pounding, dehusking by milling was much less successful in every parameter. Overall, a mortar was far more effective for dehusking hulled wheats. Similar results have recently been obtained using ancient Cretan processing as an experimental model (Hara Procopiou, pers. comm.).

One of us (DS) investigated ancient Egyptian emmer processing by experiments using actual ancient tools, and replicas based on ancient finds (see **Processing experiments**). There was no need to parch or heat spikelets to achieve a very satisfactory separation of chaff and whole grain using a mortar and pestle. It may be argued that the arid climate of Egypt dried the emmer spikelets sufficiently, so that this step could be omitted. This may be valid, but the results of experiments in Egypt should still be applicable to the Near East, the Mediterranean and other regions of dry hot summers.

Perhaps the experiments best suited to explore whether parching to dehusk hulled wheats is imperative were those made by Lüning and Meurers-Balke (1980) and Meurers-Balke and Lüning (1992), based in the Hambacher Forest between

Cologne and Aachen in Germany. Work in temperate northwest Europe should be as well suited to examine whether parching is required for dehusking hulled wheats in cooler damper climates as anywhere. In a detailed set of studies, Meurers-Balke and Lüning (1992:341-342) concluded that dehusking is best accomplished by pounding in wooden mortars; that there is no need to parch in order to dehusk hulled wheat; and that experimental and archaeological evidence indicates parching was unlikely to have been used by the earliest European farmers.

Summary

The archaeological record suggests that hulled wheats were heated, at least sometimes, during some stage of processing, but not necessarily in order to dehusk spikelets. A variety of experimental evidence shows that hulled wheats can be very effectively dehusked without parching, in both dry climates and temperate European conditions. There are scarcely any data from ethnographic observations in areas which dehusk hulled wheats by mortar and pestle. This is unfortunate, since traditional practitioners are the best source of information. We predict that where hulled wheats are still being processed without mechanization, parching is not part of the dehusking sequence.

Ancient hulled wheat processing

Archaeological and ethnographic evidence

To learn about non-mechanized hulled wheat processing, the archaeological evidence from ancient Egypt provides an excellent case study. Hulled barley was the only other cultivated cereal, but the techniques for dehusking emmer and hulling barley are probably similar. The desiccating action of Egypt's arid climate preserves organic material, including plant remains, outstandingly well (Fig. 3).

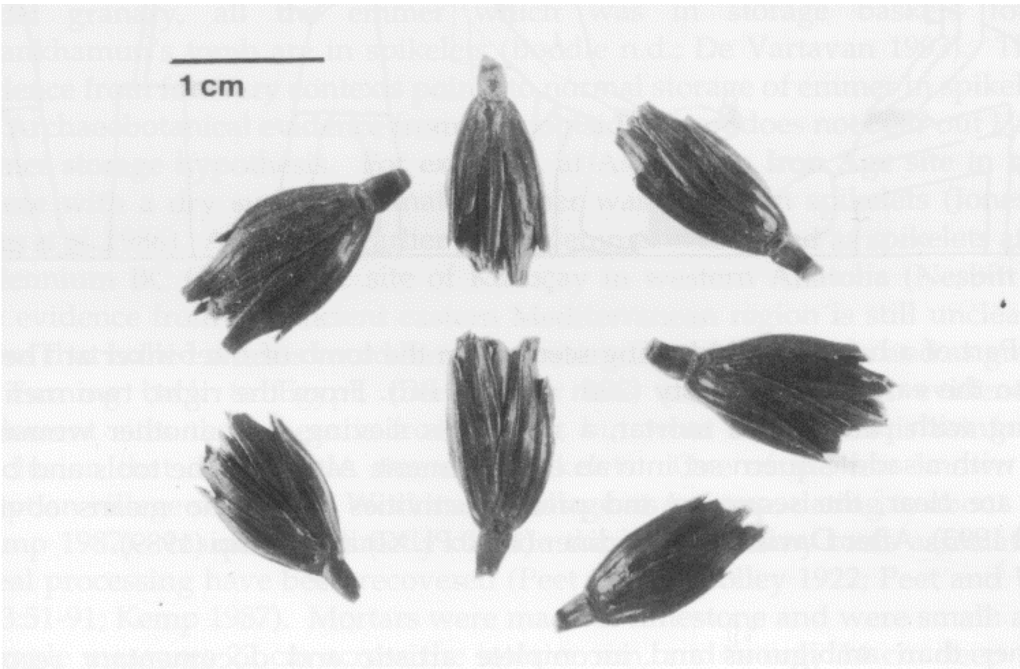


Fig. 3. Whole desiccated emmer spikelets from an unknown ancient Egyptian tomb, courtesy of the Royal Ontario Museum, Toronto. Although these spikelets appear to be twice the size of those shown in Figure 7, a direct comparison cannot be made due to the shrinking effects of charring.

Many plant parts survive, unlike in most regions of the world where botanical material has passed through the filtering and destructive action of charring. An ancient village, the Workmen's Village at Amarna, has been extensively excavated and well enough recorded to draw conclusions about cereal processing installations.

Cereal processing, as part of bread and beer production, has been of interest to Egyptologists for a long time. The subject is a classic example of the difficulties which arise when documentary evidence alone is relied upon with little or no reference to archaeological and ethnographic material. The distinctiveness but rarity of the hulled wheat has also caused problems with interpretation, which have gone largely unrecognized. The abundance of available ancient Egyptian artistic and literary evidence has distracted enquiry away from the archaeological record (Fig. 4). In addition, most scholars who have considered the topic have not been aware of the differences between hulled and free-threshing wheats. The technology and sequence of activities required for processing emmer has usually not been understood. The combination of a non-archaeological focus and the misunderstanding about hulled wheat means that there are many contradictions in most of the literature on ancient Egyptian cereal processing (Samuel 1993:277-278).

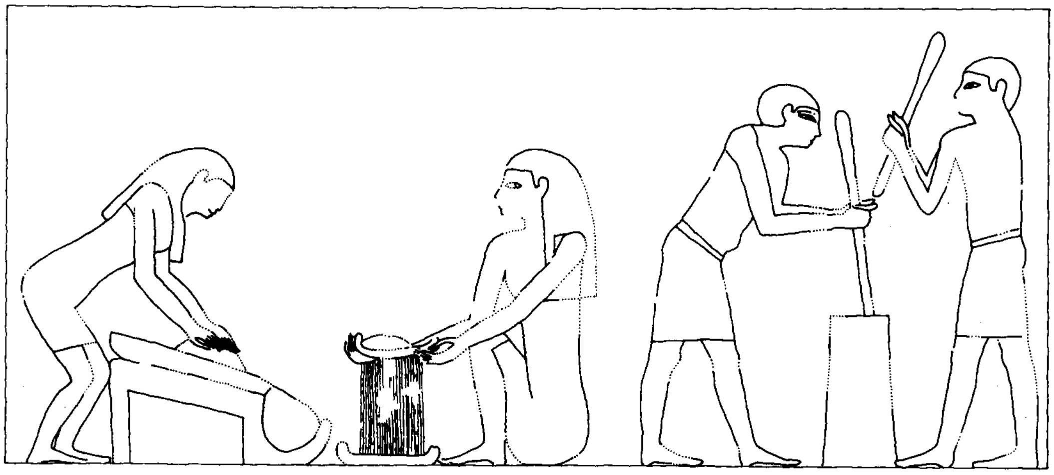


Fig. 4. Part of a baking and brewing scene from the tomb of Intef-inker at Thebes, dating to the early 12th Dynasty (20th century BC). From the right, two men are pounding with pestles in a mortar, a woman is sieving, and another woman is milling with a saddle quern set into an emplacement. Although the tools and basic actions are clear, the sequence and precise activities are by no means obvious (Samuel 1993). After Davies and Gardiner (1920:Pl. XI) and Kemp (1989).

Rather than ambiguous and incomplete artistic and documentary records, archaeology is a more fruitful route of inquiry. The archaeological evidence for cereal processing can only be interpreted with the help of appropriate ethnographic analogies. Although there is little information directly related to hulled wheats, there are relevant ethnographic parallels which can be used. Enough data from Egyptian archaeology and ethnography now exist to interpret this important activity of ancient Egyptian daily life with some confidence. The evidence from ancient Egypt is relevant not only to a specific culture, but also provides insights on hulled wheat processing elsewhere, prior to the invention of the rotary quern.

The key difference between the free-threshing wheats and the hulled wheats is the need to free the hulled wheat grain from the spikelets before it can be processed into food. This means two aspects of cereal processing need to be considered. First, how was the grain stored? Was it dehusked before bulk storage in granaries or was it stored in the spikelet? Second, what tools were used for the vigorous mechanical action required to break up the spikelets?

There is little direct information, in the form of intact Egyptian granaries, to indicate whether emmer was stored as spikelets or as clean grain. Hillman (1981:131, 138; 1984a:8, 11; 1984b:126) has suggested that dry climates would allow people to bulk process their harvest of hulled wheat up to the clean grain stage. Those living in wetter climates such as northern Europe or mountainous regions, on the other hand, would get the harvest into storage as soon as cleaned spikelets were obtained. They could then dehusk in small quantities as needed from day to day. Although this may seem reasonable from the point of view of efficiency, there are numerous strands of evidence which demonstrate that in Egypt, emmer was stored as spikelets.

Model granaries were sometimes placed in tombs, especially in the Middle (2040-1640 BC) and New Kingdoms (1500-1070 BC) to ensure a plentiful supply of grain in the afterlife. A number of these granaries survive, and some still retain their ancient cereal contents. For example, a large model granary from the tomb of Tutankhamun, now in the Cairo Museum (display number 1641, upper floor, gallery 30) contains large quantities of typical emmer spikelets, as well as some hulled barley (see Hepper 1990:54, 66). Emmer occurs as spikelets, not grain, in model granaries now at the Cairo Museum, the British Museum and the Ashmolean Museum, Oxford. The only emmer grain is in a few little dishes. As well as the model granary, all the emmer which was in storage baskets found in Tutankhamun's tomb are in spikelets (Boodle n.d.; De Vartavan 1993). Thus, the evidence from funerary contexts points to normal storage of emmer in spikelets.

Archaeobotanical evidence from sites outside Egypt does not bear out Hillman's emmer storage hypothesis. For example, at Assiros, an Iron Age site in northern Greece with a dry summer climate, emmer was stored in spikelets (Jones 1981a; Jones *et al.* 1986). At a much earlier period, emmer was stored as spikelets at the 4th millennium BC Chalcolithic site of Kuruçay in western Anatolia (Nesbitt 1996b). The evidence from the ancient eastern Mediterranean region is still unclear, but it seems that hulled wheats could have been stored both as spikelets and as grain.

Turning back to Egypt, there is far less archaeobotanical evidence from settlement sites than there is from tombs, but what little there is reinforces the conclusion that emmer was stored in spikelets. One of the few known ancient Egyptian village sites is the Workmen's Village at Amarna, dating to about 1350 BC (Kemp 1987). Inside and directly outside the houses, many tools associated with cereal processing have been recovered (Peet 1921; Woolley 1922; Peet and Woolley 1923:51-91; Kemp 1987). Mortars were made of limestone and were small: a typical example measures 22 cm across the interior rim, and is only 14 cm deep (Samuel 1994:Table 5.1).

Associated plant remains were recovered from around only one of the cereal mortars found still in place. They were composed almost entirely of shredded emmer spikelets, indicating that this mortar was used to dehusk spikelets (Samuel 1989:280-286). The huge quantities of desiccated emmer chaff in the village rubbish dumps demonstrate that emmer was an important food and that large quantities of chaff were generated from processing it. The distance of this village from the riverside cultivation, about 2 kilometres, with dense urban settlement in between, argues against the interpretation that spikelets were processed in bulk after harvest to obtain clean grain, which was then stored.

On the basis of ethnographic analogy (Hillman 1984b:130), the small size of the mortars and the fact that a mortar was found in most of the ancient village houses, it appears that each household processed a limited volume of spikelets at a time. Pounding emmer spikelets may not have been a daily task, but it must have taken place at short intervals. The archaeobotanical evidence of shredded emmer spikelets around a mortar shows that the aim of pounding was not to crush the grain, as has frequently been supposed (e.g. Sist 1987:55-56; Wilson 1988:12-14), but to free the grain from the tough glumes.

Storage in the spikelet, even in dry climates, makes sense. The tough chaff helps protect grain from insect attack. It may also allow longer viability.

In the Near East today, where most relevant ethnographic work has been done, there are few good analogies to dehusking with a mortar and pestle. This makes comparison with pre-Classical times problematic, for only mortar and pestle and saddle quern technology were available then. Mortar and pestle dehusking of hulled wheats in Europe and of other cereals such as millet and sorghum in sub-Saharan Africa still takes place, but this has not been recorded in the detail required to interpret the archaeological record. Gordon Hillman (1984b) discusses the available evidence for dehusking at length, and points out that traditional dehusking of rice in Turkey today is perhaps the closest Near Eastern parallel.

Processing experiments

The archaeological evidence has provided information about ancient Egyptian tools and their function. Ethnographic analogy gives some indication of how they must have been used. Experimentation brings these two strands of evidence together. Experiments can test whether a proposed sequence of actions with a given set of tools will work, and if not, why not. They can highlight gaps or indeed fill them. A number of people have carried out experiments on hulled wheat processing, mostly based on European data. The advantage of experimentation based on ancient Egyptian evidence is that robust ancient stone tools could be used, and the results checked against the archaeobotanical assemblage. In all published experiments of hulled wheat processing based on ethnographic analogy, pounding, not milling on saddle querns, was the technique applied. To understand ancient Egyptian cereal processing technology, one of us (DS) carried out a series of experiments. When it was not possible to use original ancient Egyptian equipment, replicas closely based on archaeological examples were substituted.

In the first experiments, emmer spikelets were pounded dry in a shallow ancient mortar (Fig. 5). Most of them quickly spilled out. Our observations of debranning grain in Turkey with mortar and pestle, as well as those of Hillman (1984b:135-136), were that the workers first sprinkle a little water on the grain before pounding.

Slightly dampening emmer spikelets before pounding in the mortar has two effects on the spikelets. It allows the spikelets to stick slightly and thus to rub against each other. The glumes and light chaff are then stripped from the rachis internodes, freeing the grain which mostly stays intact. Secondly, water softens the chaff and makes it pliable, so that whole grains often pop out of the unshattered spikelet. The experimentally produced chaff assemblage from moist pounded spikelets is very similar to that found around the mortar in the Amarna Workmen's Village, suggesting that this reconstruction is accurate.

The need to dampen spikelets may be related to the shallow mortars. Experimentally dehusking hulled wheat in tall narrow wooden mortars did not require moistening (Bower 1992:238; Meurers-Balke and Lüning 1992:352; Hara Procoupiou, pers. comm.). No experiments have been done to examine the effect of moistening using tall narrow mortars. It would be interesting to know if moistening enhanced the overall breakage of spikelets and decreased the time needed for pounding.

Once the spikelets were either broken up or emptied of grain, the damp mixture of chaff and grain had to be dried. In the hot Egyptian sun this was easily accomplished in a few hours, but excess moisture was probably driven off by artificial warming on colder days or when large quantities were processed. If moistening was used for dehusking in cooler climatic regions outside Egypt, artificial warming was probably required there too. It is at this drying, post-pounding stage that portions of chaff and grain might occasionally have been accidentally exposed to fire and charred, allowing archaeological preservation in non-arid zones. If this were the case, the number of accidents would have been less than those expected had parching been used, since the temperatures required would have been much lower. The method of drying must not normally have used any special installation, since we have already seen how scarce 'corn-drier' constructions are (see **Sources of information: the archaeological record**, above).

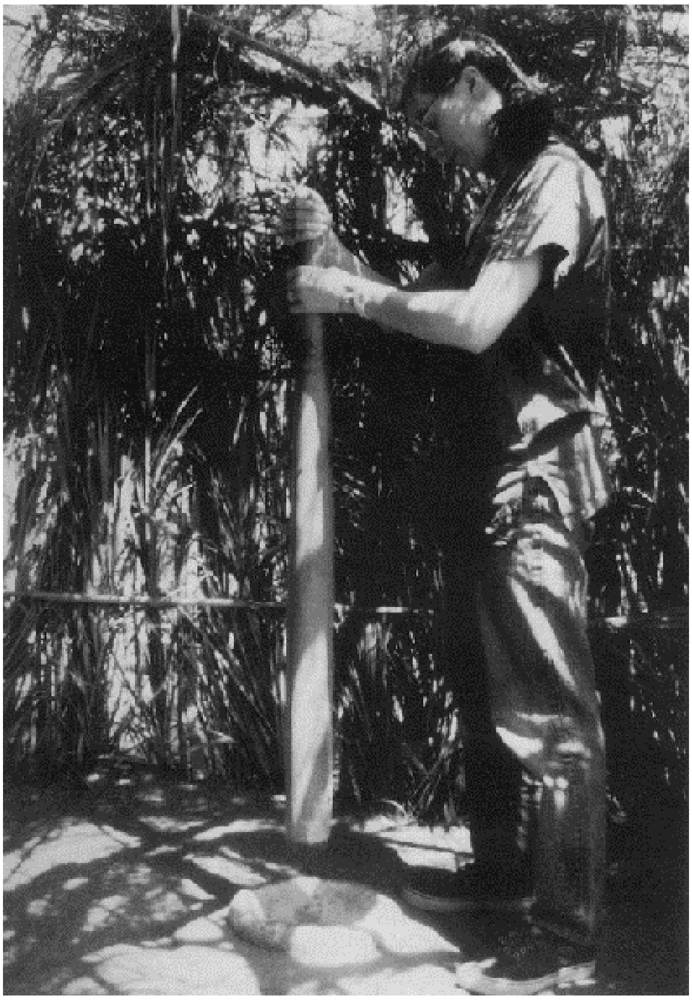


Fig. 5. Experimental reconstruction of ancient Egyptian emmer processing. Slightly moistened emmer spikelets are pounded in an ancient Egyptian limestone mortar. The mortar is set into the ground as are ancient examples. The pestle is a replica, closely based on a wooden pestle found at the Amarna Workmen's village.

The next step is the separation of chaff from grain. Hillman's (1984b) Turkish ethnographic evidence demonstrates that this can be done by a combination of winnowing and sieving. Since replicas of ancient Egyptian sieves and winnowing tools were unavailable, reasonable substitutes were used instead. A grass and palm frond basket made by traditional techniques in a village near Amarna served for winnowing, and a metal sieve with a medium (3 mm) mesh for sieving. Lack of skill and of close replicas for this processing stage led to a relatively large amount of chaff in the cleaned grain. Nevertheless, the experimental work has demonstrated that winnowing and sieving successfully separate chaff and grain. Winnowing and sieving were also used by Bower (1992:238) and Meurers-Balke and Lüning (1992:258) in their experiments although the exact techniques differ.

The combination of archaeological, ethnographic and experimental data shows that if hulled wheats are slightly dampened, they can be dehusked in a shallow mortar with a pestle without crushing the grain. After drying, the chaff is separated out by winnowing and sieving and the clean grain is then ready for further processing (Fig. 6). Variations on this technique must have been used throughout the ancient world prior to the advent of the rotary quern.

Fig. 6. Experimental reconstruction of ancient Egyptian milling. An ancient quartzitic sandstone saddle quern is set into a replica mud brick and mud plaster emplacement, based on archaeological examples. The hand stone is also ancient. The method for catching flour is a modern contingency!

Tool sizes and materials were different: for example, mortars were made of wood in Europe (Meurers-Balke and Lüning 1992:350), but in treeless Egypt limestone was used. Once the rotary mill was invented and mechanization was applied to hulled wheat processing, the range of possible dehusking solutions expanded. Ironically, after well over four millennia of emmer cultivation in Egypt, within about 300 years of the invention of the rotary quern, emmer was hardly cultivated there.

Identification techniques for archaeological remains of hulled wheats

Agronomists and botanists are able to identify present-day wheat taxa using a range of morphological characters, such as spike and glume shape. Where ploidy level is in doubt it can be checked by a chromosome count, while relationships can be checked using chromosome-pairing studies. Identification of archaeological plant remains must overcome two obstacles: the material is dead, and it is usually broken up into small parts. Both of these conditions are linked to the mode of preservation of the plant remains.

Preservation of archaeological plant remains

Plant remains require exceptional conditions to survive being eaten by scavengers or rotting away. Plant remains will be preserved in truly arid conditions such as in the Egyptian desert (Fig. 3), or in permanently waterlogged places, which are common in central Europe. Otherwise, the most frequent means of preservation is charring (Fig. 7). When plant remains – seeds, chaff, tubers, wood among a wide range of materials – come into contact with fire, they may burn to ashes, or they may be charred. Charred plant remains retain their shape and anatomical features and can thus be identified by comparison with modern reference materials. Most archaeological sites are rich in charred plant remains.

Hulled wheats are also represented in archaeological sediments by phytoliths, silica particles that form within plant cells. When the organic portions of silica-rich parts of the plant, such as the glumes, decay, sheets of phytoliths remain. The organization and shape of the cell walls allows identification of the source plant. At present phytolith analysis is in its infancy, and cereal phytolith sheets can only be distinguished to the level of genus (Ball 1992; Kaplan *et al.* 1992; Rosen 1992). The pollen of hulled wheats can not easily be distinguished from pollen of other grasses, particularly in the Near East, and pollen analysis is therefore not a suitable tool for studying the history of hulled wheats (Edwards 1989; Bottema 1992).

Hulled wheat identification criteria

The effects of crop-processing and charring mean that only parts of the hulled wheat spike are usually found: sometimes intact spikelets, more often grain, spikelet forks and glume bases. Spikelet forks and glume bases are produced when the upper parts of the glumes, palea and lemma are removed during crop-processing and/or during charring. When chaff is burnt, the papery parts are destroyed (Boardman and Jones 1990), leaving only the woody rachis segment with the two glume stumps, known as the spikelet fork (Fig. 1).

The development of identification criteria has naturally focused on characters that relate to the parts of the spikelet which normally survive processing and charring. Where whole spikes or spikelets are occasionally preserved, e.g. in the Swiss Lake villages, characters such as the shape of the glume apex can be applied (Jacomet *et al.* 1989). Usually, more subtle characters must be sought in what remains of the spikelet. These primarily relate to the shape and position of the primary and secondary keels and venation on the remains of the glumes. Other characters that can be helpful include the overall shape of spikelet forks, which are generally more gracefully curved in einkorn than in emmer and spelt (compare Fig. 8a with 8c and 8d), and the position of the rachis segment as an aid to distinguishing spelt from emmer. In emmer, spikelets usually disarticulate in 'wedge' fashion, with the rachis segment pointing down (as in Fig. 1a), while spelt spikelets sometimes disarticulate in 'barrel' style, with the upper rachis segment pressed against the lower spikelet (Fig. 7). This character is inherited from one parent of spelt, *Aegilops* *tauschii*. However, spikelets from modern populations of both emmer and spelt can break either way, so this is not a dependable character on its own.

Not all criteria work effectively across all regions or periods. For example, in prehistoric Europe the primary keel is strong in einkorn and weak in emmer and is a useful identification criterion, while in Near Eastern and Spanish material the primary keel is equally prominent for both taxa. Another example of a regional characteristic is the exceptionally heavily veined glumes of ancient emmer spikelets in the Near East and Spain (de Moulins 1993:197-198, Fig. 1.3). It is possible that the distribution of such characters will eventually give us insights into the spread of the hulled wheats into Europe.

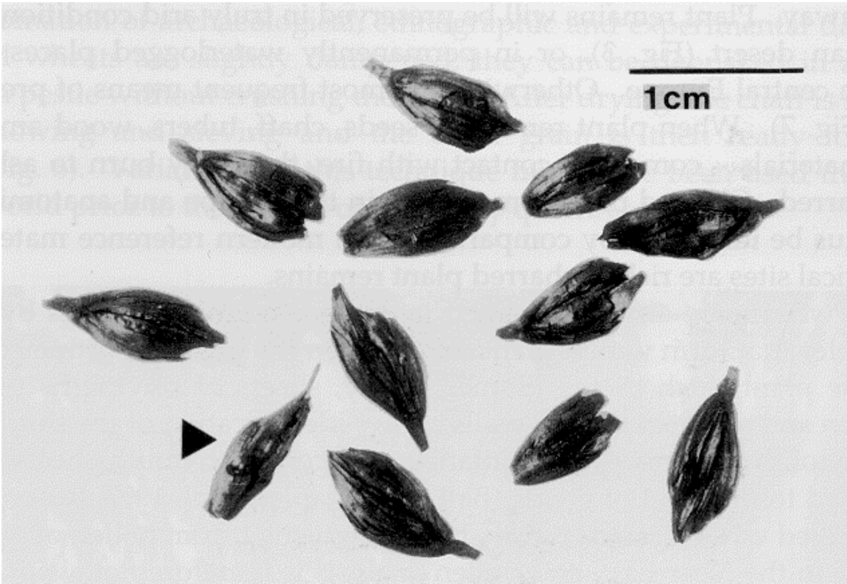


Fig. 7. Whole charred spikelets from an Iron Age pit (mid-1st millennium BC) at Wandlebury, Cambridgeshire, England, courtesy of Chris Stevens. The majority of spikelets recovered from this assemblage are emmer, but a few are spelt, such as that marked by the arrow with its barrel-type breakage. The different breakage patterns of the rachis internode, although distinctive, are not always an accurate guide to identification.

Quantitative characters are often useful; these include the width of the glume in lateral view and the relative width of the upper disarticulation scar, calculated as scar width divided by spikelet width (at scar level) (Helbaek 1970). Ideally, spikelet remains can first be separated using qualitative characters, and then plotted according to the quantitative characters. When the two methods match, this is good support for the separated groups being different (Nesbitt 1993).

Grains present us with much greater difficulties. This is partly because their morphology is more affected by charring; in part because their rounded shape makes it more difficult to identify or describe distinctive differences between taxa; but mainly because there is considerable overlap in form (Fig. 9). For example, einkorn spikelets contain one highly distinctive grain, which is laterally compressed with a spindle shape in dorsal view. However, the terminal spikelet of two-grained emmer usually contains only one grain, which is shaped like an einkorn grain. To confuse matters further, two-grained einkorn – a rare form today – appears to have been more common in the past. The distinction between emmer and spelt grains is particularly problematic, and there is disagreement as to how reliable these identifications are. Fortunately chaff remains are usually found alongside hulled wheat grains, and these offer a valuable cross-check on identifications. Significant differences in surface cell patterns in both chaff and grain have been identified, but as yet these are little used by archaeobotanists working with charred grain (Hopf 1954; Körber-Grohne 1981).

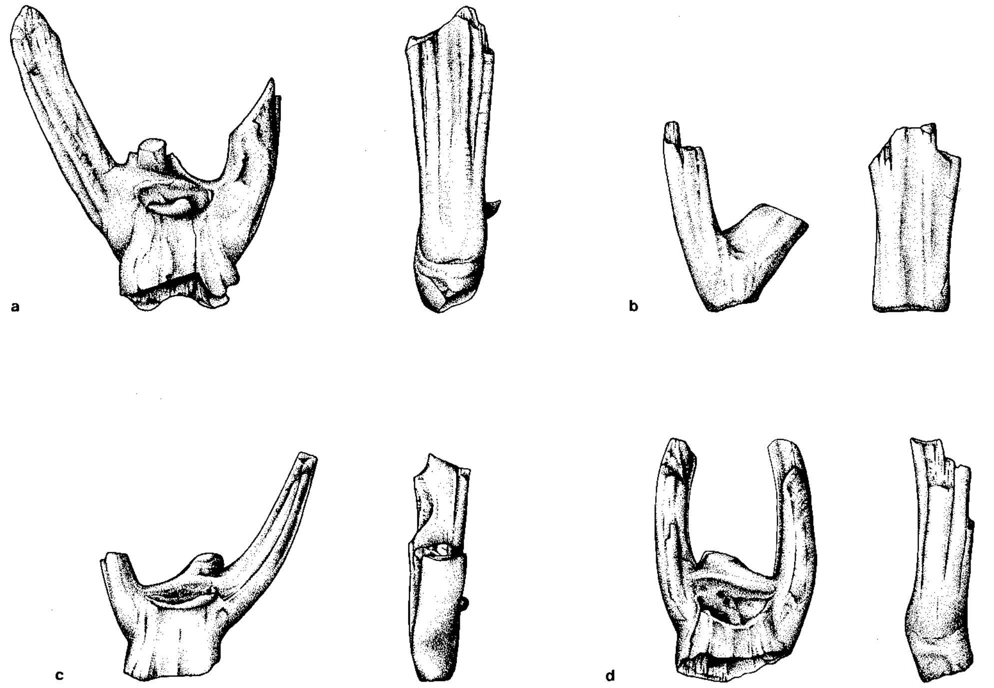
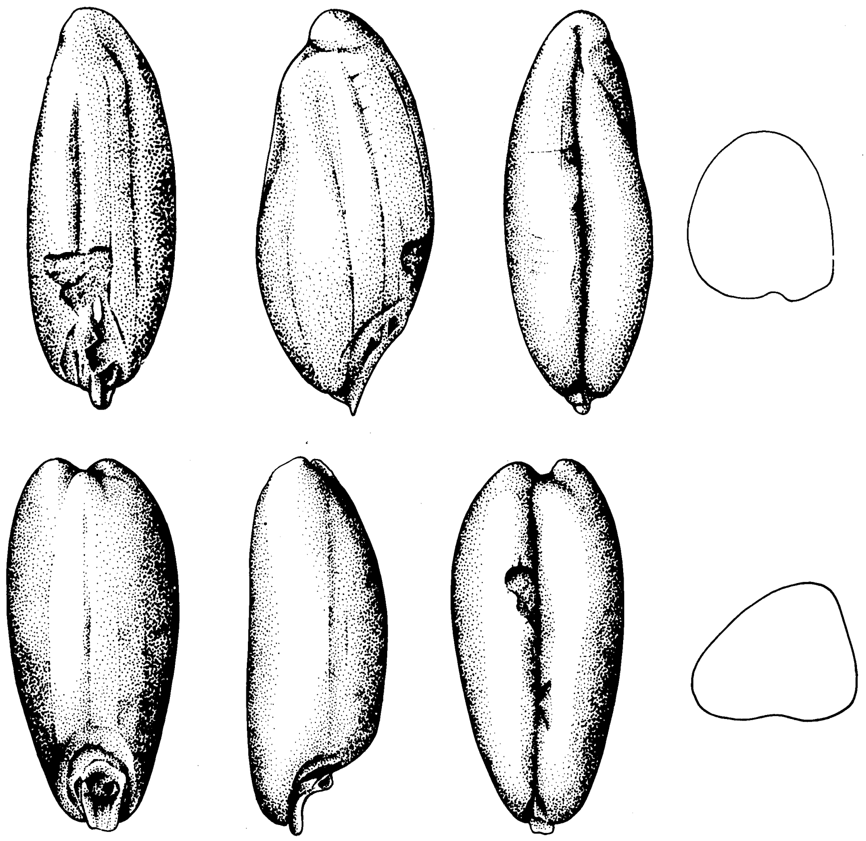


Fig. 8. Charred hulled wheat chaff from Çayböyü, Turkey, dating to the Late Chalcolithic period (4th millennium BC). (a) Normal emmer spikelet fork, which originally came from the middle of the ear. (b) Terminal emmer spikelet fork - originally from the top of the ear. (c) Normal einkorn spikelet fork, with spreading glume bases. (d) Normal einkorn spikelet fork, with parallel glume bases.

There is some agreement among archaeobotanists that well-preserved assemblages of spikelets or spikelet-forks and glume-bases can be reliably separated into einkorn, emmer and spelt. This does involve the assumption that the morphological groups we identify in ancient material match modern taxa. This is undoubtedly true in general terms: current-day einkorn, emmer and spelt can be distinguished from each other by the same character combinations which work on ancient material. However, archaeobotanists would not argue for complete similarity between modern einkorns and ancient einkorn. Our ancient einkorn remains do belong to a hulled diploid wheat, but that does not necessarily imply that they all share ecological characteristics with their modern counterparts. Also, forms of wheat may have existed in the past that are extinct today.



a

b

Fig. 9. Charred hulled wheat grains from Çayböyü, Turkey dating to the Late Chalcolithic period (4th millennium BC). The grains show the longitudinal grooves typical of hulled wheats, caused by the tightly investing chaff.
a. Einkorn grain, with the typical spindle shape, pointed apex and pronounced ventral convex curve visible in the middle view.
b. Emmer grain, with a blunter apex and straighter sides in all views. Note the typical asymmetric triangular cross-section.

Identification conclusions

Identification of archaeological wheat remains was discussed at a meeting of 25 archaeobotanists in London in 1992 and the published account is a useful source of more details (Hillman *et al.* 1996). In summary, the reader of archaeobotanical reports should bear in mind three points:

1. All identifications should be critically examined. Identification criteria should be presented in detail and backed up by illustrations. Poorly documented identifications should be treated with even greater caution, and the older literature must always be used with care. Identifications of charred material are not absolute and even desiccated material can be problematic.
2. Glume wheat chaff can, if abundant and well preserved, be identified with greater certainty than grain.
3. Identifications of hulled wheat remains can be identified with some certainty to ploidy level, but the use of terms such as einkorn, emmer or spelt does not imply full equivalency with current-day taxa.

Future prospects for ancient hulled wheat identification

Is there any way that we can check the results of morphological identification criteria using the genotype? Recent work has shown that charring apparently allows – or even promotes – the survival of organic molecules within wheat grains. DNA fragments have been recovered from 2000-year-old Iron Age spelt grains from Danebury, England (Brown *et al.* 1994). Lipids also survive in charred grain (Evershed 1993). Comparison of spectra from ancient and modern grains obtained by infra-red spectroscopy and gas chromatography mass spectrometry suggests that this may be a powerful tool for identification (Hillman *et al.* 1993). Both techniques are in their infancy and need further development and replication in different laboratories before they are widely applied. They are expensive and technically complex techniques; their role will be to confirm the results of morphological criteria rather than to replace them.

Domestication

The hulled wheats will be discussed as two groups. Einkorn and emmer were domesticated from wild ancestors growing in the Near East. These wild ancestors have been identified and much studied, and the area and time of domestication have been established with certainty. Spelt wheat, on the other hand, results from a hybridization that appears to have taken place after the origins of agriculture, under cultivation. It has no single wild ancestor, and the area and date of its domestication are still unclear.

Botanical evidence for domestication of einkorn and emmer

Identification of the wild ancestors

Einkorn

Today wild einkorn and wild emmer seem obvious candidates as wild ancestors of, respectively, einkorn and emmer wheat, because of their morphological similarity and ability to intercross. However, this has only been apparent for a hundred years or so, after a series of botanical discoveries whose history is discussed by Aaronsohn (1910), Schiemann (1956) and Feldman (1977). Wild einkorn (*Triticum boeoticum*) was discovered in Greece and Turkey in the mid-19th century, and by 1900 was widely accepted as the ancestor of domesticated einkorn wheat.

Triticum urartu, the second diploid wild wheat, was named in 1938 by the Armenian botanist, Tumanian. It grows throughout the Fertile Crescent as a minor admixture of *T. boeoticum* on outcrops of basaltic soil (Waines *et al.* 1993). Unlike *T. boeoticum*, it has not spread outside the Fertile Crescent as a weed of disturbed ground. It is morphologically similar to *T. boeoticum*, but *T. urartu* can be consistently distinguished on the basis of anther length, the presence of a third lemma awn and caryopsis colour (Johnson 1975:33-34; Morrison 1993; Waines and Barnhart 1990). Crosses between the two taxa result in sterile hybrids. Overall the evidence points to *T. urartu* as a separate species.

T. urartu is not a candidate species as a wild ancestor for domesticated einkorn (Jaaska 1993; Waines and Barnhart 1990), but may be a parent of *T. dicoccoides* (Dvorak *et al.* 1988).

Emmer

The wild ancestor of emmer was not identified until 1873, when Körnicke found part of a spike of *T. dicoccoides* in a collection of wild barley, *Hordeum spontaneum*, made on Mount Hermon in southern Syria. However, it was Aaron Aaronsohn's discovery from 1906 onwards of abundant wild emmer in Israel that led to general acceptance of its role as the wild ancestor of emmer. Two morphologically distinct forms of *T. dicoccoides* have been recognized (Poyarkova 1988; Poyarkova and Gerechter-Amitai 1991), a narrow-eared, gracile form native to the whole range of wild emmer, and a wide-eared, robust form of more restricted distribution. Although both forms are found in weedy habitats such as roadsides, both mostly grow in primary, undisturbed habitats. Unlike wild einkorn and barley, wild emmer has conspicuously failed to spread outside the Fertile Crescent. Its current distribution is therefore believed to be more representative of its early Holocene distribution than that of the other wild cereals.

As with wild einkorn, wild emmer consists of two morphologically similar but reproductively isolated tetraploid species, *T. dicoccoides* and *T. araraticum*, the latter first recognized in the 1930s and named by Jakubziner in 1947. *T. araraticum* has been identified as the wild ancestor of *T. timopheevi*, a rare domesticated glume wheat found in Georgia.

Distribution of wild ancestors at the time of domestication

Once the wild ancestors of einkorn and emmer had been identified, it became clear that the domesticates would most likely have been taken into domestication in the same area where the wild ancestors grew. We have two main sources of information for the distribution of wild cereals during the period of domestication around 10 000 years ago: the current distribution of wild cereals, and archaeobotanical finds of wild cereals from pre-agrarian sites. In this section evidence from the current distribution will be discussed, while archaeobotanical finds are considered further on.

Given the relatively slight changes in climate over the last 10 000 years, human activities have had the most impact on the distribution of wild cereals in the Holocene. On the one hand, populations of wild cereals have been reduced owing to the impact of deforestation, grazing and the spread of farming on their habitats. Archaeobotanical evidence for the distribution of wild einkorn, discussed below, suggests that the wild wheats may have grown up to 100 km beyond their current range, into the heavily grazed north Syrian steppe. On the other hand, the creation of extensive areas of disturbed habitats – especially fields and field edges – has created opportunities for some wild species to spread with the domesticates.

Harlan and Zohary (1966) established a widely used distinction between primary, relatively undisturbed habitats, and secondary, ruderal or segetal habitats. Areas in which a wild cereal only grows in secondary habitats – for example on roadsides or field edges – are likely to be areas to which it spread as a weed rather than where it grows as a truly wild plant. Given the degree to which humans have used and disturbed virtually every bit of land in southwest Asia, the distinction between primary and secondary occurrences is not always easy to put into practice. Wild emmer is reasonably straightforward: it is not weedy and has not spread outside the Fertile Crescent of hills surrounding the steppe and deserts of Mesopotamia. Wild einkorn grows over a much wider area, and some problems in establishing its primary habitat are discussed below.

Einkorn

Wild einkorn is widespread, growing from the Balkans to Iran (Zohary and Hopf 1993:32-38) in weedy habitats such as roadsides and field edges. Its primary distribution is in areas of oak park-forest and steppe in the northern and eastern parts of the Fertile Crescent, in an arc stretching from northern Syria through southeast Turkey, northern Iraq and western Iran (Fig. 10). Zohary and Hopf (1993:34) suggest that einkorn also grows in primary habitats on the central Anatolian plateau. In our experience wild einkorn in this area is almost exclusively a weed of roadsides and disturbed places, with the exception of a small population discovered in the 1970s by Gordon Hillman on the scree of Karadag, a volcanic mountain on the Konya plain (Hillman and Davies 1990:160). Otherwise, wild einkorn is conspicuously absent from the kind of oak forest or scree habitats in which it thrives in southeast Turkey.

As well as excluding central Turkey from the area of primary distribution, we would perhaps include southern Lebanon. Aaron Aaronsohn found both wild einkorn and wild emmer growing together in truly wild habitats on Mount Hermon in 1907 (Aaronsohn 1910:43-44). The recent discovery of *T. boeoticum* and *T. urartu* in southwest Syria also suggest that the einkorn is native to the western part of the Fertile Crescent (Rifaie *et al.* 1981). However, it is true that stands of *T. boeoticum* and *T. urartu* are sparser and much more scattered than further north (van Slageren *et al.* 1989). Both species are abundant in parts of Armenia and may well grow in primary habitats there (Tumanyan 1929-1930). Unlike *T. boeoticum, T. urartu* seems to be restricted to more or less primary habitats and has not spread into western Turkey or the Balkans. Its presence with *T. boeoticum* on Mount Hermon and in Armenia strengthens the case that these areas are within the primary distribution of wild einkorn.

Emmer

Johnson's (1975) large-scale study of tetraploid wild wheats pointed to a clear division between the distribution of *T. dicoccoides* in the Levant and southeast Turkey, and *T. araraticum* in northern Iraq and the Zagros mountains of Iran. Other studies have shown that although all the Levantine wild wheats are the *T. dicoccoides* form, both *T. araraticum* and *T. dicoccoides* are common in southeast Turkey, while there are occasional populations *of T. dicoccoides* among the predominantly *T. araraticum* wheats of northern Iraq and the Zagros mountains (Tanaka and Ishii 1973), and reflected in Zohary and Hopf's map (1993:41). *T. araraticum* also grows in Transcaucasia. As weedy forms of wild emmer do not exist, all these locations probably form part of the primary distribution. Figure 10 shows the Levantine populations of pure *T. dicoccoides* separately from the mixed areas of *T. araraticum* and *T. dicoccoides* elsewhere in the Fertile Crescent.

Defining the area of origin

Wild einkorn grows most abundantly in the northern and eastern parts of the Fertile Crescent. Its presence in central or western Anatolia cannot be ruled out, but archaeological evidence points to the Fertile Crescent proper as the area of domestication. Although wild einkorn grows rather sporadically in the Levant (in northern Israel and Jordan, and neighbouring areas) it may have been more abundant 10 000 years ago.

It seems likely that there has been no substantial change in distribution of wild emmer since the beginnings of farming. It must have been taken into cultivation somewhere in the Fertile Crescent. The absence of the *timopheevi* type of tetraploid hulled wheat from any population outside Transcaucasia today strongly suggests that the emmer species that spread with the first agriculture was pure *T. dicoccum*. However, we should not deduce from this that emmer was necessarily domesticated in the area where only *T. dicoccoides* grows, the Levant. Although both

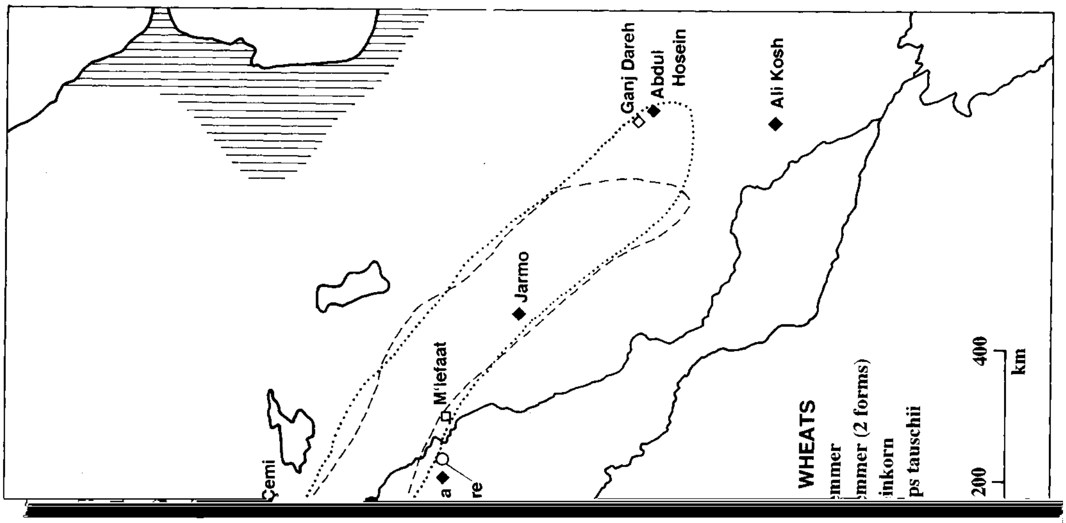

Ganj Dareh
Abdul Hosein
Ali Kosh
Jarmo
M'lefaat
WHEATS
200
400
km

Fig. 10. Distribution of archaeological sites in relation to the distribution of wild wheats. Only those Epipalaeolithic and Neolithic sites dating to before 6000 BC with available archaeobotanical reports are shown. Solid symbols indicate definite evidence of domestication; empty symbols indicate sites that are non-agrarian or of uncertain status. Full details are given in Table 2. Distribution of wild wheats in primary, truly wild, habitats is shown, but small populations of wild einkorn on Mount Hermon in southern Lebanon and of wild einkorn and emmer in Transcaucasia are not shown. Note that wild emmer in the Levant consists of pure *T. dicoccoides*; in the northern Fertile Crescent both *T. dicoccoides* and *T. araraticum* are present (indicated by the dashed line). The western extension of primary habitats of *Aegilops tauschii* is shown, around the Caspian sea.

T. araraticum and *T. dicoccoides* grow in southeast Turkey and northern Iraq, populations in this area often consist of just one species and the initial domestication episode could therefore have occurred anywhere throughout the Fertile Crescent.

A number of attempts have been made to narrow the geographical area of domestication; van Zeist and Bakker-Heeres (1982:190-191) suggested that domesticated einkorn, because it usually has one-grained spikelets, must have originated in the area where wild einkorn is primarily one-grained. This is in western Anatolia, rather than in the Fertile Crescent where wild einkorn is primarily two-grained. However, this does not fit well with the archaeological evidence showing that agricultural villages seem to appear later in western Anatolia than in the Fertile Crescent. The comparative rarity in the past and present of two-grained forms of domesticated einkorn strongly suggests that one-grained forms have adaptive value. They could thus have evolved very rapidly from the two-grained wild einkorn. In any case, in two-grained forms of wild einkorn, the lower spikelets are invariably one-grained. Intriguingly, the few ancient finds of two-grained domesticated einkorn are in Greece and surrounding areas (van Zeist and Bottema 1971; Kroll 1992) rather than in the Fertile Crescent.

The area surrounding the Jordan valley is often pinpointed as the location of the first domestication, doubtless in part because of the massive stands of wild emmer that surround Lake Galilee (McCorriston and Hole 1991). While this is a possible location for domestication of emmer, it is not the only possibility, and is an unlikely area for the domestication of einkorn. If anything, southeast Turkey is the area in which wild einkorn and wild emmer both overlap. Without new evidence, trying to narrow down the origins of agriculture to a specific region within the Near East is not possible.

The effects of domestication on einkorn and emmer

What differences did domestication make to the cereals? The main difference is between the fully brittle rachis of wild wheats and the semi-brittle hulled rachis of hulled wheats. Instead of disarticulating at maturity, the spikes of domesticated wheats stay intact and must be broken up by threshing. This is not a trivial difference. Experimental work suggests that at best 80% of a wild cereal can be harvested, with a more typical figure of around 50% depending on harvesting method (Hillman and Davies 1990:182-184); this contrasts with nearly 100% of a domesticated hulled wheat.

Domestication also involves other changes. Grain size increases markedly, but as yield is as much a function of spikelet number, we cannot be certain this led to a change in overall yield. Larger seeds could reduce the effort needed for dehusking, and would lead to larger seedlings that would be more competitive with weeds. A number of other physiological adaptations to higher yield have been noted in domesticated wheats: increased phloem area and leaf area, and changes in the timing of photosynthesis and transport of assimilates within the plant (Bamakhramah *et al.* 1984; Dunstone and Evans 1974; Evans 1976, 1993; Evans *et al.* 1970; Evans and Dunstone 1970). We cannot be certain to what extent these changes occurred as part of the first process of domestication, or are the result of thousands of years of conscious or unconscious selection.

Archaeobotanical evidence for domestication of einkorn and emmer

Identifying domestication of hulled wheats

When hulled wheats were first cultivated, they would have retained their wild morphology. However, controlled harvest and sowing of a wild plant by humans opens the possibility of strong selective pressures. Hillman and Davies (1990) have modeled wild cereal cultivation and have shown that under certain conditions a morphologically fully domesticated crop could be created in 25 years. Certain methods of harvesting in particular, such as cutting by sickle, would favour the mutated forms with tough-rachised spikes. An experiment in cultivation and harvesting of wild einkorn is currently underway in southern France to test this hypothesis (Anderson 1992; Anderson-Gerfaud *et al.* 1991; Willcox 1992). One implication of this for archaeobotany is that we are unlikely to find a site where domestication is in progress; the event may have taken place too quickly.

The characters used to identify full morphological domestication are rachis toughness and grain size. Because wild spikes disarticulate and disperse their spikelets as they mature, the disarticulation scars are smooth and untorn. In contrast, the tough rachis of domesticated hulled wheats requires threshing to break up spikelets. At agricultural sites virtually all the scars are roughly torn. However, as Mordechai Kislev and Gordon Hillman have pointed out, not all wild spikes will disarticulate freely, particularly if they are from the basal part of the ear or threshed soon after harvesting slightly under-ripe ears (Hillman and Davies 1992:157-158; Kislev 1992; cf. Zohary 1992:85). Thus a small proportion (<10%) of torn rachis nodes does not imply domestication.

Both einkorn and emmer show a marked increase in grain size with domestication, but these differences are not always easily observed on early Neolithic plant remains which are usually in poor condition. Archaeobotanists do consider the presence of reasonable quantities of free-threshing wheat grains as a good indicator of domestication because there are no wild free-threshing wheats. However, free-threshing wheats do not appear until around 7000 bc and are therefore not a useful indicator of agricultural communities for the earliest agricultural sites, dating to about 8000 bc.

Archaeobotanical remains of einkorn and emmer

Traditionally, the period around the origins of agriculture has been divided into three: the Epipalaeolithic (ca. 16 000-8000 bc), the Pre-Pottery Neolithic A (ca. 8000-7600 bc), and the Pre-Pottery Neolithic B (ca. 7600-6000 bc). The Epipalaeolithic – equivalent to the Mesolithic of Europe – is generally thought of as a pre-agrarian hunter-gatherer era, while the Neolithic marks the beginning of agricultural societies.

Plant remains from Epipalaeolithic and Neolithic sites (pre-6000 bc) are listed in Table 2. The heavy line separates sites thought to be hunter-gatherer from those thought to be agricultural. At the earlier sites the plant remains represent wild taxa.

Only three of these have produced definite hulled wheat remains: Ohalo II, Abu Hureyra and Mureybit. At Ohalo II, an Israeli site dating to 17 000 bc, 22 grains and nine spikelet forks of *T. dicoccoides* have been reported (Kislev *et al.* 1992). Of the barley rachis segments (n=30), four were of torn, non-brittle type. This conforms well to experimental results on threshing wild cereals.

At Abu Hureyra and Mureybit less information is available on the morphology of the rachis segments, but the wheat grains are consistent with wild einkorn morphology. Overall, the plant remains appear wild. The question has arisen whether wild cereals are being cultivated – but at a point before morphological domestication – or are being collected.

At present we have no definite answer to this question, although Hillman *et al.* (1989) concluded from the association of perennial species that the Abu Hureyra grain was probably collected from the wild. Both Abu Hureyra and Mureybit lie around 100 km south of the current-day distribution of wild einkorn, leading to suggestions that it must either have been cultivated or carried in. However, the latest reports on both sites stress how little is known about the past distribution of wild cereals. The presence of wild einkorn at these sites is in fact likely evidence for a more extensive distribution in the past. In view of the arid nature of the north Syrian steppe, it would be no surprise if wild einkorn has disappeared from the area under current grazing pressures.

There are real difficulties in identifying the earliest agricultural sites. First, there are problems with dating: sites such as Jericho, Ali Kosh and Ganj Dareh, once thought to date to soon after 8000 bc, have been re-dated as much as 500 years later after critical analysis of their radiocarbon dates. Dating is still often controversial and more dates made on seed remains would be highly desirable. Second, there is the problem of deciding whether the plant remains belong to an agricultural assemblage: are the remains of morphologically domesticated crops present? Mordechai Kislev (1989, 1992) has argued that reliable identification of domesticated crops in early assemblages can only be made on the basis of the proportion of torn ('domesticated-type') rachis scars in the wild cereals. Grain shape is very ambiguous at this period.

Increasingly, archaeobotanists agree with this view: sites such as Ganj Dareh and the PPNA level of Jericho lack any definite evidence of domestication, either because the plant remains are very few, or because although abundant, they are not distinctive. At Jericho a grand total of three rachis segments and less than 20 grains of cereals were recovered from the PPNA levels (Hopf 1983); at Ganj Dareh several hundred barley grains were collected, but few rachis segments and no wheat remains (van Zeist *et al.* 1986). Grains from wild and domesticated barley are very similar in appearance and thus not diagnostic. The earliest plant remains from Tell Aswad (phase I) are similarly undiagnostic. Plant remains are few because of the failure to apply large-scale flotation techniques at these sites, in contrast to the major efforts at seed recovery made at sites such as Abu Hureyra and Franchthi Cave.

In Table 2 we have indicated which sites seem to be definitely agricultural. The earliest of these are the Neolithic level of Abu Hureyra in northern Syria, and Cafer Höyük in southeast Turkey. At this and other sites details of rachis disarticulation are scarce, but large domesticated-type grains are abundant and agriculture is a reasonable assumption. The need to be cautious is illustrated by the case of Netiv Hagdud, where the presence of 10% domesticated-type rachis scars on the barley rachis segments was at first interpreted as evidence for domesticated barley (Kislev *et al.* 1986).

Table. 2. Plant remains from pre-pottery archaeological sites in the Near East. Note that sites dating to before 7800 BC are apparently pre-agricultural; definite remains of domesticated plants are present at many (but not all) sites from 7800 BC onwards.

Site (phase)	Period	Uncalibrated radioc. dates (bc)	Status	Wild einkorn	Dom. einkorn	Wild emmer	Dom. emmer	Dom. rye	Naked wheat	Hulled barley	Pea	Lentil	Bitter vetch	Source
Ohalo II	Epipal.	17 000	Wild			+				+		+		1
Wadi Hammeh 27	Epipal.	8200-7900	Wild							?		?		2
Hayonim Cave	Epipal.	10300-9000	Wild							+				3
Abu Hureyra	Epipal.	9500-8000	Wild	+								+	+	4
Hallan Cemi	PPN	8600-7900	Wild									+	+	5
Mureybit (I-III)	Epipal.	8500-7600	Wild	+						+	+	+	+	6
Qermez Dere	PPN	8100-7600	Wild							+		+	+	7
Netiv Hagdud	PPNA	8000-7400	Wild							+		+		8
M'lefaat	PPN	7900-7700	Wild	?						+		+	+	9
Tell Aswad (I)	PPN	7800-7300	?				+			+	+	+	+	10
Abu Hureyra	PPN	7700-5000	Agric.		+		+	+		+				4
Cafer Höyük	PPNB	7600-6200	Agric.	+	+		+			+	+	+	+	11
Jericho	PPNA	7400	?				+			+		+		12
Çayönü	PPN	7500-6700	Agric.	+	+	?	+			+	+	+	+	13
Jericho	PPNB	7200-6800	Agric.		+	?	+			+	+	+		12
Nahal Hemar	PPNB	7200-6000	Agric.				+			+		+		14
Nevali Çori	PPNB	7200	Agric.		+		+			+	+	+		15
'Ain Ghazal	PPNB	7250-6500	Agric.				?			+	+	+		16
Ganj Dareh	PPN	?7000-6600	?							+		+		17
Gritille	PPN	7000-6000	Agric.				+			+		+	+	18
Magzalia	PPN	6600-6000	Agric.		+		+		?	+		+		19
Ghoraife	PPN	6900-6100	Agric.		+		+		+	+	+	+	+	20
Hacilar	PPN	6900-6500	Agric.	?			+			+		+		21
Tell Aswad (II)	PPN	6900-6600	Agric.		+		+		+	+	+	+		10
Jilat 7	PPNB	6800-6500	Agric.	+	+		+		+	+		+	?	22
Yiftah'el	PPNB	6800	Agric.									+	+	23
Beidha	PPNB	6750	Agric.				+			+				24
Can Hasan III	PPN	6600-5800	Agric.	+	+		+	+	+	+		+	+	25

Site (phase)	Period	Uncalibrated radioc. dates (bc)	Status	Wild einkorn	Dom. einkorn	Wild emmer	Dom. emmer	Dom. rye	Naked wheat	Hulled barley	Pea	Lentil	Bitter vetch	Source
Abdul Hosein	PPN	6500	Agric.				+			+		+		26
Ras Shamra (Vc)	PPN	6500-6000	Agric.				+			+	+	+		27
Ali Kosh (BM)	PPN	?6400-6000	Agric.		+		+			+				28
Jarmo	PPN	?6400	Agric.	+		+	+			+				29
Azraq 31	PPN	6350	Agric.						+	+				30
El Kowm (A)	PPN	6300-6100	Agric.				+		+	+	?			31
Tell Bouqras	PN	6350-5850	Agric.	+	+		+		+	+	+	+		32
Tell Ramad (I)	PPNB	6350-6100	Agric.	+	+		+			+	+	+	+	33
Basta	PPNB	6200	Agric.				+			+	+			34
Tell Ramad (II)	PPNB	6100-5800	Agric.	+	+		+		+	+	+	+	+	35

Sources: 1. Kislev *et al.* 1992; 2. Potts *et al.* 1985; 3. Hopf and Bar-Yosef 1987; 4. Hillman *et al.* 1989; 5. Rosenberg *et al.* 1995; 6. van Zeist and Bakker-Heeres 1984b; 7. Nesbitt 1995a, Watkins *et al.* 1991; 8. Bar-Yosef *et al.* 1991, Kislev *et al.* 1986; 9. Nesbitt 1996a; 10. van Zeist and Bakker-Heeres 1982; 11. de Moulins 1993; 12. Hopf 1983; 13. van Zeist and de Roller 1991/1992; 14. Kislev 1988; 15. Rainer Pasternak (pers. comm.); 16. Rollefson *et al.* 1985; 17. van Zeist *et al.* 1986; 18. Voigt 1984; 19. Lisicyna 1983; 20. van Zeist and Bakker-Heeres 1982; 21. Helbaek 1970; 22. Garrard *et al.* 1994; 23. Garfinkel *et al.* 1988; 24. Helbaek 1966; 25. French *et al.* 1972, Hillman 1978; 26. Hubbard 1990; 27. van Zeist and Bakker-Heeres 1984a; 28. Helbaek 1969; 29. Helbaek 1959a, 1959b; 30. Garrard *et al.* 1988; 31. van Zeist 1986; 32. van Zeist and Rooijen 1985; 33. van Zeist and Bakker-Heeres 1982; 34. Gebel *et al.* 1988; 35. van Zeist and Bakker-Heeres 1982.

Kislev (1989, 1992) now suggests that this is consistent with the similar percentage of torn rachis scars found in experimental harvests of wild barley. This hypothesis is confirmed by the 13% of domesticated-type rachises found at Ohalo II, dating to 17 000 bc, for which no-one would claim domesticated status.

What is the overall archaeobotanical evidence for the distribution of wild wheats? The remains of wild wheat from Epipalaeolithic sites are still too scattered to throw much light on their distribution, although the Ohalo II wild emmer is welcome confirmation of its presence in the Levant during the last glacial. The absence of any wild wheat so far from Hallan Çemi, sited in the middle of oak forest in southeast Turkey, is surprising, but the plant remains are still under study. We have hints from the presence of wild einkorn at Abu Hureyra and Mureybit that it may have spread further south into Syria than it does today. Although elaborate models have been constructed for the increasing use of wild cereals as a food during the Levantine Epipalaeolithic (Henry 1989), these have not been tested by careful recovery of plant remains from excavations in the region.

Archaeobotanists are becoming more cautious in identifying agriculture. Nevertheless, sites such as Neolithic Abu Hureyra, Cafer Höyük and Çayönü do establish the farming of domesticated einkorn, emmer and barley by 7800-7500 bc. This is broadly in line with the widely used figure of 8000 BC for the origins of agriculture. The concentration of the earliest agricultural sites in and near the Fertile Crescent confirms that einkorn and emmer were first domesticated in this area, at much the same time as barley, pea, lentil and bitter vetch.

It is important to realize just how few sites are represented by plant remains prior to 7000 bc. In view of the small sample size – just seven sites with definite agriculture – we think that any attempt at narrowing down the origins of agriculture within the Fertile Crescent is unwise. There is no evidence that one of the hulled wheats or barley was domesticated before the others, or that domestication took place in one area rather than another. More Neolithic sites are known from the Levant than any other area, but this simply reflects an extraordinary concentration of archaeological work in Israel, Jordan and Syria. Turkey and Iraq are still poorly known, while archaeological fieldwork ended in Iran in 1979. Some authors have argued strongly that agriculture began in the Jordan valley (McCorriston and Hole 1991; Smith 1995), but neither the evidence of the wild ancestors nor archaeobotany allow this conclusion at this stage. Not only is the botanical evidence from early sites scanty, but re-evaluation of evidence for early agriculture suggests that the earliest definite evidence of plant domestication is as much present in northern Syria and southeast Turkey as in Israel and Jordan.

The Near East as the cradle of agriculture

Archaeology has played a vital role in identifying the Fertile Crescent as the area in which wheat, barley and other key Old World crop plants were domesticated. This evidence for the earliest agriculture has been in two forms: evidence for the earliest domesticated cereals, and more generally, for the presence of the earliest farming villages.

If we take 8000-7800 BC as representing the point at which domesticated plants appear, the widespread occurrence of farming sites by 7000 BC points to a rapid spread of agriculture within the Fertile Crescent. Obviously the increased productivity of cultivated land stimulated much of this rapid spread. Not only were yields increased compared with stands, but cultivation could expand into new areas.

In contrast, farming villages do not appear in Egypt, Transcaucasia, the Balkans or Central Asia before 6000 bc. The domesticated crops and animals which appear in these areas are the same as those at early Near Eastern sites. The evidence of relative dating and of a common agricultural basis fits well with a model of agriculture spreading from the Near East. It has often been argued that modern-day distribution of wild cereals may not be an accurate guide to distribution prior to the millennia of massive ecological changes caused by human farming (e.g. Barker 1985:250-256; Dennell 1985:152-168). However, there is no archaeobotanical or botanical evidence for wild einkorn or wild emmer in the Balkans or central Asia, and the archaeobotanical and archaeological evidence clearly shows that the first farming cultures developed in the core Near Eastern area. Although the wild wheats do seem to be native to Transcaucasia, the dating of its earliest farming settlements is also much later than in the Fertile Crescent.

Domestication of spelt

Genetic evidence

Unlike einkorn and emmer, the hexaploid hulled wheat spelt (*T. spelta*) has no wild hexaploid ancestor. Once it was known that both *Triticum* and *Aegilops* existed in polyploid series of diploid (14 chromosomes), tetraploid (28) and hexaploid (42), it was clear by the 1920s that hexaploid wheats must be an allopolyploid of a tetraploid *Triticum* and a diploid *Aegilops*. In a classic experiment McFadden and Sears (1946) showed that *Aegilops tauschii* Coss. (= *A. squarrosa* L.) was the *Aegilops* species involved in the hybrid. The *Aegilops* species were narrowed down to those with the barrel-type breakage pattern, and then to *A. tauschii* because its square-shouldered glumes best matched spelt. Subsequent work using other techniques has confirmed the role of *A. tauschii* as an ancestor of both the hulled and free-threshing hexaploids (Kerby and Kuspira 1987:726).

When wild or domesticated emmer wheat was crossed with *A. tauschii*, and chromosome doubling induced in the first generation, a fertile hybrid resulted that was very similar to cultivated spelt. McFadden and Sears (1946) reported that the hybrid had the domesticated, semi-tough rachis, which would select against survival in the wild. Further crosses between both naked and hulled domesticated tetraploid wheats and *A. tauschii* forms always resulted in hulled, spelt-type hexaploid wheats (Kerber and Rowland 1974). The first hexaploid wheat would, therefore, have been a hulled wheat.

Subsequent work (Sears 1976) showed that the *T. dicoccoides* accession used in the original 1940s experiments was in fact the domesticate *T. dicoccum*. When the cross was repeated with a truly wild *T. dicoccoides*, the resulting hybrid was fragile-rachised. It seems that fragile-rachised, wild hexaploid wheats could have evolved. However, the only known cases of brittle-rachised, wild-type hexaploid wheats are the wild variety of *macha* reported by Dekaprelevich (1961) and a brittle-rachised hexaploid wheat in Tibet (Shao 1983). Both grow only as weeds of cereal fields and are therefore much more likely to be a feral derivative of domesticated wheat than a truly wild species. Overall, several sources of evidence point to the tetraploid parent as being *T. dicoccum* rather than *T. dicoccoides* (Porceddu and Lafiandra 1986:151; Kimber and Sears 1987:161).

Aegilops tauschii grows as a weed of cereals over large parts of the Near East, including areas such as eastern Anatolia omitted from the map in Zohary and Hopf (1993:51). The area in which hexaploid wheats first occurred must be within the ancient distribution of *A. tauschii*, and this perhaps matched its current, more limited, primary habitats. These stretch from west of the Caspian Sea to central Asia in dry grasslands and forest edges (van Slageren 1994).

A. tauschii has been divided by some taxonomists into two subspecies: *strangulata*, with a bead-like arrangement of spikelets, and *tauschii* with cylindrical spikes. Isoenzyme studies suggest that subsp. *strangulata* is the donor of the D genome to the hexaploid wheats. Subspecies *strangulata* has a narrower distribution than subsp. *tauschii*, mainly growing in the southwest fringes of the Caspian Sea (Jaaska 1993). This strengthens the case for the hybridization of tetraploid wheat with *A. tauschii* having occurred in the Caspian region. This westernmost extension of the primary habitats of *A. tauschii* is shown on Figure 10; note that it does not overlap with the distribution of wild emmer or the Fertile Crescent zone of early domestication.

Archaeobotanical evidence

The most abundant and best-documented archaeological evidence for spelt is in Europe. Spelt remains occur at later Neolithic sites (2500-1700 BC) in eastern Germany and Poland, Jutland and possibly two sites in Southwest Germany (Körber-Grohne 1989). During the Bronze Age it spread widely in northern Europe.

Records of spelt from elsewhere are sparse and poorly documented. The earliest archaeological evidence of spelt is from the 5th millennium BC in Transcaucasia (Lisitsina 1984), from north of the Black Sea (Janushevich 1984) and from the contemporary site of Yarym-Tepe II in northern Iraq (Bakhteyev and Yanushevich 1980). Large numbers of glume imprints of spelt are recorded from Moldavia, dating to between 4800 and 4500 BC (Körber-Grohne 1987), while Popova (1991) reports three minor occurrences from the Neolithic and Chalcolithic of Bulgaria.

However all these records from outside Europe share two features: the spelt is usually present as a small proportion of the other wheats, and the identification criteria are poorly documented. It appears that the most common identification criterion is the barrel-type break of the rachis. This has two problems. First, some populations of modern emmer show mixed types of breakage. Second, fragmentary remains of spelt spikelets can be difficult to distinguish from those of the *Aegilops* species that also have barrel-type disarticulation: *A. tauschii*, *A. cylindrica* Host, *A. ventricosa* Tausch, *A. crassa* Boiss. and *A. juvenalis* (Thell.) Eig. Some of these species are common weeds of cereal fields. Although most *Aegilops* species are concentrated in a band stretching from the Mediterranean basin to Central Asia, *A. cylindrica* does grow north of the Black Sea and in the Balkans and could account for some spelt identifications there.

Aegilops spikelet remains have been identified in a number of archaeobotanical assemblages, for example in Bronze Age samples from Shortugai in Afghanistan and Selenkahiye in Syria (Willcox 1991:150; van Zeist and Bakker-Heeres 1985:255), and at early Chalcolithic Can Hasan I in central Turkey (Fig. 11).

Overall, we consider that these records of spelt from outside Europe are still doubtful, particularly bearing in mind their important role in deciding the hotly debated area of origin of ancient (and modern) European spelts.

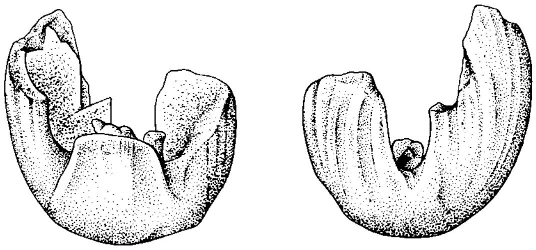


Fig. 11. Charred *Aegilops* spikelet fork dating to the Chalcolithic period (6th millennium bc) from the site of Can Hasan, Turkey. Note that the base of the upper rachis internode is still attached, and the overall robust appearance. In these respects, *Aegilops* chaff is somewhat similar to that of spelt.

Integration of evidence for spelt domestication

Seventy years ago Flaksberger (1925) drew attention to the antiquity of spelt cultivation in Europe and the lack of evidence for spelt in the Near East, and proposed that spelt evolved in Europe from bread wheat (cf. Schiemann 1948). Laboratory crosses of hexaploid free-threshing wheats with *T. dicoccum* have indeed succeeded in reconstructing synthetic spelt which is very similar to cultivated spelt (Mac Key 1966:252-255).

Zohary and Hopf (1993:52-53) consider that the archaeobotanical evidence from Transcaucasia and the Balkans is consistent with the hybridization of emmer and *A. tauschii* near the Caspian, and its travel to Europe by way of the north shore of the Black Sea. It is true that other crops, such as millet, reached Europe by this route. However, it is highly surprising that the ancestral spelt did not spread into Anatolia by way of highland Iran, particularly in view of the increased cold resistance perhaps conferred by the D genome.

Sadly we have no archaeobotanical evidence from the Caspian fringes where hybridization may have occurred. We do have evidence of free-threshing hexaploid wheats found at Near Eastern sites rather earlier than expected. While few free-threshing wheat remains have been identified on good morphological grounds to ploidy level, hexaploid free-threshing wheats have been identified on the basis of reliable rachis criteria at Can Hasan III in south-central Anatolia, dating to ca. 6500 BC (Hillman 1978:168) and at Cafer Höyük in southeast Anatolia, in levels IV-III dating to 7000-6000 BC (de Moulins 1993). This fits poorly with the model in which agriculture and tetraploid cultivated wheats are thought to have reached the Caspian area between 6000 and 5000 bc, allowing the hybridization with *A. tauschii* to occur (Zohary and Hopf 1993:50-52).

The discovery in the 1950s of spelt cultivation in Iran by Hermann Kuckuck, an FAO cereal breeding consultant, caused considerable interest. It was grown by Baktiari tribes over an extensive area surrounding the high (2000-2300 m a.s.l.) plateau of Shahr Kord, some 80 km southwest of Isfahan, central Iran. Both emmer and *T. aestivum* were also important crops in the same area (Schulz 1915; Kuckuck and Schiemann 1957). While the Iranian spelt spikes more often break up as wedge-shaped ‘emmer-type’ spikelets than European spelt, anatomical studies showed no difference in rachis structure (Pohlendt 1958). This discovery of spelt in Iran seemed to solve a critical problem: if spelt originated in the Near East, why was it no longer cultivated there?

Although a range of crossing experiments was carried out soon after the discovery of Iranian spelt (Kuckuck 1960; Gökgöl 1961), little genetic analysis has been carried out using other techniques. It is still unclear whether this isolated island of spelt cultivation is truly an ancient survival, or the result of a recent hybridization. Emmer was apparently brought to the same plateau by Armenian settlers in the 17th century. In view of the successful laboratory hybridization of spelt from emmer and bread wheat (see above), spelt may well have evolved after emmer was introduced to the area.

Conclusions on spelt

Recent publications have put forward a clear model for the history of spelt (Körber-Grohne 1987; Zohary and Hopf 1993). As domesticated emmer spread with agriculture from the Fertile Crescent in the direction of the Caspian Sea, it entered the native area of *A. tauschii* and hybridized with it to form spelt. Archaeological evidence for the earliest Neolithic farmers in the Caspian region suggests this happened around 6000 bc. The migration of spelt to Europe can then be traced by way of archaeobotanical remains in Transcaucasia, Moldavia and Bulgaria. Present-day cultivation of spelt in Iran and *T. macha* in Transcaucasia may be remnants of original spelt forms.

The archaeobotanical data are not fully consistent with this model:

1. Hexaploid free-threshing internodes are present at Turkish sites by 6500 BC, 500 years before the first hybridization of a hexaploid wheat is thought to have occurred. Could *A. tauschii* have been more widespread in the Neolithic than we assume, so that the hybridization could have occurred earlier? Why, if we have early free-threshing hexaploid wheats, are hulled hexaploid wheats absent? Could the original hybridization have occurred in a field of *T. durum*, leading to rapid selection in favour of a free-threshing hexaploid? Such a scenario would explain the absence of spelt from the ancient Near East.
2. Why is spelt absent from the ancient Near East? Even if the first hybridization did occur near the Caspian Sea or in Transcaucasia, it is highly surprising that spelt only spread to Europe north of the Black Sea. One would expect spelt to be well adapted to the highlands of Turkey or Afghanistan, but there are no ancient or modern records from these areas.
3. Archaeobotanical records from north of the Black Sea are poorly documented. The low frequency with which spelt appears to be present could be consistent with its spread as a weed to Europe, at which point it flourished and emerged as an independent crop. Equally, it could represent occasional misidentifications of emmer and *Aegilops* spikelets bearing barrel-type rachis breakage.

We suggest two areas in which research could help resolve the problem of spelt. First, early finds of spelt from Transcaucasia and the Black Sea region need to be re-examined. Second, we urgently need genetic characterization of present-day spelt landraces from Europe in comparison with the existing Iranian and Transcaucasian populations of spelt. Johnson (1972) concluded that the similarity in seed proteins between Iranian and European spelts suggested they shared a common, Near Eastern origin, but cautioned that two separate episodes of hybridization could not be ruled out. Clearly any such study will need to take into account variability between the populations of emmer and bread wheat from which spelt could have emerged. If these are broadly similar in Europe and the Near East, then any resulting forms of spelt will also be similar. The challenge is to separate similarity due to a common ancestral hybridization from similarity due to similar parental material.

The evolution of the Transcaucasian hulled wheats

We end our discussion of domestication with a group of hulled wheats that are restricted to Transcaucasia and adjacent areas.

Close relatives of emmer

Two tetraploid domesticates have been identified that are closely related to *T. dicoccum*. viz. *T. ispahanicum* and *T. palaeocolchicum*. *T. ispahanicum* is a long-glumed hulled tetraploid wheat, rather similar in appearance to the free-threshing *T. polonicum*. It is grown as a pure crop near Isfahan (Heslot 1958; Chelak 1978). *T. palaeocolchicum* was discovered in 1929 in Western Georgia. It is distinguished by a compact ear and strongly zig-zag rachis (Jakubziner 1958). The limited distribution of these taxa, and their close relationship to emmer, suggests that they may have evolved quite recently. Most taxonomists would rank these as subspecies of *T. dicoccum*, rather than as species in their own right.

Timopheevi wheats

T. timopheevi has a much wider, flatter ear than *T. dicoccum* (Dorofeev and Migushova 1979:311, Fig. 24), and grows in a limited region of Georgia. The original description describes it as weedy rather than domesticated (Zhukovsky 1928), and it remains unclear whether *T. timopheevi* grows as a crop in its own right, or is a weed of other wheats. Its wild ancestor is *T. araraticum*, a wild emmer wheat morphologically close to *T. dicoccoides*. Chromosome studies suggest that the domesticate *T. timopheevi* is more likely to have evolved from the Transcaucasian *T. araraticum* subsp. *araraticum* Jakubz. than from the more southern *T. araraticum* subsp. *kurdistanicum* Dorof. & Migusch (Badaeva *et al.* 1990).

The very limited distribution of *T. timopheevi* cultivation suggests it was a secondary domesticate: when emmer cultivation spread to Transcaucasia, local populations of *T. araraticum* could have grown as a weed of the emmer crops and, by being incorporated into the agricultural cycle of harvest and sowing, become domesticated. The lack of weedy habit in *T. araraticum* may explain why this process did not occur more widely across the northern and eastern Fertile Crescent. Although archaeobotanical records of *T. timopheevi* are claimed from the Bronze Age onwards in Georgia, we doubt that these can be distinguished from *T. dicoccum*.

Minor hexaploid wheats

T. macha is a hexaploid hulled wheat, discovered in western Georgia in 1929. In the 1940s Russian botanists suggested that *T. macha* was implicated in the origin of free-threshing hexaploid wheats. However, it appears to be rather distinct from other hexaploid wheats and is probably derived from *T. palaeocolchicum* (Jakubziner 1958). Kuckuck (1970:258) suggested that a brittle-rachised form of *T. macha*, var. *megrelicum* Dek. et Men., could be a genuinely wild hexaploid wheat, and therefore a candidate ancestor species. Dorofejev (1971) suggested that *T. macha* was the surviving form of the original hybridization from which hexaploid free-threshing wheats derived, while the Iranian and European spelts are secondary forms that arose from *T. aestivum*.

Details of the distribution and ecology of *T. macha* are scarce, but it appears to grow only as a minor admixture in fields of *T. timopheevi* and *T. monococcum* (Dekaprelevich 1961). Its fully brittle-eared form, var. *megrelicum*, is not described as growing outside cultivated fields and is therefore not a truly wild wheat, while normal forms are described as being between cultivated and wild wheats in terms of rachis brittleness (Dorofejev 1971:336). In view of its limited distribution and its apparent weed-like status as a minor component of crops, we regard *T. macha*, like the other hulled wheats endemic to Transcaucasia, as local forms that evolved in isolation. We think it unlikely that they played any role in the evolution of the more common wheat species.

T. vavilovii is also a hexaploid hulled wheat. It has elongated rachillae that give the ear a branched appearance (Singh *et al.* 1957). It was discovered in 1929 as a rare admixture of *T. aestivum* near Lake Van, eastern Turkey (Zhukovsky 1933). In view of its close relationship to *T. aestivum*, aside from the two closely linked genes controlling branching and the hulled character, it seems likely that *T. vavilovii* is another local, recently evolved form of wheat that hardly rates species status.

T. zhukovskyi is a hexaploid hulled wheat that carries the G genome and is thus closely related to *T. timopheevi*. It grows in fields in Western Georgia as an admixture *of T. timopheevi* and *T. monococcum*. It apparently resulted from the hybridization of these two species (Jakubziner 1958; Johnson 1968).

Hulled wheats in the ancient Near East

The hulled wheats in Mesopotamia

Textual evidence

Einkorn and emmer are important crops at most Near Eastern sites from the Neolithic onwards. We know little about their significance or use at many of these sites. Archaeobotanical reports are still too scarce in relation to the size of the Near East and the 10 000-year duration of agriculture. Although some patterns are slowly emerging, we are mainly working with snapshots in time rather than coherent models of agricultural change (Miller 1991; Nesbitt 1995b). Even at a domestic level, few studies have been made of food-processing technology and the ways in which hulled wheats could have been cooked and consumed. However, in lower Mesopotamia, in the irrigated plains of the Euphrates and the Tigris, textual evidence has stimulated ideas about the cultivation and role of the hulled wheats as part of agriculture.

Lower Mesopotamia is a semi-arid land that could not be cultivated until irrigation began in the Samarran (Late Neolithic) period, from about 5500-5000 BC onwards (Oates and Oates 1976). Emmer is the most abundant wheat species at Mesopotamian sites, a staple crop second only to hulled barley. Einkorn wheat and free-threshing wheat were less common (Renfrew 1984).

From early as 2900 BC, clay tablets were important instruments in the administration of a complex and highly centralized economic system centered upon temples and palaces. The vast amount of agricultural information is largely concerned with the administration of large enterprises, rather than with individual households.

Hrozný (1913) identified three commonly occurring cereals in the Sumerian texts in his classic study: ‘barley’ (še), ‘emmer’ (zíz) and ‘wheat’ (GIG). These identifications have become widely accepted, but there are still considerable difficulties with the meaning of various derivative terms. Clues to meaning come from the context of words in texts, which may indicate specific properties or that the term belongs to a specific group of words (Powell 1984; Postgate 1984a, 1984b). For example, it has been suggested (Powell 1984:52) that a form of emmer used in soup was equivalent to the German ‘Grünekern’, green kernels of spelt used for making soup. Yet mature grains of emmer are perfectly suitable; indeed, we consumed emmer grain soup during a dinner in Castelvecchio Pascoli, near the city of Pisa, northern Italy. The term is more likely to refer simply to clean, dehusked grains of emmer. Both Postgate (1984b) and Powell (1984) make it clear that there are major difficulties in using the textual evidence to identify most hulled wheat products because of difficulties in translation. It is, however, clear that emmer was used for making beer and groats (Powell 1985:17-18).

Sumerian terms were used as shorthand words (‘sumerograms’) for various terms on clay tablets by the Hittites from the 17th to 12th centuries BC in their central Anatolian empire. One sumerogram has been widely translated as emmer, on the grounds that it retained the same meaning as its earlier use in Sumeria. Hoffner (1974) suggested that the archaeobotanical evidence from the middle and late Bronze Age was lacking in hulled wheats, and that zíz could be better translated as bread wheat or wheat in general. Recent study of plant remains from a middle Bronze Age site in central Anatolia showed that bread wheat was far more common than einkorn or emmer, and that Hoffner’s identification is therefore correct (Nesbitt 1993). This kind of direct comparison between archaeobotanical results and philological analysis is still rare. However, this example shows how important it is if we are to understand both archeological and written evidence of the past.

Salinization and the decline of emmer?

In the 1950s a collaboration of historians, archaeologists and an archaeobotanist put forward the highly influential “theory of progressive salinisation”. They suggested that cereal yields in southern Mesopotamia declined between 3000 and 2000 BC, and that there was a shift from emmer to barley crops. Both trends were due to increasing salinization of irrigated fields, and that this led to the eventual decline of ancient Sumer.

The theory has been widely accepted, but the recent publication of the raw data on which it was based (Jacobsen 1982) has shown that this work suffers from three problems. First, the textual evidence for yields in antiquity or for crop quantities is deeply ambiguous (Powell 1985); second, the archaeobotanical evidence for southern Mesopotamian crops is very scarce and insufficient to demonstrate anything beyond a very general ranking of cereals for the 3rd millennium BC as a whole; third, we know next to nothing of the comparative response of emmer and barley to salinity. The only study we know of to have compared yields found that one variety of Indian emmer wheat yielded much more than barley under a number of salinity levels (Hunshal *et al.* 1990). In view of modern-day emmer’s adaptability to poor soil conditions, it is possible that some forms of ancient emmer were resistant to saline conditions. This combination of ambiguous texts, lack of archaeobotanical data, and lack of agronomic characterization of hulled wheats equally affects virtually all studies of ancient historical agriculture.

The decline of the hulled wheats in the Near East

Today cultivation of hulled wheats in the Near East is restricted to the Pontic Mountains of Turkey (einkorn and emmer) and Iran (emmer and spelt). When and why the hulled wheats fell from their positions as staple crops is one of the big questions in Near Eastern archaeobotany. As more reports on ancient plant remains are published, we are able to pick out more regional variation.

In eastern Turkey einkorn and emmer were replaced by free-threshing wheats abruptly at the beginning of the Early Bronze Age (ca. 3000 bc), and are virtually absent from the archaeobotanical record thereafter (van Zeist and Bakker-Heeres 1975; Nesbitt 1995b). In central Turkey einkorn and emmer appear to be minor crops in Middle Bronze Age samples (1900-1700 bc) from Kaman-Kalehöyük (Nesbitt 1993). In the west, archaeobotanical data are still scarce. However, Schiemann's study of the plant remains from Troy (which supersedes a number of earlier reports on the same material), in which she identified abundant einkorn and emmer, suggests that these were still important in the 2nd millennium BC (Schiemann 1951). Unfortunately the material derives from the 19th century excavations, is poorly provenanced and was destroyed in 1943. Archaeobotanical results from the new excavations at Troy are eagerly awaited.

To the south, in the Levant, einkorn and emmer appear to be limited to minor components in the 3rd millennium BC, and to have disappeared by the 2nd millennium BC (Miller 1991). In eastern Anatolia the disappearance of the hulled wheats may be linked to increasing evidence of hierarchical societies and market economies, leading us to suggest that under conditions of intensification, for example increased manuring, free-threshing wheats replaced them.

The trend towards an increase in the complexity of societies is widespread over the Near East at the beginning of the 3rd millennium, but hulled wheats disappear at different times in different places. An east-west gradient seems to run from eastern Anatolia to the Aegean, when hulled wheats were important until the mid-1st millennium BC. We need more case studies in which we can accurately plot the decline of the hulled wheats. This decline can then be related to changing crop husbandry techniques as tracked through weed taxa and parallel changes in animal husbandry, as well as wider changes in settlement and economy.

Egypt

The arrival of farming

Compared with the Near East, relatively few early prehistoric sites are known in Egypt and there is a striking lack of continuity in their occupation. As a result, we are missing many details of early subsistence patterns and their development. Nevertheless, it is clear that there was no farming economy in Egypt prior to between 6000 and 5000 bc, because it was not until that date that farming villages first appeared in the Delta to the north, and the Fayum oasis to the west of the Nile (Wetterstrom 1993:201). In the Nile valley the earliest settled, food-producing cultures date to 4500 BC (Baines and Málek 1984:30). The idea that agriculture originated in Egypt has a long history but there is as yet no evidence for any indigenous origins. It is possible that domestication or attempts at domestication of various plant and animal species may have taken place after agriculture was introduced but evidence for this has yet to be found.

Archaeobotanical evidence from early farming settlements demonstrates that the farming way of life must have been introduced into Egypt from the Near East. The package of crops found matches the crop complex known at this time in the Levant (Wetterstrom 1993:201). Of the two hulled wheats cultivated in the Levant in early Neolithic times, only emmer has ever been found in Egypt (Täckholm *et al.* 1941:241). Although much of the earlier Egyptological literature, as well as more recent publications, mentions the cultivation of spelt, this temperate northern glume wheat has never been grown in Egypt (Germer 1986). This mistake may have arisen partly from the use of the German term ‘Spelzweizen’ for the hulled wheats as a whole.

Dominance of emmer

Throughout the long and stable sociopolitical culture of ancient Egypt, there was strong continuity in agricultural practices, especially for the cereal staples. Emmer was the sole wheat which was cultivated from the beginnings of farming until Graeco-Roman times (after the conquest by Alexander the Great, in 332 BC). It was then that emmer was rapidly replaced by free-threshing macaroni wheat, *Triticum durum* (Crawford 1979:140; Bowman 1990:101). Once Egypt came under the control of Mediterranean-based foreign power, the agricultural economy was directed by political decision-making based on outside circumstances rather than purely indigenous factors. During Imperial Roman times, for example, Egypt exported vast quantities of grain to Rome (Bowman 1990:38). Thus emmer wheat lost its primacy as a crop, and it was gradually forgotten (Täckholm *et al.* 1941:241).

There is no good published evidence for the presence of free-threshing wheat in pre-Graeco-Roman Egypt. Although some archaeobotanical specimens have been identified as such, according to Täckholm *et al.* (1941:254-255) nearly all have been shown to be threshed emmer or dehusked barley grains. There are two isolated references to durum wheat identified by reliable archaeobotanists, John Percival and Elisabeth Schiemann, who identified the wheat from 12th Dynasty (1991-1783 BC) Kahun and 18th Dynasty (1550-1307 BC) Deir el-Medina respectively (Täckholm *et al.* 1941:254-255). The textual evidence, based on the interpretation of the word ‘swt’, cannot be considered reliable (Täckholm 1977:271; Germer 1986:1209). Lexicographical studies will never provide definitive evidence for the use or lack of free-threshing wheat. Even if some archaeobotanical evidence of free-threshing wheat should eventually be found, in comparison with the abundance of emmer which has been recovered, it must have been very scarce, and thus could not have been of any importance in ancient Egypt (Kemp 1994:146).

The primacy of emmer as a wheat crop in Egypt, until strong outside political control caused its rapid replacement, does not follow the pattern of hulled wheat decline elsewhere. Why was emmer the favoured wheat crop in Egypt for so long? There were no agronomic and ecological factors discouraging free-threshing wheat cultivation. The Egyptian climate has not altered appreciably since at least 2200 BC (Vercoutter 1992:28), and the annual inundation of the Nile valley has occurred for very much longer. When durum wheat was finally introduced in Graeco-Roman times, Egypt was able to produce vast surpluses (Bowman 1990:38), and only free-threshing wheats are grown today (Zahran and Willis 1992:338).

Despite Egypt’s political isolation, trade and later conquests meant that the country was in contact with peoples who grew free-threshing wheats. Particularly during the New Kingdom (1550-1070 BC), useful new ideas were quickly absorbed by the ancient Egyptians, notably the horse and chariot (Kemp 1994:146). If the ancient Egyptians perceived benefits in the cultivation of free-threshing wheats, they would surely have adopted it.

Examination of the morphology of ancient Egyptian emmer spikelets (Fig. 3) clearly demonstrates that ancient Egyptian emmer was a typical tough-glumed hulled wheat. There is no evidence to support Sallares’ (1991:370-372) contention that the long predominance of emmer in Egypt was due to the cultivation of a loose-hulled “more highly domesticated” form.

The explanation for the extended use of emmer wheat, long after neighbouring cultures grew mainly free-threshing wheat, seems to be one of cultural choice. The evidence indicates a definite dietary preference. Towards the very end of its exclusive use, we have one glimpse of this cultural attitude, recorded by an outside visitor. Herodotus, who lived from 495 to 425 BC, mentions that the people of Egypt considered emmer “the only fit cereal for bread” (cited in Täckholm *et al.* 1941:240). As for the details of what that bread was like, relatively little work has been done, but some comments are given in the following section.

Emmer as food in Egypt

The arid climate of Egypt has preserved the debris of food processing, sometimes in the very position where it was produced. Processed food itself has also sometimes survived until the present day. The staple foods of ancient Egypt into which emmer and barley were transformed were bread and beer (Drenkhahn 1975; Kemp 1989:120).

There are two sources of ancient processed foods. One is in tombs where offerings provided necessary sustenance for the afterlife. Most major museums of the world have a few or a large number of tomb loaves, dating to various periods from the predynastic (prior to 3100 BC) to Graeco-Roman times (after 332 BC) (Borchardt 1932; Währen 1960:94, 1961:3, 8, 13, 1963:24-25; Darby *et al.* 1977:520-521, 524-525; Sist 1987:58). Vessels placed in tombs sometimes also contain chaffy contents which are most likely related to brewing (Winlock 1932:32; Bruyère 1937:106, 177, 180).

The second source is from settlement sites. The 14th century BC Workmen’s Village at Amarna has many potsherds with adhering residue, and some of these contain shreds of cereal chaff and bran. A Graeco-Roman town which yielded large numbers of pot residues is Gebel Adda. This collection is now housed at the Royal Ontario Museum, Toronto. Some early Christian pottery from Qasr Ibrim in the far south of Egypt also contains residues. Residues are no doubt present on some vessels from any site in very arid regions, but are rarely recorded and collected by archaeologists.

Food remains from settlement sites are particularly interesting because they relate directly to daily life in the past. The funerary material is virtually the only known source of ancient bread, but it is connected to the rituals of death. We have no information about how closely, if at all, these related to food in daily life.

The chaff and grain fragments embedded in the food matrix permit identification of the cereal constituents of ancient Egyptian bread and beer. Only barley and emmer need to be distinguished, so that even small fragments can often be identified. Nearly all the bread which contains identifiable cereal fragments was made from emmer. Barley grain or chaff fragments are so occasional that they must have been accidental inclusions. Evidence from beer residues indicates that either emmer or barley was made into beer, and sometimes a mixture of both.

Irrespective of whether the funerary loaves are indicative of daily practice, it is clear that the ancient Egyptians frequently baked with emmer wheat. The wide range of loaf shapes and microscopic evidence points to a variety of different emmer breads (Samuel 1994), just as there is a wide variety of different bread types made today. The largest type of ancient Egyptian emmer bread measures about 200 mm in length, 175 mm in width and 100 mm in height. Unfortunately, it has not yet been possible to examine any of these particular loaves closely, so ingredients other than emmer flour cannot be ruled out. Most surviving ancient Egyptian loaves are considerably smaller, resembling modern rolls or buns. On average, they range from about 10 to 40 mm thick. Their texture is generally dense with small air cavities. Many of the loaves which have been studied with microscopy show evidence for baking with malted grain (Fig. 12).

Further work is needed to assess with accuracy whether these loaves were leavened. Yeast cells are difficult to detect in bread because they are present in low densities and are easily missed in the dense crumb of emmer bread. A few yeast cells have been identified in some loaves, using scanning electron microscopy. Not enough have been located to determine whether these were chance inclusions or deliberate additions.

Despite the small dimensions compared with modern bread and the use, perhaps frequent, of malt, there is no doubt that ancient Egyptian loaves, with their darker crusts and paler interiors, were baked products as we understand bread. This is a good example of the danger inherent in drawing conclusions about ancient foodstuffs based solely on our own modern food types, or on classical sources. Spongy textured and highly risen the ancient Egyptian loaves were not, but they were certainly bread.

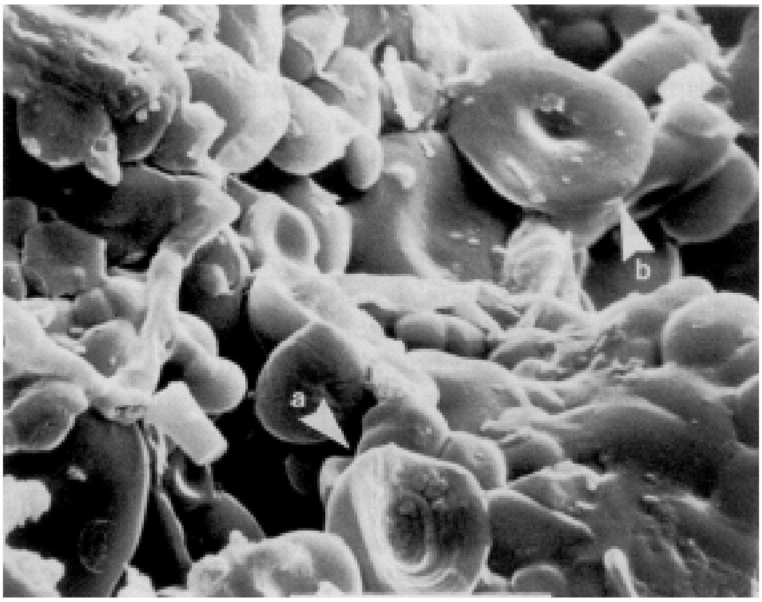


Fig. 12. The microstructure of an ancient Egyptian desiccated loaf. The bread came originally from a tomb at Deir el-Medina, Egypt dating to the 18th Dynasty (1550-1307 BC) and now at the Musée du Louvre (accession number E16410). Individual starch granules are clearly visible. One small granule (a) is hollowed, showing internal concentric layers. This is typical of enzymatic breakdown which occurs when grain is made into malt. Some granules (e.g. b) are swollen and dimpled, caused by heating in moist conditions, while other granules were even more strongly affected and have begun to fuse together (lower right corner). Bar = 10 μ.

The spread to Africa beyond Egypt

N.I. Vavilov's expedition to Ethiopia in 1927 collected a remarkable diversity of cultivated wheats and barleys, including emmer wheat (Vavilov 1951:38). Emmer wheat is still grown in the central and northern highlands as the most important minor crop after *T. durum* and *T. aestivum*, but information on its husbandry or uses is very scarce (Mekbib and Mariam 1990; Demissie and Habtemariam 1991). We know nothing about when or from where emmer came to Ethiopia. Nothing is known of the region's archaeology prior to the famous Axum empire (1st century BC to 3rd century AD), and what little is published on the history of crops in the region is highly speculative (Phillipson 1993). Whether Ethiopia received its wheats and barleys through Egypt – the most plausible route – and when this happened are unknown. It is intriguing that ongoing emmer cultivation is recorded in Yemen (Vavilov 1951:175). This may have been introduced from nearby Ethiopia.

There is evidence of recent cultivation of einkorn and emmer in Morocco (Miége 1924, 1925) and of einkorn and spelt in Algeria (Ducellier 1930; Deloye and Laby 1948). Whether these derive from the spread of early agriculturalists along the Mediterranean or are a later import from, say, the nearby Iberian peninsula is unknown.

The spread of hulled wheat from the Near East to Transcaucasia and the Black Sea

Early farming villages, with pottery and domesticated plants and animals, appear in Georgia and Armenia in the 6th millennium BC (Mellaart 1975:195-207). Although wild einkorn and wild barley, and *T. araraticum*, the wild ancestor of *T. timopheevei*, do grow in Transcaucasia, the dating of the development of agriculture strongly suggests that it spread to Transcaucasia from the Near Eastern Fertile Crescent (Fig. 13).

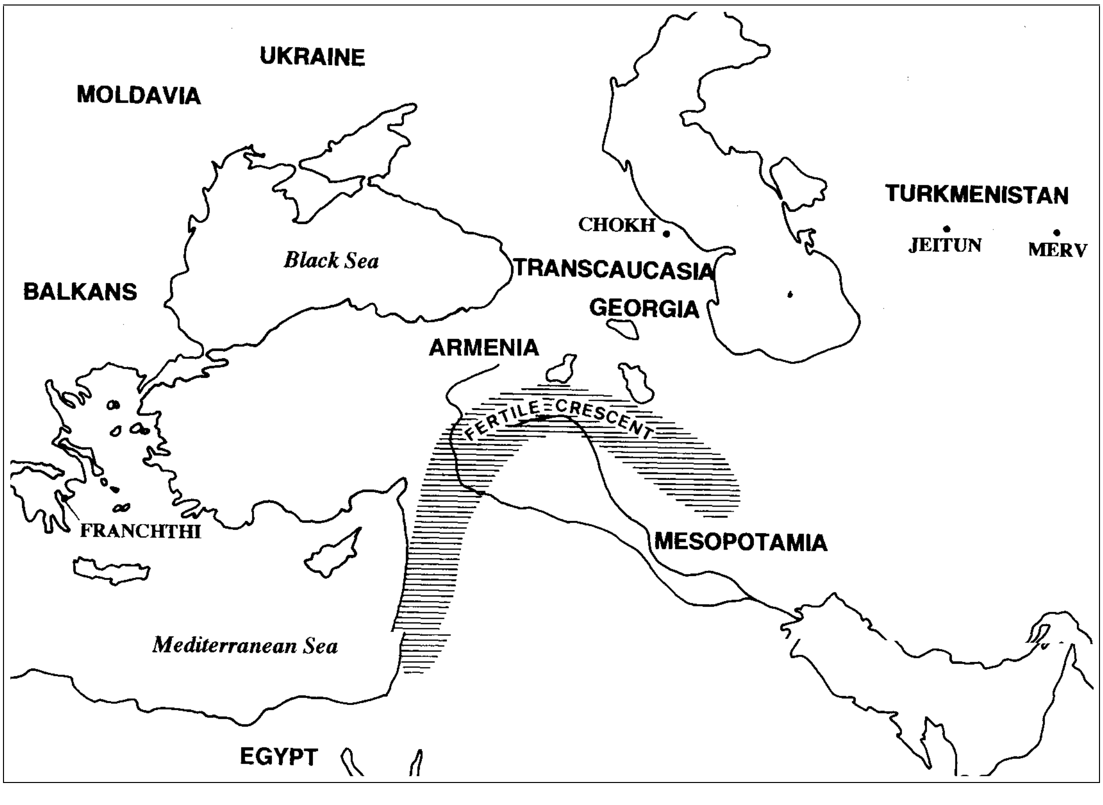


Fig. 13. Regions to which domesticated hulled wheats spread from the Fertile Crescent.

Agriculture in Transcaucasia has always been characterized by great diversity in the range of crops. This must be due in part to isolation of regions within the highly mountainous landscape. The same diversity is found in ancient plant remains (Wasylikowa *et al.* 1991:233-236). However, the morphological basis on which, for example, spelt and *T. macha*, or emmer and *T. timopheevi* have been distinguished are not clear, and these identifications should be treated with caution. Hulled wheats appear to have been important in this region up to the Iron Age (1st millennium BC), but to have declined thereafter.

North of the Black Sea lie the Ukraine and Moldavia. Early Neolithic farming villages appear in this area from 5500 to 5000 bc. Emmer was the most important cereal from the Neolithic through to the Middle Ages, with hulled and naked barley in second place. Einkorn and spelt are sporadically present. In the late medieval period emmer is replaced by free-threshing wheat.

The problem of poorly published data and lack of cultural context is perhaps greater for these areas to the north of the Near East than anywhere else. A fascinating variety of hulled wheats is grown, but we have nothing more than lists of plant species. We know virtually nothing of how the hulled wheats were used nor how their cultivation changed through time and came to cease.

The spread of hulled wheat from the Near East to the East

Central Asia

By the middle of the 6th millennium BC early farming villages were established in the northern foothills of the Kopet Dagh mountains (Mellaart 1975:208-219) in present-day Turkmenistan. Recent excavations by an international team at the key site of Jeitun (6th millennium bc) included large-scale flotation for charred plant remains (Harris *et al.* 1993). These are dominated by einkorn wheat, forming about 90% of the cereal remains. Emmer wheat and barley are also present. The cereal crops were grown on saline, high water-table areas, such as the inter-dune flats near the site. As Harris *et al.* (1993:332) point out, the dominance of einkorn has no parallels elsewhere, and may be a result of its suitability to a marginal, saline environment. This is an interesting contrast to the assumption that barley, of all the cereals, is best suited to such conditions.

By the Bronze Age, from 2200 BC onwards, large-scale irrigation agriculture was well established in the oases of the Karakum desert. In the Merv oasis, plant remains dating to about 2000 BC have been studied from Bronze Age Gonur Tepe by Naomi Miller (Moore *et al.* 1994). Here barley was the dominant crop, with free-threshing wheat second in importance. It is doubtful whether emmer was present. At Late Sasanian Merv (500-700 AD) barley and bread wheat were the main cereal crops and hulled wheats are certainly absent (Nesbitt 1994). The archaeobotanical record of other sites is not easily accessible, but barley and free-threshing wheats are generally the main crops in this region from the Bronze Age onwards. On the basis of current evidence, one can hypothesize that the shift from hulled wheats to barley and free-threshing wheats may have occurred when large-scale irrigation began in the region.

Afghanistan lies to the east of Iran and the south of Turkmenistan. Virtually no archaeobotanical work has been carried out here. The exception is George Willcox's (Willcox 1991) work at Shortugai, an archaeological site on the Amu Darya (Oxus) river. During the 3rd and 2nd millennia BC hulled barley was the most common crop, followed by bread wheat and common millet (*Panicum miliaceum*). Overall the crop assemblage fits well with Bronze Age assemblages from elsewhere in central Asia.

Hulled wheats have not been found in this century by any of the detailed survey of wheat in Afghanistan or Turkestan (Lange-de la Camp 1939; Lein 1949; Ufer 1956). When, at some point prior to the Bronze Age, hulled wheats were displaced by barley and the free-threshing wheats, this was an exceptionally thorough process.

The Indian subcontinent

The earliest evidence for a farming economy is from the Neolithic site of Mehrgarh in Pakistan (6000-5000 bc). The plant remains are dominated by naked barley, but a few impressions resembling einkorn or emmer spikelets were found in very small quantities (Costantini 1984).

In the 3rd millennium BC the great Harappan culture of the Indus valley was characterized by urban centres and massive public architecture, writing systems and long-distance trade with surrounding regions. Little is known of its cultural precursors. Large-scale recovery techniques for plant remains have not been applied at Indian sites, and we still know little of Harappan agriculture. Free-threshing wheat and hulled and naked barley seem to have been the main cereals. Evidence for hulled wheats here or at other sites in India is very scarce (Kajale 1991).

Even more so than in central Asia, we are handicapped by the limited archaeobotanical data recovered or published. Overall, the hulled wheats never seem to have been important in ancient India.

In the 20th century einkorn has not been found in the Indian subcontinent, but emmer has been recorded in scattered areas of India, mainly in the states in the southwest of India: from north to south, Gujarat, Maharashtra and Karnataka (Howard and Howard 1910; Bhatia 1938; Mithal and Kopper 1990). Its persistence in these areas may be due to its resistance to rust diseases, but it is not clear whether there is a close correlation between areas with serious rust problems and areas in which emmer cultivation is still important.

The spread of hulled wheat from the Near East to the West

How did agriculture spread?

Since European archaeobotany has been much more intensively studied than any other Old World region, it is possible to make some attempt to investigate how agriculture spread. We have already seen how the combined evidence of distribution of wild ancestors, and of archaeobotanical evidence for the earliest domesticates, points firmly to the Near Eastern ‘Fertile Crescent’ as the key area of agricultural origins about 8000 bc. By the 3rd millennium BC agriculture had reached Britain, some 3500 km to the west. How and when did this happen?

As soon as radiocarbon dating could be applied to European and Near Eastern settlements, it was clear that there is a clear gradient of agricultural sites from east to west (Fig. 14). The mechanism of this spread is still disputed, but the overall similarity in crops and husbanded animals in each area makes it clear that the plants and animals themselves were spreading, not just the idea of agriculture. Ammerman and Cavalli-Sforza (1984) have put forth the controversial argument that the distribution of certain genes in European populations is consistent with the spread of people – a demic diffusion – rather than a cultural diffusion with methods and crops passed on from one group to another. Demic diffusion would have been the result of the population increase that accompanied the introduction of farming.

This continues to be a hot topic with a large literature (e.g. Renfrew 1987; Zvelebil 1989; van Andel and Runnels 1995).

In Greece we are in the unusual position of having a site, Franchthi Cave, which spans the transition from a hunter-gatherer to farming economy, and at which a large-scale flotation effort was undertaken. The resulting monograph on the archaeobotany is a key document for the spread of agriculture into Europe (Hansen 1991). At Franchthi Cave hunter-gatherers collected a wide range of wild foods, including wild barley and lentils, during the later Upper Palaeolithic and Mesolithic (11 000-5900 bc). At about 5900 bc domesticated sheep and goats, and domesticated barley and emmer (to be followed by einkorn) are present. These domesticates appear abruptly all at the same time, but 2000 years later than in the Near East. This is consistent with the introduction of the Neolithic agricultural ‘package’ of crops and animals from the Near East, not just the idea of agriculture. Some wild ancestors, such as wild barley and wild lentil, are present beforehand, but critically, not wild emmer. This strongly argues against indigenous domestication. Presumably agriculture spread overland through Turkey. As Hansen (1991:180-181) points out, there is still a puzzling absence of early Neolithic, 7th millennium BC sites in western Turkey. It is quite possible, however, that these and earlier sites, which are inconspicuous and difficult to find, have simply not been discovered yet.

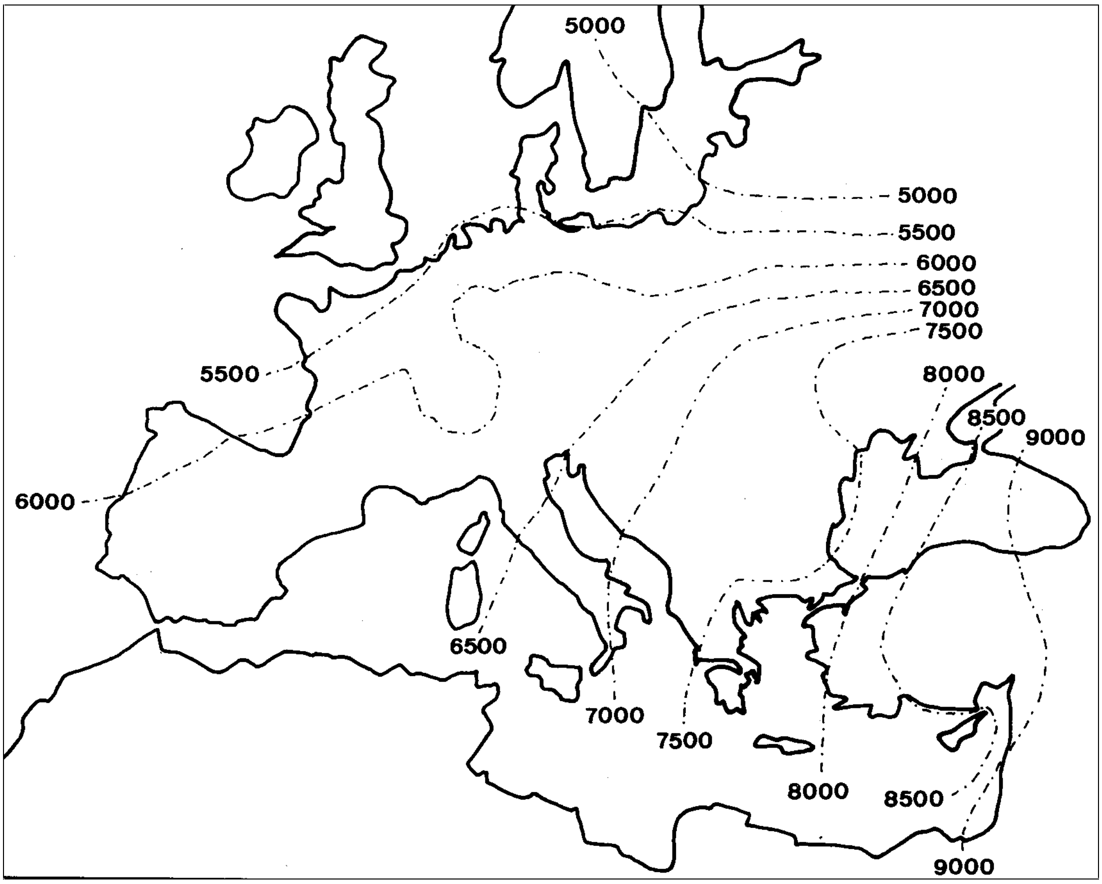


Fig. 14. The spread of agriculture into Europe. The isochrones mark the first appearance of agricultural, Neolithic villages; note that they spread out from the Near Eastern heartland. The isochrones are in radiocarbon years before present. Adapted from Ammerman and Cavalli-Sforza (1984).

From the Balkans to western Europe

After Greece, agriculture spread earliest into the Balkans, reaching the Carpathian mountains and middle Danube basin by 5500 bc. Along the north Mediterranean shore, Neolithic farming villages appear in southern Italy, southern France and Spain by 5000 bc. The first appearance of farming in the belt of Europe stretching from the Netherlands to Germany and Poland is linked to the Linearbandkeramik, a Neolithic culture identified by its distinctive pottery and wattle-and-daub longhouses, which first appears around 4500 bc (Fig. 15). Agriculture did not arrive in the Swiss Alps, British Isles or Scandinavia until 3500 bc (Barker 1985). The staple cereals of most of these early farming cultures were emmer and barley. Einkorn is usually present, but less abundant than emmer.

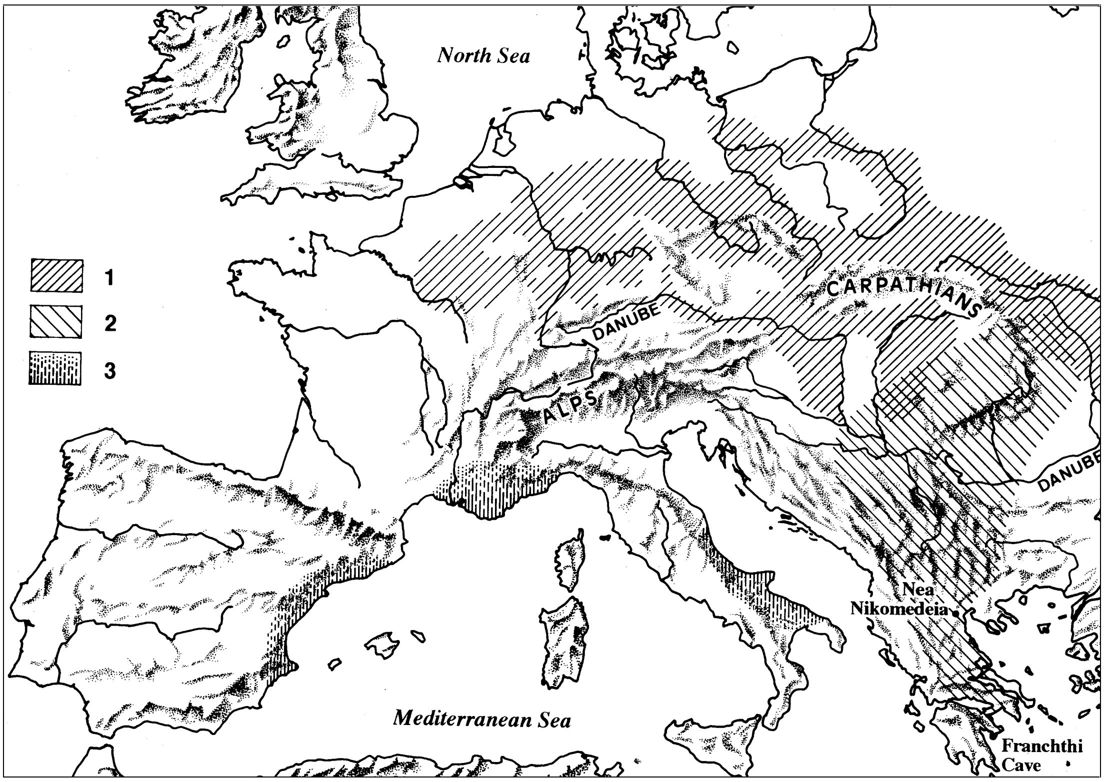


Fig. 15. The earliest agricultural cultures of Europe: 1. Linearbandkeramik; 2. Starçevo; 3. Impressed pottery. Adapted from Renfrew (1987: 155).

What happens to agriculture after its establishment is not clear. Although Barker outlines a general trend towards increasing population density and social complexity, we are still hard pressed to identify evidence for phenomena such as 'intensification' through the study of plant remains. Despite the attention to archaeobotany, in most of Europe we are just starting to get some idea of regional variations in crop choice and, rarely, crop husbandry techniques, but find it difficult to explain these (cf. van Zeist *et al.* 1991). In part this is because the evidence is still very patchy; but it is also a result of a historical divide between archaeobotanical data, seen as 'ecological' and other archaeological evidence, seen as 'economic'.

The rise of spelt

In southern Germany and Switzerland, spelt first appears in abundance in the Bronze Age (1800-1200 BC), replacing emmer as the principal wheat species in the Iron Age (750-15 BC) (Küster 1991). A similar pattern occurs in Britain, with spelt appearing at the end of the 2nd millennium BC and replacing emmer at sites in southern Britain by 500 BC (van der Veen 1992). In contrast, emmer continues to be important in northern Germany and the lowlands of western continental Europe, while spelt appears in the uplands.

A key to understanding why this shift occurred lies equally in understanding why it did not occur in some areas. Archaeobotanical work in a number of different areas – southern England (Jones 1981b), northern England (van der Veen 1992) and southern Germany (Küster 1991) – has pointed to a similar trend. The shift to spelt seems to be part of an expansion of agriculture onto poorer soils, linked in some way to more centralized and more stable societies. Exactly why spelt is the crop involved in this change is unclear (see van der Veen 1992:130-133; 145-148 for a full discussion). We do not know if spelt performs better on poor soils. The evidence for the relative performance of spelt is contradictory (Davies and Hillman 1988; Rüegger *et al.* 1990), reinforcing the point that even if differences in yield do exist between particular modern-day varieties of wheat, these need not reflect consistent differences in ecological tolerances between species. It has been suggested that the switch to spelt was also a switch to autumn sowing, but there is no evidence to suggest that emmers are inherently more likely to be spring sown. In view of the higher yields obtainable from autumn-sown crops, it is likely that the main cereal crops were always autumn sown.

Hulled wheats in Greece to classical antiquity

Numerous Neolithic settlements appear in Greece in the early 6th millennium bc. Einkorn and emmer continue to be important crops through to the end of the Late Bronze Age (late 2nd millennium BC), and are joined by spelt at Late Bronze Age Assiros (see Halstead 1994 for a useful review of the prehistoric evidence). At Assiros Touma extensive burnt storerooms have been carefully excavated (Jones *et al.* 1986). About 1350 BC (Late Bronze Age) a fire destroyed several rooms in the settlement, preserving large quantities of charred crops. By comparing the contents of each store, it became clear that emmer and spelt were grown together as a mixed ('maslin') crop. Einkorn, free-threshing wheat, hulled barley and millet were also grown. All three hulled wheats were stored in spikelet form. Cultivation of hulled wheats continues into the Iron Age at a number of sites.

Once we reach the period of classical Greece (roughly 700-300 BC), a wide range of textual evidence becomes available. The vast modern literature discussing this is perhaps more a tribute to the difficulties in translation and interpretation than an indication of how much we know about ancient Greek agriculture. Much of the older literature (for example, Jasny 1944) is unreliable because of the inadequate archaeobotanical data available at the time against which identifications could be tested. However, Jasny's work is the only modern attempt at translating ancient terms for cereals on an explicit, clearly argued basis.

During the classical period the importance of both barley and the hulled wheats seems to have sharply declined, while free-threshing wheats (of unknown ploidy level) replaced them (Amouretti 1986:36; Sallares 1991:346-348). The reason for the decline of barley and the hulled wheats has been a topic of debate for over 50 years.

Jasny (1942) draws a parallel between the decline of spelt in Germany and the decline of the hulled wheats in Greece. In the 19th century spelt was the principal bread-grain crop. Under traditional farming it yielded as much or more than bread wheat, and was therefore worth growing despite the trouble of removing the glumes. With the arrival of commercial fertilizer and modern plant breeding, bread wheat became as productive as spelt and took over as the main crop. Jasny (1942) suggests a similar economic explanation for ancient Greece: some form of agricultural intensification led to free-threshing wheats being more productive.

In contrast, Robert Sallares (1991:313-316) suggests that wheat became more important than barley because population densities fell and there was less need for farmers to concentrate on the more dependable yields available from barley. With regard to the replacement of hulled wheats by free-threshing wheats, Sallares (1991:333-361) suggests that (p. 354) "...the 'productivity' of tetraploid naked wheats gradually evolved to attain a level sufficiently high to become superior to emmer in the eyes of farmers who assessed cereal productivity on the basis of seed size".

There is no evidence, however, for a continuing increase in the seed size of free-threshing wheats in archaeological samples. In any case it seems unlikely that any selection pressure operating on seed size in free-threshing wheats would not also operate on hulled wheats. Overall it seems that the cereals stayed the same, but that economic imperatives changed.

The hulled wheats of ancient Greece were *tiphe* (τιφη), identified as einkorn, and *zeia* (ζειδ) or *alura* (αλυρα), applied to emmer or spelt (Jasny 1944:109-133). In the case of ancient Greece, the archaeobotanical evidence for the presence of spelt, albeit less common than emmer, in the late Iron Age (Kroll 1983) suggests that some ancient references may be to spelt rather than emmer. Since emmer is the most common hulled wheat archaeobotanically, it was doubtless referred to most often.

Hulled wheats in the Roman Empire

Far more literary sources survive from the Roman empire than from ancient Greece, including numerous manuals of agricultural methods and natural histories that include a wide range of agricultural information (White 1970). The main terms used in Roman texts were *tiphe*, which has been translated as einkorn, and *adoreum*, *ador* or *far*, which have been taken to be emmer. A wide range of other, less common, terms were used in different periods (Jasny 1944:112), to designate local forms, or to differentiate between grain in spikelets and clean grain. Translation of these terms is only possible by looking at how they are used; in practice, they are virtually always open to a number of interpretations and definite translation is rarely possible (Jasny 1944:112-116).

The translation of *adoreum*/*far* has been controversial in the past. Older publications suggested spelt, perhaps as a term for the hulled wheats in general. The term may also have been used because spelt was the hulled wheat most familiar to classicists in Germany who were responsible for most of this speculation. Jasny (1944:119-124) identified *ador* and *far* as emmer on two grounds. First, the Greek term *alura* was used for hulled wheat in Egypt; hulled wheat in Egypt was exclusively emmer (true – see above); Pliny identified *alura* with *far*; therefore *far* must be emmer. Second, Jasny believed the archaeobotanical evidence pointed to spelt as a central European species that did not penetrate south of the Po valley.

Archaeobotanical evidence to complement Roman written sources is still scarce from Italy. Although spelt is abundant at the middle Bronze Age site of Fiavé (1400-1200 BC), this site is in the extreme north of Italy (Jones and Rowley-Conwy 1984). Overall, such archaeobotanical evidence as exists does seem to support Spurr's (1986:13) contention that "There can be little doubt that emmer was the most widespread husked wheat in Roman Italy". The translation of *adoreum*/*far* as emmer – in the context of Italy – seems reasonable, and is supported by the evidence of the crops that survived to modern times. Both einkorn and emmer still grow in Italy and are probably the remnants of ancient cultivation; spelt is grown in Italy today but is a recent introduction (D'Antuono 1994).

Based on textal evidence, emmer seems to have been widely cultivated. It was used for making puls (porridge) and alica (groats) (Braun 1995; Währen and Schneider 1995). Although it has often been argued that emmer was not used for bread because parching would have made it unsuitable, we have shown that parching very probably did not take place (see **Parching of hulled wheats**, above). In any case, it is clear that emmer was used for bread elsewhere in the past, notably Egypt. Given the abundant ethnographic evidence for emmer bread, it seems likely that it was also made in Roman Italy (cf. Braun 1995:34-37). Experimental work by cereal breeders has shown that satisfactory risen loaves can be made from hulled wheats (Yamashita *et al.* 1957). Although Le Clerc *et al.* (1918) concluded from their experimental work that einkorn bread was not suitable for yeast-risen bread and emmer bread was barely suitable, it would be a big mistake to judge the quality of cereals by modern standards of fluffy white bread.

It has been suggested that emmer was no longer important for human food by the time of Pliny the Elder (23-79), author of the Natural History (Moritz 1958:xxii). This might be true for urban Rome, but the extensive coverage Pliny gives to emmer suggests it was still widely grown. It is likely that the decline of hulled wheats in Italy was a highly regionalized process as it was still grown in the Medieval period (D'Antuono 1993:42; Toubert 1973) and has survived until the present day. Few agricultural texts survive between the 2nd century AD and the medieval period, so archaeobotanical evidence will be needed to investigate this further. As long as appropriate sites are carefully excavated and the plant remains properly retrieved, this is a question which archaeobotany is well suited to address.

The decline of the hulled wheats in Europe

The 1st millennium AD saw the replacement of hulled wheats by free-threshing wheats over most of Europe. The timing and reasons for this change are unclear. Although the changeover is usually visible by the medieval period, archaeobotanical or textual evidence is usually very scarce for the period between the 5th and 10th centuries AD. As in the Near East, there is no reason to believe the changeover is the result of the sudden import into Europe of free-threshing wheats: both tetraploid and hexaploid forms had been growing alongside hulled wheats for millennia. However, the rise of cereals such as rye may have been a factor. In some areas hulled wheats continued to be grown, most notably in the case of spelt in southern Germany and northern Switzerland (Rösch *et al.* 1992).

Conclusions

We have covered a wide area, geographically and in terms of subject matter. Our conclusions about the current understanding of hulled wheats in the past fall naturally into four topics: domestication, the spread of hulled wheats, their subsequent decline and their distinctive uses.

Domestication of hulled wheats

The combination of botanical evidence for the distribution of wild ancestors, and archaeobotanical evidence of the first occurrences of domesticated hulled wheats, points clearly to the Fertile Crescent of the Near East as the area of domestication of einkorn and emmer. Although the dating of the earliest farming settlements can no longer be assigned so firmly to 8000 bc, they are certainly well established by 7500 bc. Archaeobotanical reports are very much skewed to those areas of the Fertile Crescent where most archaeological fieldwork has been carried out: the Levant and, to a lesser extent, southeast Turkey. The history of farming in northern Iraq and the Zagros mountains of Iran will be obscure until fieldwork resumes in these areas. At present there is insufficient evidence from botany or archaeology to pinpoint domestication in one part of the Fertile Crescent. Crop husbandry spread quickly within the Near East, so we may never know where it began; indeed, it may have developed simultaneously over a large area. It may be that an attempt to determine the precise location of domestication will prove ultimately to be impossible, but there is a great variety of evidence which remains to be explored before such a conclusion is drawn.

The history of spelt domestication is still unclear. Archaeobotanical evidence, particularly the absence of spelt from Near Eastern sites, fits poorly with the model in which spelt formed by hybridization of its two parents near the Caspian and diffused to Europe 2000-3000 years later than the Neolithic package of crops. The paucity and poor documentation of archaeological records of spelt along the proposed migration route, north of the Black Sea, is troubling. Independent evolution of spelt from local populations of bread wheat in Europe still seems highly plausible.

We have also looked at the various hulled wheats endemic to Transcaucasia. Some of these, for example *T. timopheevi* and *T. macha*, appear to occur infrequently as weeds of present-day crops and to be close to wild wheats in rachis brittleness. These are typical characters of feral derivatives of domesticated plants, and we consider these wheats to be a local development that has no significance for wheat evolution elsewhere. However, these are a useful reminder that greater variety of forms may have existed in the past, although the overall similarity of emmer from widely separated areas suggests that less variation has evolved than we might expect.

Although botanical and genetical approaches have unraveled much of the evolution of wild wheats, there is still room for studies that use a wider range of populations, and which look at regional variation in more detail. Modern populations of domesticated hulled wheats in Transcaucasia, Turkey, Iran, Ethiopia, the Maghreb and Europe are still very poorly known. The application of more sophisticated techniques of genetical characterization might well throw light on the interrelationships and spread of these crops.

Spread of hulled wheats

Around 6000 bc, agriculture – by this time often incorporating domesticated animals – had started to spread outside the Near East proper. Evidence from the east is scarce, but 6th millennium Jeitun, in Turkmenistan, is an unusual case in which einkorn is the dominant wheat. In most areas where einkorn and emmer are grown, emmer is consistently the more important crop. There is scanty evidence for hulled wheats in India, or in central Asia from the Bronze Age onwards. It is surprising that the hulled wheats failed to establish themselves in these areas of rugged environments, but as yet we can offer no explanation. The scarcity of prehistoric records of emmer in India suggests that its present-day emmer crops may be a relatively recent introduction.

To the west, the spread of farming from the Near East is clearly shown by the radiocarbon dating of early agricultural villages: the further away from the Near East, the later the arrival of farming. The distribution of different forms of pottery and the location of sites show different routes of dispersal from Greece; on the one hand with the Linearbandkeramik cultures of central Europe, on the other along the Mediterranean coast. There is no evidence from archaeobotany of local domestication of wheat in Europe, nor indeed of the existence of wild wheats to be domesticated. Emmer and einkorn spread with barley and pulses and were staple crops throughout Europe.

The introduction of emmer cultivation into Egypt from the Near East is well documented, but the origin or antiquity of modern populations of hulled wheats in Ethiopia and the Maghreb is totally unknown.

Decline of the hulled wheats

In the late 20th century hulled wheats are no longer a major crop in any area. Throughout Eurasia hulled wheats declined at different times, ranging from 3000 BC in eastern Turkey to the 20th century in southern Germany and northern Switzerland. Explanations for the decline of hulled wheats fall into three groups: economic change, dietary change and the introduction of new crops. There are few detailed case studies of specific regions that do more than note, rather than explain, changing crop patterns. However, we think that such information as exists on the decline of spelt in the last 100 years points to two factors. First, economic pressure for increased productivity seem to select in favour of free-threshing wheats that respond better to increased inputs. Second, acculturation and change in eating habits occur as rural populations are drawn into industrialized food markets. We suspect that both factors were important in the past.

In view of the wide ranges of food uses attested ethnographically for hulled wheats, we are suspicious of arguments based on dietary change (e.g. a shift to leavened bread). The introduction of new species does not seem significant; in most cases hulled wheats have been replaced by free-threshing wheats that were already in the agricultural system. It may be that hulled wheat cultivation is sometimes linked to ethnicity; this needs to be studied further.

A major obstacle to modeling the importance of hulled wheats is our very limited understanding of their agricultural ecology. Assumptions are often made about their differential response to soil fertility, drought, waterlogging and salinity that are not supported by experimental work or studies of present-day cultivation. We urgently need agronomic trials of the widest possible range of hulled wheats, replicated in different locations and using a wide range of populations. Quantification of differences (if any) in agronomic potential between different hulled wheats, and between these and other wheats and barleys, could detect characteristics of value to modern agriculture as well as enhancing our understanding of the past. Although a number of experimental studies of hulled wheats have been undertaken, these usually relate only to trials of a few plants, and do not give us the overall data on yield per unit area that we need.

Hulled wheat uses

There is no doubt that our current dependence on macaroni wheat and bread wheat, utilized in industrial food products, colours our view of the hulled wheats. A wide variety of modern writings suggests that their uses are limited. However, considered as a whole, the ethnographic and archaeological evidence points to an enormous range of uses: as bread (leavened and unleavened), porridge, gruel, in soup, cracked wheat and beer. Different societies have focused on some of these uses rather than others, but it seems that these are for cultural reasons rather than because of inherent technological limitations in the foodstuffs themselves.

The main implication of this wide range of possible uses is that we need to avoid assumptions that particular cereals are linked to particular foods. Such assumptions are pervasive throughout the literature on ancient food, but can rarely be supported. More work is needed on archaeological remains of food and associated food-processing technology. In this area too, the collection of more detailed ethnographic information, while it still exists, would be invaluable for our appreciation of these wheats. An increased interest in the diverse uses of the hulled wheats may help to rescue these crops from oblivion.

Acknowledgements

We are very grateful to Stefano Padulosi for inviting us to the highly enjoyable and stimulating meeting from which this paper developed. We thank NERC and IPGRI for financial help. The illustrations were drawn by Jane Goddard and Kate Spence. We are indebted to Gordon Hillman and Dominique de Moulins for their invaluable comments.

Note added in proof:

Since the paper was completed, an important new publication has appeared:

Harris, David R. 1996. The Origins and Spread of Agriculture and Pastoralism in Eurasia. UCL Press, London.

In relation to emmer as food in Egypt, two more papers are now available:

Samuel, Delwen. 1996. Archaeology of ancient Egyptian beer. J. Am. Soc. Brewing Chemists 54(1):3-12.

Samuel, Delwen. 1996. Investigation of ancient Egyptian baking and brewing methods by correlative microscopy. Science 273 (in press).

References

Aaronsohn, A. 1910. Agricultural and botanical explorations in Palestine. Bureau of Plant Industry Bulletin 180. United States Department of Agriculture, Washington, DC.

Ammerman, A.J. and L.L. Cavalli-Sforza. 1984. The Neolithic Transition and the Genetics of Populations in Europe. Princeton University Press, Princeton, NJ.

Amouretti, M.-C. 1986. Le pain et l’huile dans la Grèce antique: de l'araire au moulin. Annales Littéraires de l'Université de Besançon 328. Les Belles Lettres, Paris.

Anderson, P.C. 1992. Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques. Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Anderson-Gerfaud, P., G. Depaprahamian and G. Willcox. 1991. Les premières cultures de céréales sauvages et domestiques primitives au Proche-Orient Néolithique: résultats préliminaires d'expériences à Jalès (Ardèche). Cahiers de l'Euphrate 5-6:191-232.

Badaeva, E.D., R.L. Boguslavsky, N.S. Badaev and A.V. Zelenin. 1990. Intraspecific chromosomal polymorphism of *Triticum araraticum* (Poaceae) detected by C-banding technique. Plant Systematics and Evolution 169:13-24.

Baines, J. and J. Málek. 1984. Atlas of Ancient Egypt. Equinox, Oxford.

Bakhteyev, F.K. and Z.V. Yanushevich. 1980. Discoveries of cultivated plants in the early farming settlements of Yarym-Tepe I and Yarym-Tepe II in northern Iraq. J. Archaeol. Sci. 7:167-178.

Ball, T.B. 1992. Phytolith morphometrics: the use of image analysis for morphologic and systematic study of various grass phytoliths (*Bouteloua*, *Panicum*, *Zea*, and *Triticum*). PhD thesis, Brigham Young University.

Bamakhramah, H.S., G.M. Halloran and J.H. Wilson. 1984. Components of yield in diploid, tetraploid and hexaploid wheats (*Triticum* spp.). Ann. Botany 54:51-60.

Barker, G. 1985. Prehistoric Farming in Europe. Cambridge University Press, Cambridge.

Bar-Yosef, O., A. Gopher, E. Tchernov and M.E. Kislev. 1991. Netiv Hagdud: an Early Neolithic village site in the Jordan Valley. J. Field Archaeol. 18:405-424.

Beranová, M. 1986. Origins of agricultural production in the light of coordinated experiments. Pp. 307-324 *in* Archaeology in Bohemia 1981-1985. Archaeological Institute of the Czechoslovak Academy of Sciences, Prague.

Bhatia, G.S. 1938. A new variety of "Khapli emmer" wheat from India, and its bearing upon the place of origin of emmer wheats. J. Genetics 35(3):321-329.

Boardman, S. and G. Jones. 1990. Experiments on the effects of charring on cereal plant components. J. Archaeol. Sci. 17:1-11.

Boodle, L.A. n.d. Botanical report on contents of Tutankhamun's tomb. Unpublished typescript. Griffith Institute, Oxford.

Borchardt, L. 1932. Ein Brot. Z. für Ägyptische Sprache und Altertumskunde 68:73-79.

Bottema, S. 1992. Cereal-type pollen in the Near East as indicators of wild or domestic crops. Pp. 95-111 *in* Préhistoire de l'agriculture (P. C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Bower, M. 1992. Cereal pollen dispersal: a pilot study. Cambridge Archaeological J. 2(2):236-241.

Bowman, A. K. 1990. Egypt after the Pharaohs. Oxford University Press, Oxford.

Braun, T. 1995. Barley cakes and emmer bread. Pp. 25-37 *in* Food in Antiquity (J. Wilkins, D. Harvey and M. Dobson, eds.). University of Exeter Press, Exeter.

Brown, T.A., R.G. Allaby, K.A. Brown, K. O'Donoghue and R. Sallares. 1994. DNA in wheat seeds from European archaeological sites. Experientia 50:571-575.

Bruyère, B. 1937. Rapport sur les fouilles de Deir el Médineh (1934-1935). Deuxième partie: La nécropole de l'est. Fouilles de l'Institut Français du Caire 15. L'Institut Français d'Archéologie Orientale, Cairo.

Charles, M.P. 1984. Introductory remarks on the cereals. Bull. Sumerian Agric. 1:17-31.

Chelak, V.R. 1978. Phylogeny of the Ispahan emmer wheat *T. ispahanicum* Heslot. Cytology and Genetics [English translation of Tsitologiya i Genetika] 12(4):34-41.

Costantini, L. 1984. The beginnings of agriculture in the Kachi plain: the evidence of Mehrgarh. Pp. 29-33 *in* South Asian Archaeology 1981 (B. Allchin, ed.). Cambridge University Press, Cambridge.

Crawford, D.J. 1979. Food: tradition and change in Hellenistic Egypt. World Archaeology 11(2):136-146.

Curwen, E.C. 1937. Querns. Antiquity 11(42):133-151.

Curwen, E.C. 1941. More about querns. Antiquity 15:15-32.

D'Antuono, L.F. 1989. Il farro: areali di coltivazione, caratteristiche agronomiche, utilizzazione e prospettive colturali. L'Informatore Agrario 45(24):49-57.

D'Antuono, L.F. 1993. Production and utilization of traditional and new specialist crops in Italy. Pp. 39-58 *in* Agriculture. The Production and Impact of Specialist Minor Crops in the Rural Community (G. Marshall and K. Svoboda, eds.). Commission of the European Communities.

D'Antuono, L.F. 1994. Obsolete wheats in Italy: an overview on cultivation, use and perspectives for their conservation. Pp. 41-48 *in* Report of the IPGRI workshop on conservation and use of underutilized Mediterranean species (S. Padulosi, H. Ager and E. Frison, eds.). International Plant Genetic Resources Institute, Rome.

Darby, W.J., P. Ghalioungui and L. Grivetti. 1977. Food: The Gift of Osiris. 2. Academic Press, London.

Davies, M.S. and G.C. Hillman. 1988. Effects of soil flooding on growth and grain yield of populations of tetraploid and hexaploid species of wheat. Ann. Botany 62:597-604.

Davies, N.G. and A.H. Gardiner. 1920. The tomb of Antefoker, Vizier of Sesostris I, and of his wife, Senet (No. 60). The Theban Tombs Series Second Memoir. George Allen & Unwin, London.

de Moulins, D. 1993. Les restes de plantes carbonisées de Cafer Höyük. Cahiers de l'Euphrate 7:191-234.

De Vartavan, C. 1993. "Combined-systems" analysis for the interpretation of plant remains from the tomb of Tutankhamun. PhD thesis, University College, University of London.

Dekaprelevich, L.L. 1961. Die Art *Triticum macha* Dek. et Men. im Lichte neuester Untersuchungen über die Herkunft der hexaploiden Weizen. Z. für Pflanzenzüchtung 45:17-30.

Deloye, H. and H. Laby. 1948. Les varietés des céréales cultivées en Algérie. Agria.

Demissie, A. and G. Habtemariam. 1991. Wheat genetic resources in Ethiopia. Pp. 33-46 *in* Wheat Research in Ethiopia: a Historical Perspective (H. Gebre-Mariam, D.G. Tanner and M. Hulluka, eds.). Institute of Agricultural Research, Addis Ababa.

Dennell, R. 1985. European Economic Prehistory: a New Approach. Academic Press, London.

Dorofeev, V.F. and E.F. Migushova. 1979. Flora of Cultivated Plants. 1. Wheat. Kolos, Leningrad.

Dorofejev, W.F. 1971. Die Weizen Transkaukasiens und ihre Bedeutung in der Evolution der Gattung *Triticum* L. 3. Die Spelzweizen Transkaukasiens (*T. macha* Dek. et Men., *T. spelta* L. subsp. *spelta* Dorof., subsp. *kuckuckianum* Gökg. und subsp. *vavilovii* Sears). Z. für Pflanzenzüchtung 66:335-360.

Drenkhahn, R. 1975. Brot. Pp. 871 *in* Lexikon der Ägyptologie. A-Ernte (W. Helck and E. Otto, eds.). Volume 1. Otto Harrassowitz, Wiesbaden.

Ducellier, L. 1930. Espèces et variétés de céréales cultivées en Algérie. Alger.

Dunstone, R.L. and L.T. Evans. 1974. Role of changes in cell size in the evolution of wheat. Am. J. Plant Physiol. 1:157-165.

Dvorak, J., P.E. McGuire and B. Cassidy. 1988. Apparent sources of the A genome of wheats inferred from polymorphism in abundance and restriction fragment length of repeated nucleotide sequences. Genome 30:680-689.

Edwards, K.J. 1989. The cereal pollen record and early agriculture. Pp. 113-135 *in* The Beginnings of Agriculture (A. Milles, D. Williams and N. Gardner, eds.). International Series 496. BAR, Oxford.

Evans, L.T. 1976. Physiological adaptation to performance as crop plants. Philosophical Trans. of the Royal Society of London. Series B. 275:71-83.

Evans, L.T. 1993. Crop Evolution, Adaptation and Yield. Cambridge University Press, Cambridge.

Evans, L.T. and R.L. Dunstone. 1970. Some physiological aspects of evolution in wheat. Australian J. Biological Sci. 23:725-41.

Evans, L.T., R.L. Dunstone, H.M. Rawson and R.F. Williams. 1970. The phloem of the wheat stem in relation to requirements for assimilate by the ear. Australian J. Biological Sci. 23:743-52.

Evershed, R.P. 1993. Biomolecular archaeology and lipids. World Archaeology 25(1):74-93.

Feldman, M. 1977. Historical aspects and significance of the discovery of wild wheats. Pp. 121-145 *in* Stadler Symposium 9. University of Missouri, Columbia, Missouri.

Fenton, A. 1978. The Northern Isles: Orkney and Shetland. John Donald, Edinburgh.

Flaksberger, C.A. 1925. Pshenitsa odnozernyahki (wheat-einkorn). Bull. Appl. Botany and Plant-Breeding (Trudy po Prikladnoi Botanike i Selektsii) 15(1):207-227.

French, D. 1973. Chemical and physical properties of starch. J. Anim. Sci. 37(4):1048-1061.

French, D.H., G.C. Hillman, S. Payne and R.J. Payne. 1972. Excavations at Can Hasan III 1969-1970. Pp. 181-190 *in* Papers in Economic Prehistory (E.S. Higgs, ed.). Cambridge University Press, Cambridge.

Garfinkel, Y., M.E. Kislev and D. Zohary. 1988. Lentil in the Pre-Pottery Neolithic B Yiftah'el: additional evidence of its early domestication. Israel J. Botany 37:49-51.

Garrard, A., D. Baird, S. Colledge, L. Martin and K. Wright. 1994. Prehistoric environment and settlement in the Azraq Basin: an interim report on the 1987 and 1988 excavation seasons. Levant 26:73-109.

Garrard, A.N., S. Colledge, C. Hunt and R. Montague. 1988. Environment and subsistence during the late Pleistocene and early Holocene in the Azraq Basin. Paléorient 14(2):40-49.

Gebel, H.G., M.S. Muheisen and H.J. Nissen. 1988. Preliminary report on the first season of excavations at Basta. Pp. 101-134 *in* The Prehistory of Jordan. The State of Research in 1986 (A.N. Garrard and H.G. Gebel, eds.). International Series 396 (i). BAR, Oxford.

Germer, R. 1986. Weizen. Pp. 1209-1210 *in* Lexikon der Ägyptologie. Stele-Zypresse (W. Helck and E. Otto, eds.). Volume 6. Otto Harrassowitz, Wiesbaden.

Gökgöl, M. 1961. Die iranischen Weizen. Z. für Pflanzenzüchtung 45:315-333.

Gunda, B. 1983. Cultural ecology of old cultivated plants in the Carpathian area. Ethnologia Europaea 13(2):145-179.

Halstead, P. 1994. The North-South divide: regional paths to complexity in prehistoric Greece. Pp. 195-219 *in* Development and Decline in the Mediterranean Bronze Age (C. Mathers and S. Stoddart, eds.). J.R. Collis, Sheffield.

Hansen, J.M. 1991. The palaeoethnobotany of Franchthi Cave. Excavations at Franchthi Cave, Greece 7. Indiana University Press, Bloomington, IN.

Harlan, J.R. 1967. A wild wheat harvest in Turkey. Archaeology 20(3):197-201.

Harlan, J.R. and D. Zohary. 1966. Distribution of wild wheats and barley. Science 153:1074-1080.

Harris, D.R., V.M. Masson, Y.E. Berezin, M.P. Charles, C. Gosden, G.C. Hillman, A.K. Kasparov, G.F. Korobkova, K. Kurbansakhatov, A.J. Legge and S. Limbrey. 1993. Investigating early agriculture in Central Asia: new research at Jeitun, Turkmenistan. Antiquity 67(255):324-338.

Helbaek, H. 1959a. Domestication of food plants in the old world. Science 130(3372):365-372.

Helbaek, H. 1959b. How farming began in the old world. Archaeology 12:183-189.

Helbaek, H. 1966. Pre-pottery Neolithic farming at Beidha: a preliminary report. Palestine Exploration Quarterly 98:61-66.

Helbaek, H. 1969. Plant collecting, dry-farming, and irrigation agriculture in prehistoric Deh Luran. Pp. 383-426, plates 40-41 *in* Prehistory and Human Ecology of the Deh Luran Plain. An Early Village Sequence from Khuzistan, Iran (F. Hole, K.V. Flannery and J.A. Neely, eds.). Mem. of the Museum of Anthropology 1. University of Michigan, Ann Arbor, MI.

Helbaek, H. 1970. The plant husbandry of Hacilar. Pp. 189-244 *in* Excavations at Hacilar. Volume I (J. Mellaart, ed.). British Institute of Archaeology at Ankara, Occasional Publication 9. Edinburgh University Press, Edinburgh.

Henry, D.O. 1989. From foraging to agriculture: the Levant at the end of the Ice Age. University of Pennsylvania Press, Philadelphia, PA.

Hepper, F.N. 1990. Pharaoh's Flowers. The Botanical Treasures of Tutankhamun. Her Majesty's Stationery Office, London.

Heslot, H. 1958. *Triticum hispahanicum*: une nouvelle espèce de blé cultivé originaire d'Iran. C. R. Hebdomadaires des Séances de l'Académie des Sciences 247:2477-2479.

Hillman, G.C. 1978. On the origins of domestic rye - *Secale cereale*: the finds from Aceramic Can Hasan III in Turkey. Anatolian Studies 28:157-174.

Hillman, G.C. 1981. Reconstructing crop husbandry practices from charred remains of crops. Pp. 123-162 *in* Farming Practice in British Prehistory (R. Mercer, ed.). Edinburgh University Press, Edinburgh.

Hillman, G.C. 1982. Evidence for spelt malting at Catsgore. Pp. 137-141 *in* Excavations at Catsgore 1970-1973: a Romano-British village (R. Leech, ed.). Western Archaeological Trust, Bristol.

Hillman, G.C. 1984a. Interpretation of archaeological plant remains: the application of ethnographic models from Turkey. Pp. 1-41 *in* Plants and Ancient Man. Studies in Palaeoethnobotany (W. van Zeist and W. A. Casparie, eds.). A.A. Balkema, Rotterdam.

Hillman, G.C. 1984b. Traditional husbandry and processing of archaic cereals in modern times: Part I, the glume-wheats. Bull. Sumerian Agric. 1:114-152.

Hillman, G.C., S.M. Colledge and D.R. Harris. 1989. Plant-food economy during the Epipalaeolithic period at Tell Abu Hureyra, Syria: dietary diversity, seasonality, and modes of exploitation. Pp. 240-268 *in* Foraging and Farming: The Evolution of Plant Exploitation (D.R. Harris and G.C. Hillman, eds.). Unwin Hyman, London.

Hillman, G.C. and M.S. Davies. 1990. Measured domestication rates in wild wheats and barley under primitive cultivation, and their archaeological implications. J. World Prehistory 4(2):157-222.

Hillman, G.C. and M.S. Davies. 1992. Domestication rate in wild wheats and barley under primitive cultivation: preliminary results and archaeological implications of field measurements of selection coefficient. Pp. 113-158 *in* Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques (P.C. Anderson, ed.). Monographie du CRA 6. Éditions du CNRS, Paris.

Hillman, G.C., S. Mason, D. de. Moulins and M. Nesbitt. 1996. Identification of archaeological remains of wheat: the 1992 London workshop. Circaea (In press).

Hillman, G.C., S. Wales, F. McLaren, J. Evans and A. Butler. 1993. Identifying problematic remains of ancient plant foods: a comparison of the role of chemical, histological and morphological criteria. World Archaeology 25(1):94-121.

Hoffner, H.A. 1974. Alimenta hethaerorum: food production in Hittite Asia Minor. American Oriental Series 55. American Oriental Society, New Haven, CT.

Hopf, M. 1954. Anatomische Untersuchungen an Weizenspelzen und -körnern verschiedener Polyploidiestufen als Vorarbeit für die Bestimmung prähistorischer Funde. Der Züchter 24(6):174-180.

Hopf, M. 1983. Appendix B. Jericho plant remains. Pp. 576-621 *in* Jericho. Volume V. The Pottery Phases of the Tell and Other Finds (K. Kenyon and T. A. Holland, eds.). British School of Archaeology in Jerusalem, London.

Hopf, M. and O. Bar-Yosef. 1987. Plant remains from Hayonim Cave, western Galilee. Paléorient 13(1):117-120.

Howard, A. and G.L.C. Howard. 1910. Wheat in India: its production, varieties and improvement. Imperial Department of Agriculture in India, Calcutta.

Hrozný, F. 1913. Das Getreide im alten Babylonien. Ein Beitrag zur Kultur- und Wirtschaftsgeschichte des alten Orients. I. Teil. Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien, phil.-hist. Klasse 173/I. Vienna.

Hubbard, R. 1990. Archaeobotany of Abdul Hosein. The carbonised seeds from Tepe Abdul Hosein: results of preliminary analyses. Pp. 217-221 *in* Tepe Abdul Hosein: a Neolithic Site in Western Iran, Excavations 1978 (J. Pullar, ed.). International Series 563. BAR, Oxford.

Hunshal, C.S., R.B. Balikai and D.P. Viswanath. 1990. *Triticum dicoccum* - its performance in comparison with barley under salinity. J. Maharashtra Agric. Univ. 15(3):376-377.

Jaaska, V. 1993. Isoenzymes in the evaluation of germplasm diversity in wild diploid relatives of cultivated wheat. Pp. 247-257 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley, Chichester.

Jacobsen, T. 1982. Salinity and irrigation agriculture in antiquity. Diyala Basin archaeological projects: report on essential results 1957-58. Bibliotheca Mesopotamica 14. Undena, Malibu, CA.

Jacomet, S., C. Brombacher and M. Dick. 1989. Archäobotanik am Zürichsee. Berichte der Zürcher Denkmalpflege, Monographien 7. Orell Füssli, Zürich.

Jakubziner, M.M. 1958. New wheat species. Pp. 207-220 *in* Proceedings of the First International Wheat Genetics Symposium (B.C. Jenkins, ed.). Winnipeg.

Janushevich, Z.V. 1984. The specific composition of wheat finds from ancient agricultural centres in the USSR. Pp. 267-276 *in* Plants and Ancient Man: Studies in Palaeoethnobotany (W. van Zeist and W.A. Casparie, eds.). Balkema, Rotterdam.

Jasny, N. 1942. Competition among grains in classical antiquity. Am. Historical Review 47:747-764.

Jasny, N. 1944. The Wheats of Classical Antiquity. Johns Hopkins Press, Baltimore, MD.

Johnson, B.L. 1968. Electrophoretic evidence on the origin of *Triticum zhukovskyi*. Pp. 105-110 *in* Proceedings of the third International Wheat Genetics Symposium. Canberra.

Johnson, B.L. 1972. Seed protein profiles and the origin of the hexaploid wheats. Am. J. Botany 59(9):952-960.

Johnson, B.L. 1975. Identification of the apparent B-genome donor of wheat. Can. J. Genetics and Cytology 17:21-39.

Jones, G.E.M. and P. Rowley-Conwy. 1984. Plant remains from the North Italian lake dwellings of Fiavé (1400-1200 b.c.). Patrimonio Storico e Artistico del Trentino 8:323-355.

Jones, G., K. Wardle, P. Halstead and D. Wardle. 1986. Crop storage at Assiros. Scientific American 254(3):96-103.

Jones, G.E.M. 1981a. Crop processing at Assiros Toumba - a taphonomic study. Z. für Archäologie 15:105-111.

Jones, M. 1981b. The development of crop husbandry. Pp. 95-127 *in* The Environment of Man: the Iron Age to the Anglo-Saxon Period (M. Jones and G. Dimbleby, eds.). British Series 87. BAR, Oxford.

Kajale, M.D. 1991. Current status of Indian palaeoethnobotany: introduced and indigenous food plants with a discussion of the historical and evolutionary development of Indian agriculture and agricultural systems in general. Pp. 155-189 *in* New Light on Early Farming: Recent Developments in Palaeoethnobotany (J.M. Renfrew, ed.). Edinburgh University Press, Edinburgh.

Kaplan, L., M.B. Smith and L.A. Sneddon. 1992. Cereal grain phytoliths of southwest Asia and Europe. Pp. 149-174 *in* Phytolith Systematics: Emerging Issues (G. Rapp and S.C. Mulholland, eds.). Advances in Archaeological and Museum Science 1. Plenum, New York, NY.

Kemp, B.J. 1987. The Amarna Workmen's village in retrospect. J. Egyptian Archaeol. 73:21-50.

Kemp, B.J. 1989. Ancient Egypt. Anatomy of a Civilization. Routledge, London.

Kemp, B.J. 1994. Food for an Egyptian city. Pp. 133-153 *in* Whither Environmental Archaeology? (R. Luff and P. Rowley-Conwy, eds.). Monograph 38. Oxbow, Oxford.

Kemp, B.J. 1995. Outlying temples at Amarna. Pp. 411-462 *in* Amarna Reports VI (B.J. Kemp, ed.). Occasional Publications 10. Egypt Exploration Society, London.

Kerber, E.R. and G.G. Rowland. 1974. Origin of the free threshing character in hexaploid wheat. Can. J. Genetics and Cytology 16:145-154.

Kerby, K. and J. Kuspira. 1987. The phylogeny of the polyploid wheats *Triticum aestivum* (bread wheat) and *Triticum turgidum* (macaroni wheat). Genome 29:722-737.

Kimber, G. and E.R. Sears. 1987. Evolution in the genus *Triticum* and the origin of cultivated wheat. Pp. 154-164 *in* Wheat and Wheat Improvement. Second Edition (E.G. Heyne, ed.). Agronomy 13. American Society of Agronomy, Madison, WI.

Kislev, M.E. 1988. Desiccated plant remains: an interim report. 'Atiqot 18:76-81, pl. XXVII-XXVIII.

Kislev, M.E. 1989. Pre-domesticated cereals in the Pre-Pottery Neolithic A period. Pp. 147-151 *in* Man and Culture in Change (I. Hershkovitz, ed.). International Series 508. BAR, Oxford.

Kislev, M.E. 1992. Agriculture in the Near East in the VIIth millennium bc. Pp. 87-93 *in* Préhistoire de l'agriculture (P.C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Kislev, M.E., O. Bar-Yosef and A. Gopher. 1986. Early Neolithic domesticated and wild barley from the Netiv Hagdud region in the Jordan valley. Israel J. Botany 35:197-201.

Kislev, M.E., D. Nadel and I. Carmi. 1992. Epipalaeolithic (19,000 BP) cereal and fruit diet at Ohalo II, Sea of Galilee, Israel. Review of Palaeobotany and Palynology 73:161-166.

Körber-Grohne, U. 1981. Distinguishing prehistoric cereal grains of *Triticum* and *Secale* on the basis of their surface patterns using the scanning electron microscope. J. Archaeol. Sci. 8:197-204.

Körber-Grohne, U. 1987. Nutzpflanzen in Deutschland. Konrad Theiss, Stuttgart.

Körber-Grohne, U. 1989. The history of spelt (*Triticum spelta*) on the basis of archaeobotanical findings from Neolithic to Medieval times, and the data by written sources until today. Pp. 51-59 *in* L'épeautre (*Triticum spelta*): histoire et ethnologie (J.-P. Devroey and J.-J. van Mol, eds.). Dire, Treignes.

Kroll, H.J. 1983. Kastanas. Die Pflanzenfunde. Prähistorische Archäologie in Südosteuropa 2. Volker Spiess, Berlin.

Kroll, H.J. 1992. Einkorn from Feudvar, Vojvodina, II. What is the difference between emmer-like two-seeded einkorn and emmer? Review of Palaeobotany and Palynology 73:181-185.

Kuckuck, H. 1960. Über das Vorkommen von *Triticum spelta* im Iran, mit einem Beitrag zur Entwicklung der hexaploiden Kulturweizen. Pp. 27-34 *in* Berichte der 2 Kongress Eucarpia, Köln 1959. Köln.

Kuckuck, H. 1970. Primitive wheats. Pp. 249-266 *in* Genetic Resources in Plants - Their Exploration and Conservation (O. H. Frankel and E. Bennett, eds.). London.

Kuckuck, H. and E. Schiemann. 1957. Über das Vorkommen von Spelz und Emmer (*Triticum spelta* L. und *Tr. dicoccum* Scübl.) im Iran. Z. für Pflanzenzüchtung 38:383-396.

Küster, H. 1984. Neolithic plant remains from Eberdingen-Hochdorf, southern Germany. Pp. 307-311 *in* Plants and Ancient Man. Studies in Palaeoethnobotany (W. van Zeist and W.A. Casparie, eds.). A.A. Balkema, Rotterdam.

Küster, H. 1985. Neolithische Pflanzenreste aus Hochdorf, Gemeinde Eberdingen (Kreis Ludwigsburg). Pp. 15-83 *in* Hochdorf I (H. Küster and U. Körber-Grohne, eds.). Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 19. Konrad Theiss, Stuttgart.

Küster, H. 1991. Mitteleuropa südlich der Donau, einschliesslich Alpenraum [Central Europe south of the Danube]. Pp. 179-187 *in* Progress in Old World Palaeoethnobotany (W. van Zeist, K. Wasylikowa and K.-E. Behre, eds.). Balkema, Rotterdam.

Lange-de la Camp, M. 1939. Die Weizen der Deutsches Hindukush-Expedition 1935. Landwirtschaftliche Jahrbücher 88:14-133.

Le Clerc, J.A., L.H. Bailey and H.L. Wessling. 1918. Milling and baking tests of einkorn, emmer, spelt, and Polish wheat. J. Am. Soc. Agron. 10:215-217.

Lein, A. 1949. Asiatische Weizensortimente. Kühn-Archiv 62:216-310.

Lisicyna, G. 1983. Die ältesten paläoethnobotanischen Funde in Nordmesopotamien. Vorläufiger Bericht. Z. für Archäologie 17:31-38.

Lisitsina, G.N. 1984. The Caucasus - a centre of ancient farming in Eurasia. Pp. 285-292 *in* Plants and Ancient Man: Studies in Palaeoethnobotany (W. van Zeist and W. A. Casparie, eds.). Balkema, Rotterdam.

Lüning, J. and J. Meurers-Balke. 1980. Experimenteller Getreideanbau im Hambacher Forst, Gemeinde Elsdorf, Kr. Bergheim / Rheinland. Bonner Jahrbücher 180:305-344.

Mac Key, J. 1966. Species relationship in *Triticum*. Pp. 237-276 *in* Proceedings of the Second International Wheat Genetics Symposium. Hereditas Supp. 2.

Markus, M. 1975. Tenkel' a jeho karpatoeurópske obmeny (Der Dinkel und seine Karpatoeuropäischen Varianten). Slovensky Národopis 23:23-39.

McCorriston, J. and F. Hole. 1991. The ecology of seasonal stress and the origins of agriculture in the Near East. American Anthropologist 93(1):46-69.

McFadden, E.S. and E.R. Sears. 1946. The origin of *Triticum spelta* and its free-threshing hexaploid relatives. J. Heredity 37(4):81-89, 107-116.

Mekbib, H. and G.H. Mariam. 1990. Evaluation and utilization of Ethiopian wheat germplasm. Pp. 179-185 *in* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). John Wiley, Chichester.

Mellaart, J. 1975. The Neolithic of the Near East. Thames and Hudson, London.

Meurers-Balke, J. and J. Lüning. 1992. Some aspects and experiments concerning the processing of glume wheats. Pp. 341-362 *in* Préhistoire de l'agriculture (P.C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Miége, E. 1924. Les formes marocaines de *Triticum monococcum* L. Bull. de la Société des Sciences Naturelles du Maroc 4(7):154-160.

Miége, E. 1925. Sur la présence au Maroc de *Tr. dicoccum*. Bull. de la Société des Sciences Naturelles du Maroc 5(3):98-109.

Miller, N.F. 1991. The Near East. Pp. 133-160 *in* Progress in Old World Palaeoethnobotany (W. van Zeist, K. Wasylikowa and K.-E. Behre, eds). Balkema, Rotterdam.

Mithal, S.K. and M.N. Kopper. 1990. Evaluation and conservation of wheat genetic resources in India. Pp. 201-209 *in* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). John Wiley, Chichester.

Moore, K.M., N.F. Miller, F.T. Hiebert and R.H. Meadow. 1994. Agriculture and herding in the early oasis settlements of the Oxus Civilization. Antiquity 68(259):418-427.

Moritz, L.A. 1955. Husked and ‘naked’ grain. Classical Quarterly New Series 5(3 and 4):129-141.
Moritz, L.A. 1958. Grain-mills and Flour in Classical Antiquity. Clarendon Press, Oxford.
Morrison, L.A. 1993. *Triticum-Aegilops* systematics: taking an integrative approach. Pp. 59-66 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, London.
Nesbitt, M. 1993. Ancient crop husbandry at Kaman-Kalehöyük: 1991 archaeobotanical report. Pp. 75-97 *in* Essays on Anatolian Archaeology (T. Mikasa, ed.). Bulletin of the Middle Eastern Culture Center in Japan 7. Harrassowitz, Wiesbaden.
Nesbitt, M. 1994. Archaeobotanical research in the Merv Oasis. Iran 32:71-73.
Nesbitt, M. 1995a. 4. The search for plant remains. Pp. 9-11, 40-45 *in* Qermez Dere, Tell Afar: interim report no. 3 (T. Watkins, ed.). Project Paper 14. Department of Archaeology, University of Edinburgh, Edinburgh.
Nesbitt, M. 1995b. Plants and people in ancient Anatolia. Biblical Archaeologist 58(2):68-81.
Nesbitt, M. 1996a. Preliminary report on the Epipalaeolithic plant remains from M'lefaat. In Excavations at M'lefaat (S.K. Kozlowski, ed.). Warsaw, Poland.
Nesbitt, M. 1996b. A preliminary report on the plant remains from Kuruçay. In Kuruçay II. (R. Duru, ed.). Türk Tahrih Kurumu, Ankara.
Oates, D. and J. Oates. 1976. Early irrigation agriculture in Mesopotamia. Pp. 109-135 *in* Problems in Economic and Social Archaeology (G. de. G. Sieveking, I.H. Longworth and K.E. Wilson, ed.). Duckworth, London.
Peet, T.E. 1921. Excavations at Tell el-Amarna: A preliminary report. J. Egyptian Archaeol. 7:169-185.
Peet, T.E. and C.L. Woolley. 1923. The city of Akhenaten. Part I. Excavations of 1921 and 1922 at el-'Amarneh. 38th Memoir. Egypt Exploration Society, London.
Phillipson, D.W. 1993. The antiquity of cultivation and herding in Ethiopia. Pp. 344-357 *in* The Archaeology of Africa. Food, Metals and Towns (T. Shaw, P. Sinclair, B. Andah and A. Okpoko, eds.). One World Archaeology. Routledge, London.
Pliny. 1950. Natural History V. Libri XVII-XIX. William Heinemann, London.
Pohlendt, G. 1958. Anatomische Untersuchungen über die Brüchigkeit der hexaploiden Weizen unter Berücksichtigung der iranischen Spelzfunde. Z. für Pflanzenzüchtung 39:339-347.
Popova, C. 1991. Palaeoethnobotanic studies of the Neolithic and Eneolithic epoch in the territory of Bulgaria. Pp. 269-272 *in* Palaeoethnobotany and Archaeology (E. Hajnalová, ed.). Acta Interdisciplinaria Archaeologica 7. Archaeological Institute of the Slovak Academy of Sciences, Nitra.
Porceddu, E. and D. Lafiandra. 1986. Origin and evolution of wheats. Pp. 143-178 *in* The Origin and Domestication of Cultivated Plants (C. Barigozzi, ed.). Elsevier, Amsterdam.
Postgate, J.N. 1984a. Introduction. Bull. on Sumerian Agriculture 1:1-7.
Postgate, J.N. 1984b. Processing of cereals in the cuneiform record. Bull. on Sumerian Agriculture 1:103-113.
Potts, T.F., S.M. Colledge and P.C. Edwards. 1985. Preliminary report on a sixth season of excavation by the University of Sydney at Pella in Jordan (1983/84). Annual Report of the Department of Antiquities in Jordan 29:181-210.
Powell, M.A. 1984. Sumerian cereal crops. Bull. on Sumerian Agriculture 1:48-72.
Powell, M.A. 1985. Salt, seed, and yields in Sumerian agriculture. A critique of the theory of progressive salinization. Z. für Assyriologie und Vorderasiatische Archäologie 75(1):7-38.
Poyarkova, H. 1988. Morphology, geography and infraspecific taxonomics of *Triticum dicoccoides* Korn. A retrospective of 80 years of research. Euphytica 38:11-23.
Poyarkova, H. and Z.K. Gerechter-Amitai. 1991. Two variants of wild emmer (*Triticum dicoccoides*) native to Israel: morphology and distribution. Can. J. Botany 69:2772-2789.
Renfrew, C. 1987. Archaeology and Language. The Puzzle of Indo-European Origins. Jonathan Cape, London.
Renfrew, J.M. 1984. Cereals cultivated in ancient Iraq. Bull. on Sumerian Agriculture 1:32-44.
Rifaie, R., J.-J. Bourgois and J.R. Witcombe. 1981. *Aegilops* and wild wheat in Syria. Plant Genet. Resources Newsl. 45:2-7.

Rollefson, G.O., A.H. Simmons, M.L. Donaldson, W. Gillespie, Z. Kafafi, I.U. Kohler-Rollefson, E. McAdam, S.L. Ralston and K. Tubb. 1985. Excavation at the Pre-Pottery Neolithic B village of 'Ain Ghazal (Jordan) 1983. Mitteilugen der Deutschen Orient-Gesellschaft zu Berlin 117:69-116.

Rösch, M., S. Jacomet and S. Karg. 1992. The history of cereals in the region of the former Duchy of Swabia (*Herzogtum Schwaben*) from the Roman to the Post-medieval period: results of archaeobotanical research. Vegetation History and Archaeobotany 1:193-231.

Rosen, A.M. 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach. Pp. 129-147 *in* Phytolith Systematics: Emerging Issues (G. Rapp and S.C. Mulholland, eds.). Advances in Archaeological and Museum Science 1. Plenum, New York, NY.

Rosenberg, M., M. Nesbitt, R.W. Redding and T.F. Strasser. 1995. Hallan Çemi Tepesi: some preliminary observations concerning early Neolithic subsistence behaviors in eastern Anatolia. Anatolica 21:1-12.

Rüegger, A., H. Winzeler and J. Nösberger. 1990. Die Ertragsbildung von Dinkel (*Triticum spelta* L.) und Weizen (*Triticum aestivum* L.) unter verschiedenen Umweltbedingungen im Freiland. J. Agron. and Crop Sci. 164:145-152.

Sallares, R. 1991. The Ecology of the Ancient Greek World. Duckworth, London.

Sallares, R. 1995. Molecular archaeology and ancient history. Pp. 87-100 *in* Food in Antiquity (J. Wilkins, D. Harvey and M. Dobson, eds.). University of Exeter Press, Exeter.

Samuel, D. 1989. Their staff of life: initial investigations on ancient Egyptian bread baking. Pp. 253-290 *in* Amarna Reports V (B.J. Kemp, ed.). Occasional Publications 6. Egypt Exploration Society, London.

Samuel, D. 1993. Ancient Egyptian cereal processing: beyond the artistic record. Cambridge Archaeological J. 3(2):276-283.

Samuel, D. 1994. An archaeological study of baking and bread in New Kingdom Egypt. Ph.D thesis, University of Cambridge.

Schiemann, E. 1948. Weizen, Roggen, Gerste. Systematik, Geschichte und Verwendung. Gustav Fischer, Jena.

Schiemann, E. 1951. Emmer in Troja. Berichte der Deutschen Botanischen Gesellschaft 64:155-170.

Schiemann, E. 1956. Fünfzig Jahre *Triticum dicoccoides*. Aaronsohns Entdeckung des Wildemmer einst und jetzt. Berichte der Deutschen Botanischen Gesellschaft 59:309-322, Tafel VII, VIII.

Schulz, A. 1915. Über eine Emmerform aus Persien und einige andere Emmerformen. Berichte der Deutschen Botanischen Gesellschaft 33(4):233-242.

Sears, E.R. 1976. A synthetic hexaploid wheat with fragile rachis. Wheat Information Service 41-42:31-32.

Shao, Q. 1983. Semi-wild wheat from Xizang (Tibet). Pp. 111-113 in Proceedings of the Sixth International Wheat Genetics Symposium (ed.). Kyoto.

Singh, H.B., E. Anderson and B.P. Pal. 1957. Studies in the genetics of *Triticum vavilovi* Jakub. Agron. J. 49:4-11.

Sist, L. 1987. Food production. Pp. 46-75 *in* Egyptian Civilization: Daily Life (A.M. Donadoni Roveri, ed.). Electa, Milan.

Smith, B.D. 1995. The Emergence of Agriculture. Scientific American Library, New York, NY.

Spurr, M.S. 1986. Arable cultivation in Roman Italy c.200 B.C.-c.A.D. 100. Journal of Roman Studies Monographs 3. Society for the Promotion of Roman Studies, London.

Sumner, W.M. 1967. A typology of ancient Middle Eastern saddle querns. MA thesis, University of Pennsylvania.

Täckholm, V. 1977. Flora. Pp. 267-275 *in* Lexikon der Ägyptologie. Band II. Erntefest-Hordjedef (W. Helck and E. Otto, ed.).Volume 2. Otto Harrassowitz, Wiesbaden.

Täckholm, V., G. Täckholm and M. Drar. 1941. Flora of Eygpt. Volume I. Fouad I University, Cairo.

Tanaka, M. and H. Ishii. 1973. Cytogenetical evidence on the speciation of wild tetraploid wheats collected in Iraq, Turkey, and Iran. Pp. 115-121 *in* Proceedings of the Fourth

International Wheat Genetics Symposium (E.R. Sears and L.M.S. Sears, eds.). University of Missouri, Columbia, MI.
Toubert, P. 1973. Les structures du Latium médiéval. Le Latium méridional et la Sabine du IXe siècle à la fin du XIIe siècle. Ecole Francaise de Rome, Rome.
Tumanyan, M.G. 1929-1930. Wild einkorns and emmers in Armenia. Bulletin of Applied Botany, of Genetics and Plant-Breeding (Trudy po Prikladnoi, Botanike, Genetike i Selektsii) 24(1):1-14.
Ufer, M. 1956. Studien an afghanischen Weizen. Z. für Pflanzenzüchtung 36:133-152.
van Andel, T.H. and C.N. Runnels. 1995. The earliest farmers in Europe. Antiquity 69(264):481-500.
van der Veen, M. 1989. Charred grain assemblages from Roman-period corn driers in Britain. Archaeological J. 146:302-319.
van der Veen, M. 1992. Crop husbandry regimes: an archaeobotanical study of farming in northern England 1000 BC - AD 500. Sheffield Archaeological Monographs 3. J.R. Collis, Sheffield.
van Slageren, M.W. 1994. Wild wheats: a monograph of *Aegilops* L. and *Amblopyrum* (Jaub. & Spach) Eig (Poaceae). Agricultural Papers 94-7. Wageningen Agricultural University, Wageningen.
van Slageren, M.W., A. Elings, L. Holly, B. Humeid, A.A. Jaradat and K. Obari. 1989. Cereals, food legumes and their wild relatives in Syria and Jordan. Plant Genet. Resources Newsl. 80:5-14.
van Zeist, W. 1986. Plant remains from Neolithic El Kowm, central Syria. Pp. 65-68 *in* A Neolithic village at Tell El Kowm in the Syrian desert (R. H. Dornemann, ed.). Studies in Ancient Oriental Civilisation 43. Oriental Institute of the University of Chicago, Chicago, ILL.
van Zeist, W. and J.A.H. Bakker-Heeres. 1975. Prehistoric and early historic plant husbandry in the Altinova Plain, southeastern Turkey. Pp. 221-257 *in* Korucutepe 1 (M.N. van Loon, ed.). North-Holland, Amsterdam.
van Zeist, W. and J.A.H. Bakker-Heeres. 1982. Archaeobotanical studies in the Levant. 1. Neolithic sites in the Damascus basin: Aswad, Ghoraifé, Ramad. Palaeohistoria 24:165-256.
van Zeist, W. and J.A.H. Bakker-Heeres. 1984a. Archaeobotanical studies in the Levant 2. Neolithic and Halaf levels at Ras Shamra. Palaeohistoria 26:151-170.
van Zeist, W. and J.A.H. Bakker-Heeres. 1984b. Archaeobotanical studies in the Levant. 3. Late-Palaeolithic Mureybit. Palaeohistoria 26:171-199.
van Zeist, W. and J.A.H. Bakker-Heeres. 1985. Archaeobotanical studies in the Levant 4. Bronze Age sites on the north Syrian Euphrates. Palaeohistoria 27:247-316.
van Zeist, W. and S. Bottema. 1971. Plant husbandry in early Neolithic Nea Nikomedeia, Greece. Acta Botanica Neerlandica 20(5):524-538.
van Zeist, W. and G.J. de Roller. 1991/1992. The plant husbandry of aceramic Çayönü, SE Turkey. Palaeohistoria 33/34:65-96.
van Zeist, W. and W.-v. Rooijen. 1985. The palaeobotany of Tell Bouqras, eastern Syria. Paléorient 11(2):131-147.
van Zeist, W., P.E.L. Smith, R.M. Palfenier-Vegter, M. Suwijn and W.A. Casparie. 1986. An archaeobotanical study of Ganj Dareh Tepe, Iran. Palaeohistoria 26:201-224.
van Zeist, W., K. Wasylikowa and K.-E. Behre. 1991. Progress in Old World Palaeoethnobotany. Balkema, Rotterdam.
Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. Selected writings of N.I. Vavilov. Chronica Botanica 13/1-6. Ronald Press, New York, NY.
Vercoutter, J. 1992. L'Égypte et la vallée du Nil. Des origines à la fin de l'Ancien Empire 12000-2000 av. J.-C. Nouvelle Clio. L'Histoire et ses problèmes 1. Presses Universitaires de France, Paris.
Voigt, M.M. 1984. Village on the Euphrates. Excavations at Neolithic Gritille in Turkey. Expedition 27(1):10-24.
Währen, M. 1960. Die Backvorrichtungen des Altertums im Orient. Brot und Gebäck 5:86-96.
Währen, M. 1961. Typologie der altägyptischen Brote und Gebäck. Brot und Gebäck 6:1-17.

Währen, M. 1963. Brot und Gebäck im Leben und Glauben der alten Ägypter. Schweizerischer Bäcker-Konditorenmeister-Verband, Bern.

Währen, M. and C. Schneider. 1995. Die puls. Römischer Getreidebrei. Augster Museumshefter Römermuseum Augst, Augst.

Waines, J.G. and D. Barnhart. 1990. Constraints to germplasm evaluation. Pp. 103-111 *in* Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). John Wiley, Chichester.

Waines, J.G., M.M. Rafi and B. Ehdaie. 1993. Yield components and transpiration efficiency in wild wheats. Pp. 173-186 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley, Chichester.

Wasylikowa, K., M. Cârciumaru, E. Hajnalová, B.P. Hartyányi, G.A. Pashkevich and Z.V. Yanushevich. 1991. East-central Europe. Pp. 207-239 *in* Progress in Old World Palaeoethnobotany (W. van Zeist, K. Wasylikowa and K.-E. Behre, eds.). Balkema, Rotterdam.

Watkins, T., A. Betts, K. Dobney and M. Nesbitt. 1991. Qermez Dere, Tel Afar: interim report no 2. Project Paper 13. Department of Archaeology, University of Edinburgh, Edinburgh.

Wetterstrom, W. 1993. Foraging and farming in Egypt: the transition from hunting and gathering to horticulture in the Nile valley. Pp. 165-226 *in* The Archaeology of Africa. Food, Metals and Towns (T. Shaw, P. Sinclair, B. Andah and A. Okpoko, eds.). One World Archaeology. Routledge, London.

White, K.D. 1970. A bibliography of Roman agriculture. Bibliographies in Agricultural History 1. Institute of Agricultural History, Reading.

Willcox, G. 1991. Carbonised plant remains from Shortughai, Afghanistan. Pp. 139-153 *in* New Light on Early Farming: Recent Developments in Palaeoethnobotany (J.M. Renfrew, ed.). Edinburgh University Press, Edinburgh.

Willcox, G.H. 1992. Archaeobotanical significance of growing Near Eastern progenitors of domestic plants at Jalès (France). Pp. 159-177 *in* Préhistoire de l'agriculture (P.C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Wilson, H. 1988. Egyptian Food and Drink. Shire Egyptology, Aylesbury.

Winlock, H.E. 1932. The Tomb of Queen Meryet-Amun at Thebes. Metropolitan Museum, New York.

Winton, A.L. and K.B. Winton. 1932. The Structure and Composition of Foods. Volume I. Cereals, Starch, Oil Seeds, Nuts, Oils, Forage Plants. John Wiley, New York.

Woolley, C.L. 1922. Excavations at Tell el-Amarna. J. of Egyptian Archaeol. 8:48-82.

Wright, K. 1992. A classification system for ground stone tools from the prehistoric Levant. Paléorient 18(2):53-81.

Yamashita, K., M. Tanaka and M. Koyama. 1957. Studies on the flour quality in *Triticum* and *Aegilops*. Seiken Zito 8:20-26.

Zahran, M.A. and A.J. Willis. 1992. The Vegetation of Egypt. Chapman and Hall, London.

Zhukovsky, P.M. 1928. (A new species of wheat [*T. timopheevi* Zhuk.]). Bull. Applied Botany, of Genetics and Plant-Breeding (Trudy po Prikladnoi Botanike, Genetike i Selektsii) 19(2):59-66.

Zhukovsky, P.M. 1933. La Turquie agricole. Selkhozgiz, Leningrad.

Zohary, D. 1992. Domestication of the Neolithic Near Eastern crop assemblage. Pp. 81-86 *in* Préhistoire de l'agriculture (P.C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Zohary, D. and M. Hopf. 1993. Domestication of plants in the Old World. The Origin and Spread of Cultivated Plants in West Asia, Europe, and the Nile Valley. Second Edition. Clarendon Press. Oxford, England.

Zvelebil, M. 1989. On the transition to farming in Europe, or what was spreading with the Neolithic; a reply to Ammerman (1989). Antiquity 63:379-383.

Ecogeographical distribution of hulled wheat species

***P. Perrino*[1]*, G. Laghetti*[1]*, L.F. D'Antuono*[2]*, M. Al Ajlouni*[3]*, M. Kanbertay*[4]*, A.T. Szabó*[5] *and K. Hammer*[6]**

[1] Germplasm Institute, National Research Council (CNR), Bari, Italy
[2] Department of Agronomy, Faculty of Agriculture, University of Bologna, Italy
[3] Faculty of Agriculture, University of Science and Technology, Irbid, Jordan
[4] Cereal Department, Aegean Agricultural Research Institute, Izmir, Turkey
[5] Botany Department, BDTF, University of Western Hungary, Szombathely, Hungary
[6] Institut für Pfanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany

Summary
Einkorn, emmer and spelt are hulled wheat species which are underutilized in spite of their well-recognized genetic and agronomic potentials. This paper reviews their origin, progenitors, domestication and ecogeographical distribution. Ecogeographical data are very useful for understanding relationships among species and the adaptation to different environments of cultivation, whereas attention to infra- and interspecific genetic diversity assists scientists in understanding evolutionary mechanisms. Much more information on these aspects is needed in regard to hulled wheat species. Some priority actions, such as (i) collecting expeditions in centres of origin or major diversification, together with (ii) characterization and preliminary evaluation of the world collection of hulled wheats, are suggested.

Introduction

Importance of wheats
Wheats are the most common cereals of Old World agriculture. Together with barley, they represented the principal grain stock that founded Neolithic agriculture and the main element responsible for its successful spread. Since this early start, wheats have retained their crucial role in Old World food production and have given rise to numerous advanced types. Today, wheats rank first in the world's grain production and account for more than 20% of the total food calories consumed by man. They are now extensively grown throughout temperate, Mediterranean-type and subtropical regions of the world.

Wheats are superior to most other cereals (e.g. maize, rice or barley) in their nutritive value. Their grains contain not only carbohydrates (60-80%), but also significant amounts of proteins (8-14%). The gluten proteins in the seed endosperm confer to wheat dough a stickiness and an ability to rise during baking, which are its unique baking qualities. Wheats were, and still are, the preferred staple of traditional farming communities throughout the Old World from the Atlantic coast of Europe to the northern parts of the Indian subcontinent and from Scandinavia and Russia to Egypt. Thus it is not surprising that in numerous cultures food has been always identified with bread.

Classification of wheats

Wheat is a complex crop (Zohary and Hopf 1993). Several distinct species of *Triticum* L. have been brought into cultivation through thousands of years of domestication and selection.

From a cytogenetic point of view, wheats belong to a polyploid series (Feldman 1976). Some cultivated forms have a diploid chromosome number ($2n = 14$) and contain two sets of a single genome (AA). Other wheats are tetraploid ($2n = 28$) and combine two distinct genomes (AABB or AAGG), whereas still others are hexaploid ($2n = 42$) and contain three different genomes (AABBDD). The classification (see also Szabó and Hammer in this volume) of cultivated wheats and their closely related wild types is based on a concise cytogenetic grouping.

Hulled and unhulled wheats

Cultivated wheats fall into two distinct classes according to their response to threshing. The more primitive forms – einkorn, emmer and spelt – have hulled grains. Their kernels are covered by tough pales and spikelet glumes, thus the product of their threshing is spikelets, not grains. More advanced cultivated wheats – tetraploid durum-type and hexaploid bread wheats – are free-threshing crops. Their glumes and pales are thinner and are not attached so tightly to the grain; thus threshing operations release naked kernels. Processing hulled wheats is therefore different from handling free-threshing wheats. In the case of hulled wheats, spikelets are stored and marketed. Before their use the grains of hulled wheats have to be freed (this is done usually by pounding). The utilization of naked wheats is simpler. After threshing, the free grains are winnowed and stored ready for milling.

Because of the different appearance of the marketed products, hulled and free-threshing wheats were often regarded as different cereals and called by different names. Yet one has to bear in mind that hulled and naked wheat species can be genetically very close to one another. In most free-threshing *T. turgidum* wheats, the shift from 'hulledness' to 'nakedness' was brought about by a polygenic system, whereas in *T. aestivum* the difference between hulled and free-threshing varieties is only controlled by a single mutation (the 'q' gene).

Shattering and non-shattering wheats

Another important morphological trait in wheats is the manner in which the ear shatters in wild forms, or fractures in the cultivated forms. Wild wheats are adapted to disseminate their seeds by having brittle ears that disarticulate at maturity into individual spikelets. In wild einkorn (AA), wild emmer (AABB) and wild Timopheev's wheat (AAGG), the point of disarticulation is below each spikelet. In *Aegilops fauschii* Coss. (DD), the disarticulation point is above the spikelet. In contrast, all cultivated wheats have non-brittle ears that stay intact after maturation. Thus they depend on humans for their reaping, threshing and sowing.

Farro

Cultivated hulled wheats – einkorn, emmer and spelt – known in Italy under the common name of 'farro' (Perrino *et al.* 1994), are among the most ancient Triticeae cultivated by humankind, although for about a century they have been progressively replaced by modern and high-yielding varieties of unhulled wheats. It is only in the last few years that increased attention to more natural foods and biological agriculture has brought about renewed attention to this forgotten crop. In light of this growing attention to hulled wheat from the market, Italian scientists in collaboration with local producer associations have started experimental programmes in Italy to study the yield potentials of this crop in several regions (IPGRI 1994; Perrino *et al.* 1994; Laghetti *et al.* 1994).

Data obtained by recent studies conducted on farro genetic diversity will contribute to the enhancement of breeding programmes devoted to this crop (Perrino and Hammer 1982, 1984; D'Antuono 1989; Tallarico 1990; Perrino *et al.* 1991, 1993; Mariani *et al.* 1992; Vallega 1992; D'Antuono and Pavoni 1993; Piergiovanni and Bianco 1994).

Centres of origin and progenitors of hulled wheats

Triticum monococcum L. (einkorn) originated in mountainous areas of Turkey (Fig. 1), where its wild progenitor (*T. baeoticum* Boiss.) can still be found growing spontaneously (Harlan and Zohary 1966).

Flaksberger (cited in Gökgöl 1955) divided *T. monococcum* into three ecomorphologic groups called 'proles'. Gökgöl (1955) indicated that *T. monococcum* prol. (abbreviation for proles) *heotinum* Flaksb. is the possible progenitor of two other groups. *T. monococcum* prol. *heotinum*, also called oriental type, has rachis and bottom of spikelets slightly hairy, the plant is medium tall, of late maturity and distributed in Anatolia, South Caucasia and Crimea. *T. monococcum* prol. *allemannum* Flaksb. presents rachis glabrous, latest in maturity, distributed in southern and mountain areas in Germany and Switzerland. *T. monococcum* prol. *ibericum* Flaksb is an early type; plant and spikes are smaller than other groups and distributed in Spain, South France and Morocco.

T. dicoccon Schrank (emmer) originated more eastward, in the mountains of the Fertile Crescent, in Iran, Iraq, Jordan, Syria and Palestine (Fig. 2), where its wild progenitor (*T. dicoccoides* Koern. ex Schweinf.) still thrives (Harlan and Zohary 1966). According to Gökgöl (1955) four subspecies should be recognized in *T. dicoccon*:

- *dicoccon* subsp. *maroccanum* Flaksb.
- *dicoccon* subsp. *abyssinicum* Vav.
- *dicoccon* subsp. *europeum* Vav.
- *dicoccon* subsp. *euroum* Flaksb.

Triticum spelta L. (spelt) derived possibly from crosses between *Aegilops tauschii* and *T. dicoccon.* These crosses involving both wild and cultivated emmer gave rise to spelt types following a doubling of the chromosome number (McFadden and Sears 1946). The most probable centre of origin of this taxon is in a geographical area further east, i.e. south of Caspian Sea, Kazakstan and Afghanistan (Fig. 3), where *Ae. tauschii* grows naturally (Hammer 1980).

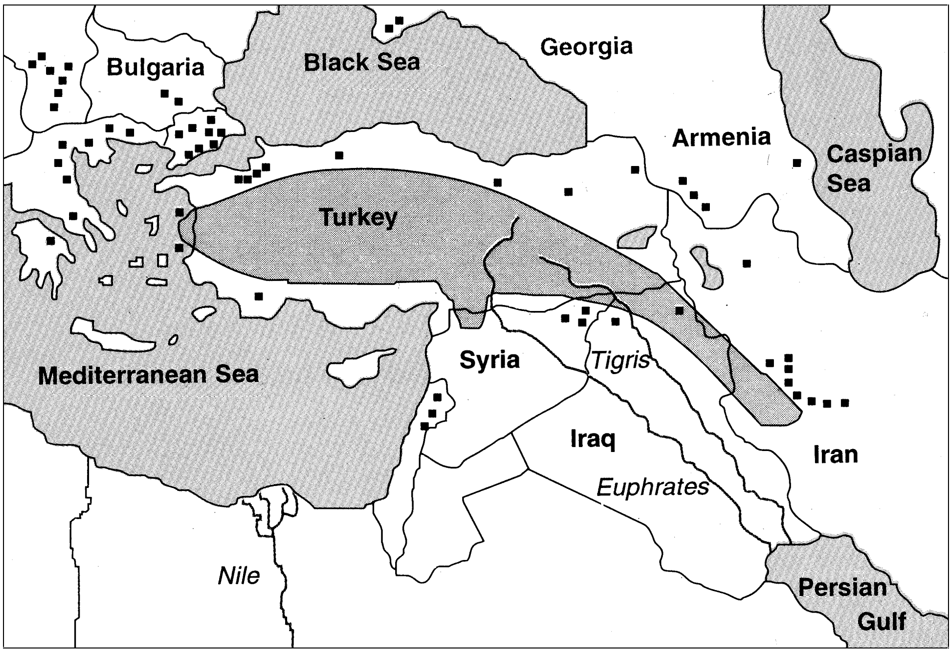


Fig. 1. Shaded area represents the main centre of origin of *Triticum boeoticum*, wild progenitor of *T. monococcum*; dots indicate areas of secondary importance where *T. boeoticum* also has been found (from Harlan and Zohary 1966).

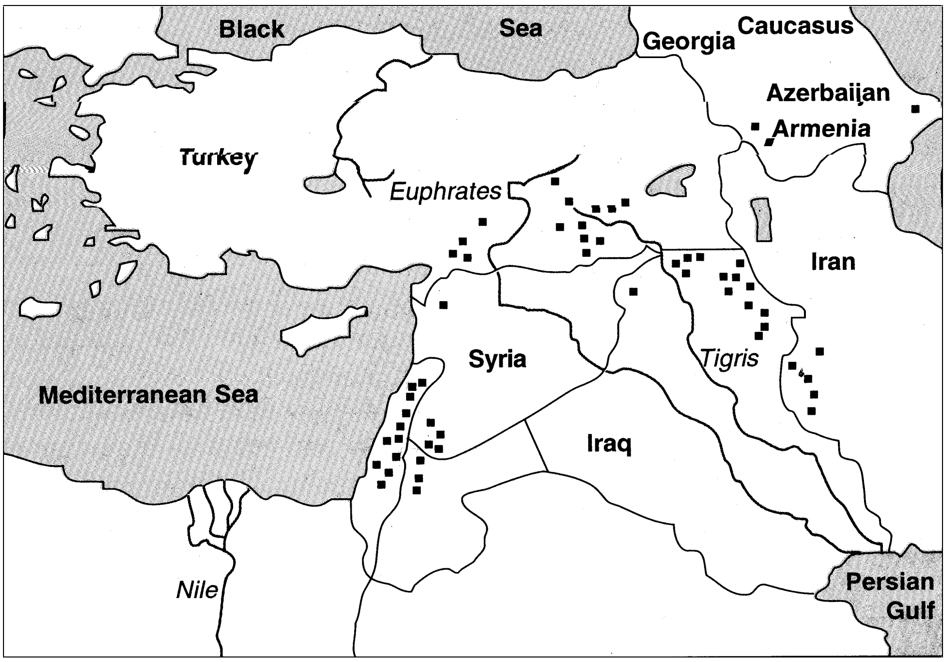


Fig. 2. Dots indicate the presence of *Triticum dicoccoides*, progenitor of *T. dicoccon* (from Harlan and Zohary 1966).

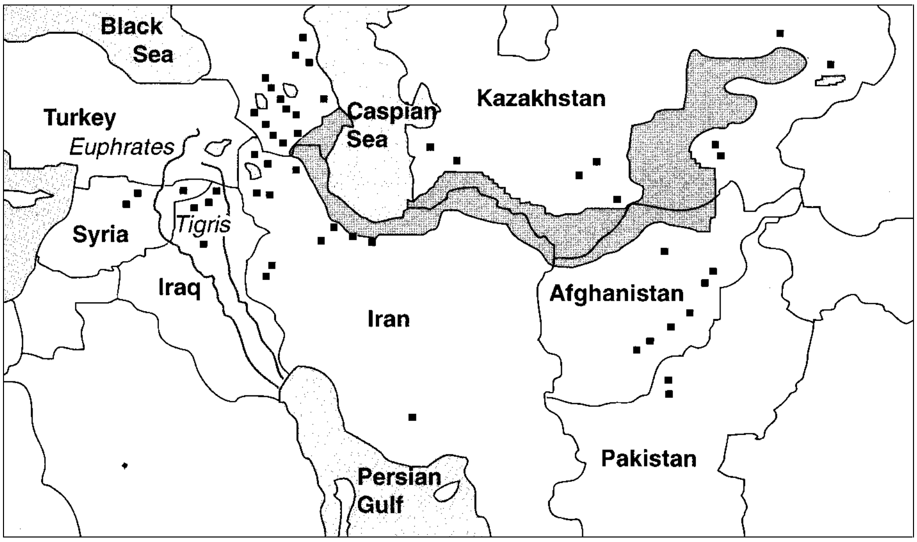


Fig. 3. Shaded area represents the centre of origin of *Aegilops squarrosa*, donor of D genome and progenitor of *Triticum spelta*.

Domestication and spreading of hulled wheat cultivation

Archaeological evidence

Seed remains of *T. baeoticum* dating back to 9000-10 000 BC were found during an archaeological survey in its centres of origin (Hillman 1975). Helbaek (cited in Harlan 1975) reported that seed of cultivated einkorn, emmer, free-threshing wheat, pea, vetch and bitter vetch identified at Çatalhöyük on the Konya plain of Turkey dated approximately 5800-5600 BC. The wide range of variability found in these crops implied that full-scale agriculture was already established when the site was first settled. A summary of findings is given in Table 1.

Seed remains of spelt dating to 5000-6000 BC (Lisitina 1978) were found during archaeological research carried out in the centre of origin of *A. tauschii*. The origin of spelt is therefore probably 2000 years earlier than that of the other two hulled wheats.

First explorations and collecting of hulled wheats germplasm

Gökgöl (1939) collected and classified wheat species including hulled wheats originated in Turkey (Table 2.). However, she clearly affirmed that these missions were not specifically addressed at collecting hulled species, and therefore the number of samples might have been too small to represent the whole distribution of hulled wheats in that country. At present, 10 herbarium samples of hulled wheat from her collections are preserved at the Turkish genebank in Menemen, Izmir.

Zhukovsky (1951) organized three explorations in Turkey to collect crop species in the period 1925-1927. He reported that *T. monococcum* and *T. dicoccon* covered only 1-2% of total wheat acreage in that country, and that they were mostly found as contaminants in *T. aestivum* fields and rarely in pure stands. He indicated that these species were mostly sown in autumn, though having basically a spring habit. The main cultivation area was found in Northern Anatolia, around Kastamonu province. The author also noticed how Anatolian emmers looked similar to those grown in the Volga region of Russia.

Table 1. Finds of hulled wheat species from Near East and Europe before 5000 BC (adapted from Renfrew 1969).

Sites	Dates	Wild einkorn	Einkorn	Wild emmer	Emmer
Ali Kosh	7500-6750 BC	X	X	-	X
Çavönü, Turkey	7500-6500 BC	X	X	X	X
Tell as-Sawwan	5800-5600 BC	-	X	-	X
Tell Mureybat	8050-7542 BC	X	-	-	-
Jericho	ca. 7000	-	-	-	X
Bcidha	ca. 6750	X	-	X	X
Tell Ramad	ca. 6500	-	X	-	X
Matarrah	ca. 5500	-	-	-	X
Amuq A	ca. 5750	-	-	-	X
Çatalhöyük, Turkey	5850-5600 BC	-	X	-	X
Hacilar, aceramic, Turkey	ca. 7000	X	-	-	X
Hacilar, ceramic, Turkey	5800-5000 BC	-	X	-	X
Can Hasan, Turkey	ca. 5250	-	-	-	X
Knosos, Stratum	ca. 6100	-	-	-	X
Ghediki, aceramic	ca. 6000-5000	-	X	-	X
Seskdo, aceramic	ca. 6000-5000	-	-	-	X
Argissa, aceramic	ca. 6000-5000	-	X	-	X
Achilleion, aceramic	ca. 6000-5000	-	-	-	X
Nea Nikomedia	ca. 6200	-	-	-	X
Karanova I	ca. 5000	-	X	-	X
Azmaska Moghila	ca. 5200	-	X	-	X

Domestication and spreading of hulled wheats

In light of the above findings, Renfrew (1969) concluded that southeast Turkey is the native home of wild einkorn, suggesting that this species might have been domesticated in South Anatolia and then spread into Europe as an agricultural crop.

These studies demonstrate that einkorn spread especially in areas characterized by a relatively cold weather whereas it was less cultivated in warmer regions and absent in very hot countries like Egypt and Southern Mesopotamia. Over the whole range of its distribution, einkorn was always less common than emmer and barley.

In Harlan and Zohary (1966), the distribution of known and reasonably certain sites of wild einkorn diffusion has been reported. Such a map includes Lebanon, Iraq, Iran, Turkey, Greece, Bulgaria and former Yugoslavia. The authors also stated that Turkey is the probable centre of origin of *T. monococcum*. In the work of Kimber and Feldman (1987) it is reported that *T. monococcum* is distributed in Bulgaria, Italy, Albania, Greece, Turkey, Syria, Lebanon, Northern Iraq, Northwest Iran, Crimea, Ciscaucasia and Transcaucasia.

Einkorn cultivation in Europe was still practised, though on a small scale, up to the Middle Ages, but it became rather discontinuous since the first half of this century (Zohary and Hopf 1993).

Renfrew (1969) indicated that the distribution area of emmer covers a broad area from the southeastern shores of the Black Sea, through eastern Turkey and reaches the shore of the eastern Mediterranean as far as Mt. Carmel. He also pointed out that emmer is the most widely spread of all the early domesticated cereals.

Table 2. Early data on distribution of hulled wheat species in Turkey (compiled from Gökgöl 1939).

Species	Province	City	Prevalence (%)
T. monococcum var. *flavescens* Körn.	Kütahya	Tavsanli	85
T. dicoccum var. *farrum* Körn.	Kütahya	Tavsanli	12
T. monococcum var. *pseudo-vulgare* Flaksb.	Bolu	Göynük	98
T. monococcum var.*eredivianum* Zhuk.	Bolu	Göynük	0.5
T. dicoccum var. *farrum* Bayle.	Kastamonu	Araç	100
T. monococcum var.*macedonicun* Papaz.	Kastamonu	Araç	30
T. monococcum var. *vulgare* Körn.	Kastamonu	Araç	70
T. monococcum var. *macedonicum* Papaz.	Kastamonu	Cide	35
T. monococcum var. *pseudo-vulgare* Flaksb.	Kastamonu	Cide	65
T. monococcum var. *eredivianum* Zhuk.	Kastamonu	Inebolu	10
T. monococcum var. *macedonicum* Papaz.	Kastamonu	Inebolu	28
T. monococcum var. *pseudo-vulgare* Flaksb.	Kastamonu	Inebolu	35
T. monococcum var. *vulgare* Körn.	Kastamonu	Inebolu	27
T. monococcum var. *pseudo-vulgare* Flaksb.	Kastamonu	Daday	–
T. monococcum var. *eredivianum* Zhuk.	Kastamonu	Daday	–
T. monococcum var. *macedonicum* Papaz.	Kastamonu	Daday	–
T. dicoccum var. *farrum* Körn.	Zonguldak	Eregli	40
T. dicoccum var. *farrum* Körn.	Siirt	Garzan	1
T. dicoccum var. *farrum* Bayle.	Kars	Ardahan	98
T. dicoccum var. *farrum* Körn.	Giresun	Aluçra	–
T. dicoccum var. *farrum* Körn.	Tokat	Rosadiye	1
T. monococcum	Tokat	Niksar	8

Another map in Harlan and Zohary's paper (1966) shows wild emmer sites, including south Turkey, Lebanon, Israel, Jordan, Iraq, Iran and Georgia. The authors also concluded that the Near East should be considered as the probable gene centre for *T. dicoccon*. Emmer, although originated from a wild species less antique and widely spread than the wild progenitor of einkorn, was domesticated faster than the latter.

Nowadays emmer, which was the main wheat in the Old World during the Neolithic and Bronze Ages, is still grown in some areas of the Balkans, former Czechoslovakia, Italy, Anatolia, Iran, Caucasia and India. This old crop also spread to Ethiopia on the Abyssinian plateau, where it is still being cultivated and appreciated.

Spelt, probably because of its cold resistance, spread north and northwest, to Moldova, Bulgaria, Poland, Germany, Greece and North Europe. Its cultivation as a pure stand increased in late Neolithic, Bronze and Iron Ages (Hajnalovà 1975). Spelt was known by the Romans (Jasny 1944) and like the other two species of farro, was an important cereal in Europe until the beginning of this century. Today, much smaller areas of this crop are being grown in Europe and West Asia.

A more detailed account of this spread of hulled wheats cultivation is given in the paper of Nesbitt and Samuel in this volume.

Today's distribution of hulled wheats

The world collection of *Triticum* spp. is stored in a few genebanks, the largest collections being those of Fort Collins (USA), Kyoto (Japan), Bari (Italy) and St. Petersburg (Russia). Passport data from the USDA / ARS computerized databank are available to users (USDA 1992).

A summary of germplasm holdings of both unhulled and hulled wheats deposited in the American and Italian genebanks is given in Table 3. Among hulled wheats, *T. spelta* is the most represented species with 1178 accessions, followed by *T. dicoccon* (530) and *T. monococcum* (234). Spelt accessions originated from 21 countries, the most represented being Spain (356 accessions), Germany (332), Switzerland (277) and Belgium (134). Emmer accessions are less numerous although represented in a larger number of countries, 38 in total, where Ethiopia (164 accessions), Spain (65), Iran (49) and former Yugoslavia (41) are the most represented. Einkorn grows in 34 countries, mainly in Turkey (70 accessions) and former Yugoslavia (25). The conservation of genetic resources of hulled wheat is also dealt with elsewhere in this monograph (see the paper of Jaradat *et al.*).

Today, hulled wheats are still cultivated for both human and animal consumption, mainly in restricted marginal areas, where they are often grown on the poorest soils, in Eastern Europe, Austria, Italy, Greece, Albania and in other countries of Near East where these species originated. A more detailed situation regarding the distribution of hulled wheats in some of these countries is illustrated hereafter. These data are accompanied by relevant information regarding research work and the degree of utilization of these species in those countries.

Former Czechoslovakia (*T. dicoccon*)

A relic cultivation of emmer wheat is still practised in the white Carpathian Mountains, a border area between the now Czech and Slovak republics (Kühn 1970; Hanelt and Hammer 1975). It is interesting that this material does not belong to the Central-European ecotype but has to be seen in connection with accessions from the Volga area (Kühn *et al.* 1976).

Albania (*T. monococcum*)

T. monococcum has survived as a relic crop in several places in the mountains of Albania. Material sampled in recent collecting missions is still under investigation (Hammer *et al.* 1994). Emmer is extremely rare in the country.

Jordan (*T. dicoccoides*)

Jordan comprises a sizable part of the Near East Fertile Crescent which is considered to be a major centre of origin and diversity of many cultivated and wild species. The geographic and climatic regions of Jordan are extremely diverse.

Until 1984, the availability of data regarding plant genetic resources of this country was still scarce. A long-term project was started in that year aimed at the collecting, conservation, evaluation and characterization of plant genetic resources in Jordan, including wheat and barley and their wild relatives. Landraces of wheat were evaluated for phenotypic diversity, associations among characters, drought tolerance and developmental and yield-related traits. These landraces are currently being evaluated for storage proteins and duration and rate of seed-filling period. Wild wheat, the immediate progenitor of cultivated wheat, was also found in Jordan (Jaradat 1990) and subsequently evaluated for morphological and developmental traits. Wild wheat and *Aegilops* spp. are also being evaluated for storage proteins and salt tolerance. The results of these studies indicate that Jordan is a rich reservoir of genetic diversity for wheat.

Among hulled wheats only *Triticum dicoccoides* was collected and studied, while *T. spelta* and *T. monococcum* were not found in any study in Jordan. *T. dicoccoides* is widely distributed in the Fertile Crescent, especially in Jordan (Jaradat and Humeid 1990), Palestine (Nevo *et al.* 1984), Syria and Lebanon (Zohary 1983), where it grows over a wide altitudinal range (–100 to 1400 m a.s.l.), more often in association with wild barley and wild oats. In Jordan *T. dicoccoides* has been collected in 12 sites in the northern mountains. This collection represents 12 major and 19 minor populations occurring mainly in mountainous regions of northern and central Jordan, with a rainfall regime ranging from 250 to about 600 mm (Jaradat 1993).

Five ecogeographical races of *T. dicoccoides* were determined and characterized by Jaradat (1993). Two of them were described before by Kusher and Halloran (1982) and Poyarkova (1988). The three new races are found to be intermediate types between the 'grassy' and 'robust' types described earlier. These types are being considered by Jaradat as ecogeographical races on the basis of their morphological and developmental traits. This conclusion has been supported by univariate analysis of variance, principal components analysis and correlation analysis.

Turkey (*T. monococcum* and *T. dicoccon*)

Genetic diversity of cereals in Turkey attracted many scientists and stimulated the surveying and collection of wheats, including hulled species. These activities became more organized after the establishment at Menemen, Izmir, of the Plant Introduction and Research Center, now named Aegean Agricultural Research Institute. However none of the expeditions organized since then was exclusively targeted on hulled wheat species. The summary of data presented in Table 3 indicates 64 sites of collection for *T. monococcum* and 16 for *T. dicoccon*. The wide adaptability and distribution of these species are stressed by the wide range of altitude of the collection sites, from sea level to 1950 m a.s.l. Recent expeditions made in 1984 and 1993 showed that einkorn and emmer are still being cultivated in small fields in Kastamonu, Bolu, Sinop, Balikesir, Bilecik and Çankiri provinces. At the end of these expeditions 370 accessions of *T. monococcum* subsp. *boeticum*, 39 *T. turgidum* subsp. *dicoccoides*), 64 *T. monococcum* subsp. *monococcum* and 16 *T. turgidum* subsp. *dicoccon* were collected and stored at the Izmir Gene Bank.

More detailed information on the cultivation of einkorn in Turkey is given by Karagöz in this volume.

Italy (*T. monococcum, T. dicoccon* and *T. spelta*)

Archeological findings clearly indicate that emmer and einkorn wheats have been used in the Italian peninsula since prehistoric times. It is also very likely that at least a part of the present emmer populations could represent the direct descendants of the Etruscan and Roman farro (D'Antuono 1994).

Nowadays, all three species of hulled wheats are being grown in Italy. However the situation regarding the cultivation of emmer, spelt and einkorn is very different and should be analyzed by referring to cultivations of landraces in their native areas (section A) or to those just recently established (section B):

Table 3. Summary of collection data of hulled wheat species stored in Izmir Gene Bank.

***Triticum* species**	**Date**	**Province**	**Location**	**Elevation (m a.s.l.)**	**Habitat**
monococcum	28.06.1967	Balikesir	27 km E Havran	420	CL
monococcum	29.06.1967	Balikesir	32 km S Balikesir - Tasköv	270	CL
monococcum	29.06.1967	Balikesir	15 km NE Savaspinar	400	CL
monococcum	28.06.1967	Balikesir	12 km NE Ayvalik	35	CL
monococcum	29.06.1967	Balikesir	5 km S Savastepe - Karaçam Vil.	280	CL
monococcum	29.06.1967	Balikesir	5 km S Savastepe - Karaçam Vil.	280	CL
monococcum	29.06.1967	Balikesir	5 km S Savastepe - Karaçam Vil.	280	CL
monococcum	29.06.1967	Manisa	14 km S Savastepe	240	CL
dicoccon	29.06.1967	Manisa	11 km SE Kirkagaç	250	CL
monococcum	13.07.1967	Bilecik	8 km W of Pazaryeri	780	CL
dicoccon	13.07.1967	Bilecik	4 km W Bozüyük	800	CL
monococcum	14.07.1967	Balikesir	19 km NW Bigadiç	220	CL
monococcum	13.07.1967	Bilecik	8 km W of Pazaryeri	780	CL
monococcum	14.07.1967	Bursa	14 km W Bursa	150	CL
monococcum	14.07.1967	Bursa	14 km W Bursa	150	CL
dicoccon	14.08.1967	Samsun	13 km NE Kavak	530-570	CL
monococcum	12.06.1968	Izmir	15 km S of Izmir	140	CL
monococcum	18.08.1968	Izmir	Cumaovasi oglananasi Vil.	130	CL
monococcum	24.06.1968	Izmir	Manisa - Soma road	120	CL
monococcum	24.06.1968	Manisa	Akhisar	100-150	CL
monococcum	15.07.1968	Çanakkale	Ezine - Bahçeli Vil.	90-190	CL
monococcum	16.07.1968	Çanakkale	Musaköy	200	CL
monococcum	16.07.1968	Çanakkale	Umurbey Vil.	10	CL
monococcum	16.07.1968	Çanakkale	Umurbey Vil.	10	CL
monococcum	10.07.1968	Çanakkale	Lapseki - Çardak	5	CL
monococcum	17.07.1968	Çanakkale	Biga - Balikliçesme	50	CL
monococcum	17.07.1968	Balikesir	Gönen - Tuzakçi Vil.	10	CL
monococcum	18.07.1968	Bursa	Gürsü - Aksu Vil.	360	CL
monococcum	18.07.1968	Bilecik	Yerhisar	570	CL
monococcum	19.07.1968	Bursa	Demirtas	120	CL
monococcum	19.07.1968	Bursa	Demirtas	120	CL
monococcum	01.07.1970	Kastamonu	Kastamonu Plain	780	CL
monococcum	01.07.1970	Kastamonu	Tasköprü	580	CL
monococcum	26.06.1971	Çanakkale	Ecebat - Büyük Anafartalar	20	CL
monococcum	26.06.1971	Çanakkale	Gelibolu Kuruköv	40	CL
monococcum	27.06.1971	Edirne	Kesan - Silliköy 5 km SW of Kesan	50	CL
monococcum	27.06.1971	Edirne	5 km N / NE Ipsala	50	CL
monococcum	29.06.1971	Tekirdag	15 km W Malkara	300	CL
monococcum	28.06.1971	Tekirdag	5 km E Malkara - Balliköy	180	CL
monococcum	01.07.1971	Edirne	5 km NE Edirne	200	CL
monococcum	04.07.1971	Istanbul	5 km SE of Ormanköy	85	CL
monococcum	21.07.1972	Çanakkale	23 km W Lapseki	100	TP
monococcum	23.07.1972	Bursa	Orhaneli Erenli Vil.	610	CL
monococcum	29.07.1972	Adapazari	5 km E Dokurcan	400	CL

Triticum species	Date	Province	Location	Elevation (m a.s.l.)	Habitat
monococcum	29.07.1972	Bolu	15 km E Dokurcan	700	CL
monococcum	30.07.1972	Bolu	30 km NE Bolu	650	CL
monococcum	30.07.1972	Bolu	10 km E Mengen - Pazarköy	700	CL
monococcum	11.07.1973	Çanakkale	280 km SW Çan	320	CL
monococcum	11.07.1973	Balikesir	31 km S Gönen	280	CL
monococcum	13.07.1973	Bolu	Düzce	170	CL
monococcum	14.07.1973	Zonguldak	Bartin Yazicilar Vil.	10	CL
monococcum	15.07.1973	Zonguldak	45 km W Devrek	50	CL
monococcum	15.07.1973	Zonguldak	45 km W Devrek	50	CL
monococcum	16.07.1973	Sakarya	13 km SE Kaynarca	100	CL
monococcum	19.08.1973	Sinop	Vezirköprü	–	M
dicoccon	19.08.1973	Sinop	Gerze - Soguksu	1200	CL
dicoccon	21.08.1973	Kastamonu	Küre Uzunöz	100	TP
monococcum	21.08.1973	Kastamonu	Küre Sipahiler Vil.	1090	TP
monococcum	22.08.1973	Kastamonu		700	M
monococcum	22.08.1973	Kastamonu	Tasköprü	700	M
monococcum	04.06.1975	Adana	30 km Ne Osmaniye Osm.-G.Anteb RO	500	CL
monococcum	07.08.1976	Zonguldak	Karabük - Danismentler Vil.	800	CL
monococcum	07.08.1976	Kastamonu	Araç 30 km E	1120	CL
dicoccon	03.09.1976	Kars	Posof - Çakirkoç Vil.	1150	TP
dicoccon	03.09.1976	Kars	Posof - Çakirkoç Vil.	1550	TP
dicoccon	04.09.1976	Kars	Yolboyu Vil. Akkaya	1550	TP
dicoccon	04.09.1976	Kars	Yolboyu Vil. Arpaçay - Akyaka	1650	TP
dicoccon	04.09.1976	Kars	16 km SW Dogruyol - Tasbas Vil.	1950	CL
dicoccon	01.09.1976	Kars	15 km SW Dogruyol - Tasbas Vil.	1950	CL
dicoccon	04.09.1976	Kars	15 km NW Basgedikler	1640	TP
dicoccon	04.09.1976	Kars	Arpaçay 15 km NW Basgedikler	1640	TP
dicoccon	20.08.1979	Kars	12 km SW Arpaçay	1590	–
dicoccon	20.08.1979	Kars	12 km SW Arpaçay	1590	–
monococcum	20.08.1979	Kars	12 km SW Arpaçay	1590	–
monococcum	14.07.1984	Bolu	7 km NE Mudurnu - Delice Vil.	1250	CL
monococcum	14.07.1984	Bolu	7 km NE Mudurnu - Delice Vil.	1250	CL
monococcum	24.07.1986	Kastamonu	2 km NE Araç	750	CL
monococcum	14.08.1967	Kastamonu	13 km NE Kavak	530-570	CL
dicoccon		Incomplete data		–	CL
dicoccon		Incomplete data		–	CL
dicoccon		Incomplete data		–	CL
dicoccon		Incomplete data		–	CL
dicoccon		Incomplete data		–	CL

CL = Cultivar; M = Market; TP = Threshing Place.

Section A

Landraces consist of native populations grown by traditional farmers. Seed exchanges are rather common within the same district, whereas they were almost unknown outside the traditional areas of cultivation until a few years ago.

T. dicoccon

Experimental trials carried out in homogeneous environments demonstrated that the native Italian populations of emmer can be clearly distinguished in winter types, needing a certain degree of vernalization, and alternative types. Winter emmers are spread all along the Apennine range, between about 44º and 40º latitude north, whereas the alternative types are limited to a rather restricted area of the central Apennines (D'Antuono and Pavoni 1993).

- Garfagnana and Alta Valle del Serchio (Tuscany region)
  A winter landrace is cultivated in an altitude range included between 200 and 1000 m a.s.l. on a total surface amounting at about 50 ha. Garfagnana is one of the areas in which farmers better exploited the economic potential of emmer. The main use is for human alimentation and only by-products are still employed to feed animals.
- Alta Valnerina (Umbria region)
  Relict populations of winter landraces are still cultivated by one or two farmers, at an altitude of about 800 m a.s.l., exclusively for animal feed.
- Valle del Corno (Umbria region) and Altopiano di Leonessa (Lazio region)
  In the area of Monteleone di Spoleto (Umbria region) the local spring emmer landrace has been subject to a successful economic valorization thanks to some enterprising farmers (D’Antuono and Lucidi 1989). Similar uses are also common in the neighbouring Altopiano di Leonessa, where the crop expands when the market situation is more favourable. The altitudinal range of cultivation in this area is about 900-1000 m a.s.l. and the total surface ranges from about 20 to more than 50 ha according to the years.
- Alta Valle del Tronto (Lazio region) and Valle dell’Aterno (Abruzzo region)
  The alternative landrace grown in this area is very similar to that of point 3, although apparently more heterogeneous for some morphological characters and slightly later. The total surface was very limited until a few years ago, but now it probably amounts to 30 ha. Altitudinal range: 800-1000 m a.s.l.
- Alta Valle dell'Aniene (Lazio region)
  Alternative populations akin to those of the former two points are present also in this area at an altitudinal range included from 500 to 700 m a.s.l. The cultivated surfaces have fluctuated in time and were probably reduced during the last years since economic benefits were not as good as in other areas.
- Alto Molise region
  In this territory both winter and spring types were grown between 700 and 1200 m a.s.l. and well known by traditional farmers. The alternative landrace is often sown in late spring as an emergency crop, especially when weather conditions did not allow the planting of other crops. The utilization of emmer is exclusively zootechnic and an improvement strategy for the product is not in progress at the moment (D’Antuono *et al.* 1993). These residual cultivations are, however, really relict and confined to the more marginal areas. Nowadays they may also have disappeared or be in the process of extinction. A close resemblance was noted between these old populations and the material used for planting new cultivations in other parts of Molise and bordering regions: it

is therefore possible that the older germplasm has been used and rashly mixed in these last sites.

- Daunian Apennine (Campania and Apulia regions)
  Winter emmer landraces similar to those of Alto Molise are present as relict marginal crops. Detailed information on this germplasm and its utilization can be found in Perrino and Hammer (1982, 1984).
- Basilicata region
  Until 4-5 years ago winter emmer was grown as animal feed in the mountains surrounding the city of Potenza, on a total area of about 40-50 ha. Recent surveys confirmed the survival of that crop, although probably on a slightly reduced surface. On the contrary, according to information of local experts, no trace of on-farm maintenance of the accessions collected by Perrino and Hammer (1984) in other parts of the Basilicata region was found.

T. monococcum

One main site of einkorn cultivation is known (Perrino and Hammer 1982), corresponding to a mountainous area of the Daunian Apennine, at ca 700 m a.s.l., where also winter emmer is present (see above referring to Daunian Apennine area). For some minor sites see Hammer and Perrino (1984) and Perrino *et al.* (1988). The local landraces consist in an alternative, late type (D'Antuono and Pavoni 1993). Einkorn is there being grown as a fodder crop by traditional farmers families. However in 1990 only one farmer was still growing einkorn but it is very likely that since then the crop has been lost due to its mixing with barley during threshing.

Section B

T. dicoccon

Over the last years emmer cultivation has been spreading outside the traditional production areas, especially in the central regions of Italy like Marche, Umbria, Tuscany, Abruzzi and Molise on a total area not easy to estimate. Recently an expansion also occurred in fertile soils of the southern Po valley. The origin of the seed employed for these new cultivations is not always easy to determine. However, an important part of the crops planted in the Abruzzi, Marche, Molise and Basilicata regions are clearly originated from mixed seed of winter and spring types; it is common opinion that the Cooperative Nuova Europa 2000 of Trivento, Molise, distributed its mixed seed to many producers of those regions. In Umbria, and partly in Marche and Abruzzi, new cultivations were planted with pure seed of the spring landraces of Valle del Corno and Valle del Tronto. The seed of the Garfagnana landrace has been frequently exchanged and used to plant new crops, but at present it seems to be used almost exclusively within the Tuscany region.

T. spelta

Spelt of foreign origin was introduced in Italy about 20 years ago by some German amateurs who moved to central Italy to practise pioneer biologic and biodynamic agriculture. The two main areas of spelt cultivation were the Maremma area (Tuscany) and some internal valleys of Umbria and northern Lazio regions. At present some of these crops still survive and new fields were sown with both self-reproduced and certified seed. Spelt reached Molise too, where it was mixed with emmer. Among the modern cultivars recently introduced in Italy, the Belgian 'Rouquin' and the Swiss 'Altgold Rotkorn' are noteworthy.

Romania (*T. monococcum*)

Historical data on einkorn cultivation and its distribution in a sample territory of Transylvania are reported in Szabó (1976) and Péntek and Szabó (1985) respectively. Data on *in situ* conservation of *T. monococcum* in Kalotaszeg (Calata Area, Transylvania) including acreage, yield and sample composition can be found in Szabó and Marton (1980). A synthesis of historical and *in situ* conservation data from the Carpathian area, together with the list of localities, are reported in Szabó (1995a, 1995b).

The main results of these research investigations were the following:

a. In some areas einkorn is the main crop for home consumption (local industry) (e.g. in Central Transylvanian Basin, Szék-Sic or around Székelyudvarhely - Odorheiu Secuiesc by Hungarian farmers); in other localities this species is the main fodder crop (e.g. in Muntii Apuseni by Romanian farmers), mostly used for horses, pigs and chickens.
b. In general einkorn is a component of fodder mixtures. However, sometimes it appears as a relic weed in cereal fields, mostly in *Avena sativa* (Kalotaszeng and in Bistrita-Nasaud region) in fields cultivated by Romanian, Hungarian or formerly even by German (Transylvanian Saxon) farmers.
c. Einkorn is cultivated as a pure stand crop in marginal lands, often alternated with *T. aestivum*, *Avena sativa* and *Secale cereale*, since it is considered more resistant to damages of wild animals. Einkorn cultivation is also practised in small plots next to houses for home consumption.
d. The sowing period, according to the localities, varies from late autumn to midwinter and early spring. Altitudinal range varies between 300 and 1200 m a.s.l. and rainfall regime between 550 and 950 mm per year. In Romania einkorn is mostly grown on brown forest and calcareous rendzina soils.

The fields are cultivated with einkorn just for one year. In the past, it was considered as an important crop after wood clearings or meadow ploughing, as a starting crop capable of tolerating the intense competition of the native species.

France (*T. spelta* and *T. monococcum*)

In the past, spelt was widely cultivated in several parts of France (Marinval 1989; De Moreau de Gerbehaye 1989). At present the cultivation of local landraces has probably disappeared, whereas some new selected cultivars are grown.

T. monococcum (Devaux and Lieutaghi, pers. comm.). Some populations of einkorn have survived until today in mountainous areas of the region Alpes-Provence-Côte d'Azur. Their current number and extent are unknown. Einkorn in France has suffered the same fate of emmer in Italy (i.e. recovery of traditional uses in human diet) together with the same troubles (i.e. public financial supports to build equipment without an adequate enterprising capacity, with a consequent estrangement by farmers). However, einkorn is still cultivated in France, where has been rediscovered by some farmers in the Provence area of Sault, who now produce it biologically in a perimeter delimited by Mount Ventoux. The product is processed in the area, in a cereal-processing unit which is unique in Europe, recently taken over by a private firm after its failure under public management. Cleaning, trimming, husking, dechaffing and pearling are fully automatic. However, the capacity of the plant presently exceeds market demand.

Spain (*T. monococcum,T. dicoccon, T. spelta*)

T. monococcum is extremely rare and strongly endangered by extinction. In the past einkorn was surely grown in Andalucía, in the provinces of Cordoba, Cadiz and Jaen; at present its cultivation is probably restricted to one or two forms in the province of Cordoba.

T. dicoccon is also present in the Asturias Region, but almost exclusively as a weed of spelt cultivation. Only one farmer grows a pure crop of emmer, a spring type.

T. spelta is widespread in Asturias Region (Buxo I Capdevila 1989). Nowadays its presence in the region is reduced to the administrations of Soerniedo (west), Aller (east), Oviedo (north) up to the border with Leon region in the south. The altitudinal range is from 200 to 1000 m a.s.l.

USA (*T. spelta*)

In the USA, spelt has been introduced into the state of Ohio during the last 10 years, where at present it is cultivated on an area ranging from 20 000 to 40 000 ha per year. The less fertile soils of northern Ohio are employed for spelt cultivation, where the yield of other cereals is reduced by low rainfall level. In this situation spelt can guarantee appreciable productions without any pesticide treatment. For a historical paradox, it seems that spelt appeared or reappeared as a consequence of seed demand by European seed companies to the chairman of American Purity Foods firm (Marjorie 1990). Research started around 1980 at the University of Ohio, financed by Purity Foods, and stopped in 1985 for lack of funds. Nevertheless, in 1989 Purity Foods again proposed spelt and its products in the market as health foods.

Germany (*T. spelta*)

In southwest Germany spelt is used in several ways for human consumption, and also as a complementary remedy to many health and allergy problems since the time of Saint Hildegard of Bingens, 12th Century AD (Strehlow and Hertzka 1989). In this country, in the last 30 years, some nursing-homes dedicated to Saint Hildegard have arisen, where people are subject to treatments based on food among which spelt represents a staple element.

Conclusions

From this short review on the ecogeographical distribution of hulled wheats some considerations arise:

- spelt, emmer and einkorn are spread, in decreasing order of importance, in several countries, mainly of Europe, Near East, central Africa and north America
- good information on the cultivation of these old crops is available for only a few countries, whereas for most of the others is scarce or almost completely lacking
- only a few and rarely specific expeditions have been carried out to collect these species in their centres of diversity
- in many cultivation areas native populations are often extinct or mixed with other germplasm and/or replaced by modern cultivars, showing that the risk of genetic erosion is very high
- characterization and evaluation data are available only for a part of the world collection

- a systematic survey on genetic diversity and mutual relation between genetic and geographical distances is lacking.

Recommended actions

We would like to end this paper by stressing the importance that collaboration, particularly at the international level, plays in ensuring better conservation and use of hulled wheat species. In regard to the future activities of the Hulled Wheat Genetic Resources Network, we would like to recommend a number of important actions that we feel deserve urgent attention from this newly established group:

- *Ad hoc* collecting missions in the countries of origin and in any other place where an ancient tradition on hulled wheats survives (e.g. Turkey, Italy, Balkan countries).
- Set up a strategy of conservation (on-farm, *in situ* and *ex situ*) of hulled wheat genetic resources, with priority in those sites where the risk of genetic erosion is high (e.g. Italy, Albania, former Yugoslavia, eastern Europe, Spain, Middle East).
- Build a specific descriptor list for hulled wheats with special emphasis on free-threshing parameters, to estimate the degree of hulling of each population.
- Characterize and evaluate for yield, adaptation, nutritional and technological traits the whole world collection.
- Carry out a study on hulled wheat germplasm regarding phenetic and genetic variability and diversification in the centre of cultivation of each species.

Acknowledgements

The authors wish to thank Dr. A. Ertug Firat, Director of the Aegean Agricultural Research Institute, Izmir (Turkey) and Dr. L. Peña-Chocarro from the Institute of Archeology, University College, London, for their valuable information on the distribution and collections of hulled wheats species in Turkey and Spain, respectively.

References

Buxo, I. and R. Capdevila. 1989. La présence de l'épeautre (*Triticum spelta* L.) dans l'alimentation en Espagne: les temps anciens et les temps modernes. Pp. 107-122 *in* L'épeautre (*Triticum spelta*). Histoire et technologie (J.P. Devroey e J.J. Van Mol, eds.). Editions Dire, Treignes.

D'Antuono, L.F. 1989. Il farro: areali di coltivazione, caratteristiche agronomiche, utilizzazione e prospettive colturali. L'Informatore Agrario. 45(24):49-57.

D'Antuono, L.F. 1994. Obsolete wheats in Italy: an overview on cultivation, use and perspectives for their conservation. *In*: Report of the IPGRI workshop on conservation and use of underutilized Mediterranean species, Valenzano, Bari, Italy, 28-30 March 1994 (S. Padulosi, H. Ager and E. Frison, eds.). International Plant Genetic Resources Institute, Rome.

D'Antuono, L.F. and A. Lucidi. 1989. L'ambiente agricolo dell'Alta Valnerina. Monti e Boschi, 40(6):17-25

D'Antuono, L.F. and A. Pavoni. 1993. Phenology and grain growth of *Triticum dicoccum* and *T. monococcum* from Italy. Pp. 273-286 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). John Wiley and Sons, UK.

D'Antuono, L.F., C. Bignami, E. Mastronardi 1993. Traditional agroecosystems and old genotypes of cultivated plants inventory and conservation: case study in a Mediterranean highland (Alto Molise, Central Italy). Pp. 269-286 *in* Socio-economic and

Policy Issues for Sustainable Farming Systems (M.G. Paoletti, T. Napier, O. Ferro, B. Stinner and D. Stinner. eds.). Coop. Amicizia. Padova,. Proc. Int. Symp.: Agroecology and conservation issues in temperate and tropical regions, Padova, 26-29 September 1990.

De Moreau de Gerbehaye, C. 1989. Une Ardenne sans épeautre? Notes sur la culture de l'épeautre en Ardenne occidentale. (1766-1846). Pp. 195-198 *in* L'épeautre (*Triticum spelta*). Histoire et technologie (J.P. Devroey e J.J. Van Mol, eds.). Editions Dire, Treignes.

Gökgöl, M. 1939. Türkiyc Bugdaylari. Die Türkischen Weizen. Tom. II. Tan Matbaasi., Istambul, Turkey.

Gökgöl, M. 1955. Bugdaylarin Tasnif Anahtari. Ziraat Vekaleti Yayin. No:716, Istambul, Turkey.

Hajnalovà, E. 1975. Archeoigickè nàlezy kultùrnych rastlin a bruin na slovensku (Archäologische Funde von Kulturpflanzen un Unkrautern im Gebiet der Slovakei). Slovenskà Archeologia 23(1):227-254.

Hammer, K. 1980. Vorarbeiten zur monographischen Darstellung von Wildpflanzen-sortimenten: *Aegilops* L. Kulturpflanze 28: 33-180.

Hammer, K., G. Laghetti, D. Pignone, K. Pistrick, L Xhuveli and P. Perrino.1994. Emergency collecting missions to Albania 1993. Plant Genet. Resources Newsl. 97: 59-62.

Hammer, K. and P. Perrino. 1984. Further information on farro (*Triticum monococcum* L. and *T. dicoccon* Schrank) in South Italy. Kulturpflanze 32:143-151.

Hanelt, P. and K. Hammer. 1975. Bericht über eine reise nach Ostmähren und der Slowakei 1974 zur Sammlung autochthoner Sippen von Kulturpflanzen. Kulturpflanze 23:207-215.

Harlan, J.R. 1975. Crops and Man. ASA, Madison, Wisconsin, USA.

Harlan, J.R. and D. Zohary. 1966. Distribution of wild wheats and barley. Science 153:1074-80.

Hillman, G. 1975. The plant remains from Tell Abu Hureyra: a preliminary report. Proc. Prehist. Soc. 41:306-322.

IPGRI. 1994. Report of the IPGRI Workshop on Conservation and Use of Underutilized Mediterranean Species. Valenzano (BA), Italy. March 28-30. IPGRI, Rome, Italy.

Jaradat, A.A. and B.O. Humeid. 1990. Morphological variation in *Triticum dicoccoides* from Jordan. *In*: Wheat Genetic Resources: Meeting Diverse Needs (J.P. Srivastava and A.B. Damania, eds.). John Wiley, Chichester, UK.

Jaradat, A.A. 1990. Levels of phenotypic variation for developmental traits in landraces genotypes of durum wheat (*Triticum turgidum* subsp. *turgidum* L. conv. *durum* (Desf.) MK) from Jordan. Euphytica 51:267-271.

Jaradat, A.A. 1993. Ecogeographical races in natural populations of *Triticum dicoccoides*. Biodiversity and Wheat Improvement (A.B. Damania, ed.). Wiley-Sayce Publication, UK.

Jasny, N. 1944. The wheats of classical antiquity. Studies in History and Political Science, Series 62, No.3, pp. 176. Johns Hopkins Press, Baltimore.

Kimber, G. and M. Feldman. 1987. Wild Wheat. An Introduction. Special Report. College of Agriculture, University of Missouri, Columbia, USA.

Kühn, F. 1970. Das Ausklingen der Emmerkultur in der Tschechoslowakei. Acta Univ. Agric. fac. agron. 18, 4:587-594.

Kühn, F. K. Hammer and P. Hanelt. 1976. Botanische Ergenbnisse einer reise in die CSSR 1974 zur Sammlung autochthoner landsorten von Kulturpflanzen. Kulturpflanze 24:283-347.

Kusher, V. and G.M. Halloran. 1982. Variation in vernalization and photoperiod response in tetraploid wheat (*Triticum turgidum* var. *dicoccoides*) ecotypes. J. Appl. Ecol. 19:545-547.

Laghetti, G., R. Castagna, L.F. D'Antuono and P. Perrino. 1994. Risultati delle ricerche condotte sul farro in Italia. Agricoltura Ricerca 156:119-124.

Lisitina, G.N. 1978. Main types of ancient farming on the Caucasus, of the basis of a palaeoethnobotanical research. Ber. Dtsch. Bot. Ges. 91; pp. 47-57.

Mariani, G., Belocchi, A., Bravi, R. and Bernardi, G. 1992. Indagini sulla coltivazione del farro *(Triticum dicoccum* Schübler). 1. Risultati di prove condotte su farro in Garfagnana. L'Informatore Agrario, 48(37):67-71.

Marinval, P. 1989. Bilan des découvertes archéologiques d'épeautre (*Triticum spelta* L.) en France de la Préhistoire au Moyen Age. Pp. 69-76 *in* L'épeautre (*Triticum spelta*). Histoire et technologie (J.P. Devroey e J.J. Van Mol, eds.). Editions Dire, Treignes.

Marjorie, H.J. 1990. Superfood # 5: spelt. Mastering food allergies Newsletter. N.43. Mast Enterprises, Inc., Idaho (USA).

Mcfadden, E.S. and E.R. Sears. 1946. The origin of *Triticum spelta* and its free threshing hexaploid relatives. J. Heredity 37, 81-89, 107-116.

Nevo, E., A. Beiles, Y. Gutterman, N. Storch and D. Kaplan. 1984. Genetic resources of Israel and vicinity. I. Phenotypic variation within and between populations of wild wheat, *Triticum dicoccoides*. Euphytica 33:717-735.

Péntek, J. and T.A. Szabó. 1985. Ember és növényvilág. Kalotaszeg növényzete és népi növényismerete. [In Hungarian]. (Man and Plant. Plant Kingdom and Human Life in Kalotaszeg) Kriterion. Bukarest, Romania.

Perrino, P. and K. Hammer. 1982. *Triticum monococcum* L. and *T. dicoccum* Schübler (sin. di *T. dicoccon* Schrank) are still cultivated in Italy. Genet. Agric. 36:343-352.

Perrino, P. and K. Hammer. 1984. The farro: further information on its cultivation in Italy, utilization and conservation. Genet. Agric. 38:303-311.

Perrino, P., G. Laghetti and K. Hammer. 1988. Collection of plant genetic resources in Italy 1987. Kulturpflanze 36, 377-390.

Perrino, P., D. Semeraro and G. Laghetti. 1994. Il Farro: un cereale della salute. Editors of Procc. of Meeting in Potenza (Italy), 18 June 1994. pp. 145.

Perrino, P., S. Infantino, G. Laghetti, N. Volpe and A. Di Marzio. 1991. Valutazione e selezione di farro in ambienti marginali dell'Appennino molisano. L'Informatore Agrario 42:57-62.

Perrino, P., S. Infantino, P. Basso, A. Di Marzio, N. Volpe and G. Laghetti. 1993. Valutazione e selezione di farro in ambienti marginali dell'Appennino molisano (II nota). L'Informatore Agrario 43:41-44.

Piergiovanni, A.R. and M.G. Bianco. 1994. Primi risultati di una valutazione bromatologica di linee selezionate di farro. Pp. 89-95 *in* Il Farro: un cereale della salute (P. Perrino, D. Semeraro and G. Laghetti, eds.). Proc. of Meeting in Potenza (Italy), June 18.

Poyarkova, H. 1988. Morphology, geography and interspecific taxonomy of *Triticum dicoccoides* Korn. A retrospective of 80 years of research. Euphytica 38:11-23.

Renfrew, J.M. 1969. The archaeological evidence for the domestication of plants: methods and problems. *In*: The Domestication and Exploitation of Plants and Animals (Peter J. Uoko and G.W. Dimbley, eds.). Gerald Duckworth & Co. Ltd.

Strehlow, W. and M.D. Hertzka. 1989. Hildegard of Bingens's medicine. Bear & Company, Santa Fe, New Mexico. pp.163.

Szabó T.A. senior. 1976. Wortgeschichtlicher Thesaurus der siebenbürgisch-ungarischen Sprache. Bd. I. A-C. Kriterion Verlag, Bucuresti. 1-1225 (203-204).

Szabó, T.A. 1995a. Historical, Ethnobotanical and genetic resources research regarding the evolution of cultivated plants and their wild relatives in the Carpathian Basin. DrSci Thesis. In Hungarian. Budapest - Szombathely, Hungary

Szabó, T.A. 1995b. The history and present situation of einkorn (*Triticum monococcum* L.) genetic resources in Transylvania. [Abstract in Hungarian]. Pp. 2-3 *in* Proceedings of the Memorial "Barabás Zoltán" Cereal Breeding Session. 2-3 March 1995 Szeged. [Full version in English prepared for publication in Haynaldia Bio Tár Electr.]

Szabó, T.A. and A. Màrton. 1980. The traces of the einkorn. An ancient wheat species in the light of modern research. [in Hungarian]. Bucharest, 33, 1:35-44, 2:45-46.

Tallarico, R. 1990. Il farro: coltura alternativa per il recupero delle aree marginali. L'Informatore Agrario 46(12):107-110.

USDA. 1992. U.S. Department of Agriculture, Agricultural Research Service (USDA / ARS), - Germplasm Resources Information Network 1992. pc Grin. Germplasm Resources Information Network data Query System for the PC. U.S. Department of Agriculture, Agricultural Research Service, ARS-108, pp. 79.

Vallega. V. 1992. Agronomical performance and breeding value of selected strains of diploid wheat, *Triticum monococcum*. Euphytica 61:13-23.

Zhukovsky, P. 1951. Türkiye'nin Zirai Bünyesi. Türkiye Seker Fabrikalari Nesriyati No. 20:887. [Translation from La Turquie Agricol. Russian edition in 1933. French summary]. pp. 908. Moscow, Leningrad.

Zohary, D. and M. Hopf. 1993. Domestication of plants in the Old World. Pp. 32-38 *in* The Origin and Spread of Cultivated Plants in West Asia, Europe, and the Nile Valley. Second Edition. Clarendon Press. Oxford, England.

Zohary, D. 1983. Wild genetic resources of crops in Israel. Israel J. Bot. 32:97-127.

II. Genetic Diversity, Collecting, Conservation and Documentation

Ex situ conservation of hulled wheats

A.A. Jaradat[1], M. Kanbertay[2], L. Peña-Chocarro[3], K. Hammer[4], N. Stavropoulos[5] and P. Perrino[3]

1 IPGRI, WANA Office, Aleppo, Syria
2 Cereal Department, Aegean Agricultural Research Institute, Izmir, Turkey
3 Institute of Archeology, University College London, London, England
4 Institut für Pfanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany
5 National Agricultural Research Foundation, Agricultural Research Center of Makedonia and Thraki, Greek Gene Bank, Thermi-Thessaloniki, Greece
6 Germplasm Institute, National Reserach Council, Bari, Italy

Introduction

The earliest finding of cultivated wheat is represented by the semi-brittle tetraploid *Triticum dicoccum* sample gathered at Tel Aswad in Syria and dated ca. 8000 BC. The cultivated semi-brittle diploid *T. monococcum* dating ca. 7500 BC has been found at Tel Abu Hureyra, also in Syria (Zohary and Hopf 1993). Although limited, this evidence suggests that diploid and tetraploid wheats were taken into cultivation at around the same time. During the following millennia these early cultivated wheats spread from the Middle East to central and western Europe, *T. dicoccum* reaching the British Isles before 4000 BC. Today, *T. monococcum* and *T. dicoccum* remain as relic crops in Spain, Italy, Turkey, the Balkans and India. The hexaploid species *T. spelta*, *T. vavilovii* and *T. macha* are also hulled wheats. The primitive status of hulled hexaploid wheats is supported by the observation that artificial hybridization between all tetraploid wheats, either free-threshing or hulled, with all known races of *Ae. squarrosa* give rise to hulled types. However, the genetic data, which show that hulled hexaploid wheats are more primitive than free-threshing forms, do not match the archaeobotanic findings. Although domesticated materials can sometimes be maintained where they were originally selected, unless there is an incentive to continue planting them they tend to be replaced by modern cultivars, or lost, due to human neglect. Hulled wheats are no exception to this rule.

The purpose of this paper is to provide updated information on the status of *ex situ* conservation of hulled wheats, namely *Triticum monococcum*, *T. dicoccum*, and *T. spelta*. Such information has been gathered by experts, including genebank managers, from a number of European and Middle Eastern countries.

The Global Database on Wheat

The global database maintained by ICARDA (The International Center for Agricultural Research in the Dry Areas) on *Triticum* species was searched specifically for hulled wheats holdings, i.e.*Triticum monococcum*, *T. dicoccum*, and *T. spelta*. The results of this search are summarized in Tables 1, 2 and 3. Table 1 reports number of accessions of *T. monoccocum* according to their country of origin (or genebank, where the samples are being maintained, in case information on their origin is not available) and their status. In several cases it has only been possible to obtain information on the total number of accessions, unlike the cases of Germany, Spain and Hungary. A total of 1053 accessions, 27 of which belonging to subsp. *boeoticum*, have been recorded. No indication of the state of duplication of these samples or the availability of additional passport data could be gathered through this survey.

Table 1. Summary of *T. monococcum* holdings according to the Global Wheat Data Base.

Country	UN	LR	WS	AC	GS	IF	CU	BL	MT
Brazil (27)	–	X	–	X*	–	–	–	–	–
Germany (193)	–	X	X	X	–	–	–	–	–
Hungary (189)	–	–	X	X	X	X	–	X	–
India	–	–	1	–	–	–	–	–	–
Italy	–	–	1	–	–	–	–	–	–
Japan	1	–	–	–	–	–	–	–	–
Poland (15)?	–	–	–	–	–	–	–	–	–
Rep. South Africa (4)	–	–	–	–	–	–	–	–	–
Spain	(15)	–	X	X	–	–	–	–	–
Sweden	–	3	3	–	–	–	–	–	–
The Netherlands	1	24	18	–	–	–	–	4	–
UK	–	1	–	–	–	–	–	–	–
USA	(172)?	–	–	–	–	–	–	–	–
USA	(381 OL)	–	–	–	–	–	–	–	–

UN=unknown; LR=landrace; WS=wild, weedy; AC=agricultural cultivar; GB= genetic stock; IF=introgressed form; CU=cultivated; BL=breeding line; MT=mutation.
* subsp. *boeoticum*.

Table 2. Summary of *T. dicoccum* holdings according to the Global Wheat Data Base.

Country	UN	WS	LR	AC	BL	MT
Brazil	–	92	–	–	–	–
Bulgaria	32	–	–	–	–	–
Canada	–	16	–	–	–	–
Czech Rep.	94	–	–	–	48	–
Germany	198	–	225	9	–	25
Hungary (13)	–	–	–	–	–	–
India	–	2	–	–	–	–
Japan	–	–	1	1	3	–
Rep. S. Afr. (199)	–	–	–	–	–	
Sweden	–	4	1	–	–	–
Switzerland	2	–	62	–	–	–
The Netherlands	58	–	22	1	1	–
USA (498)	–	–	–	–	–	–
USA	–	–	431	–	–	–

Legend: UN=unknown; LR=landrace; WS=wild, weedy; AC=agricultural cultivar; GB= genetic stock; IF=introgressed form; CU=cultivated; BL=breeding line; MT=mutation.

More information was available, however, on the tetraploid hulled wheat *T. dicoccum*, whose germplasm collections were larger and more numerous than the previous one (Table 2). A total number of 2040 accessions were counted, out of which 742 (36%) are landraces stored mainly in Germany and the USA. An additional 498 accessions are also reported from the USA collection, although these are not accompanied by any detailed information.

The survey shows also the presence of 6306 accessions for *T. spelta*. A large part of this number (3774, equivalent to 60%) is represented by landraces, and a still sizeable amount (2072, equivalent to 32%) belongs to breeding material. Most of these accessions are stored in the Swiss, German and Swedish genebanks.

Table 3. Summary of *T. spelta* holdings according to the Global Wheat Data Base.

Country	UN	LR	OL	BL	AC	MT	GS	IF
Belgium	37	90	70	–	–	–	–	–
Canada (6)								
Czech Rep.	10	–	–	–	–	–	–	–
Germany	–	44	–	–	–	–	–	–
Germany	–	216	–	1993	51	9	–	–
Hungary (35)	–	–	–	X	X	–	X	X
India (7)	–	–	–	–	–	–	–	–
Israel (100)	–	X	–	–	X	–	–	–
Italy ?	–	–	–	–	–	–	–	–
Japan (13)	–	–	–	–	–	–	–	–
Poland (65)	–	–	–	–	–	–	–	–
Portugal	–	2	–	–	–	–	–	–
Sweden	–	1154	–	–	–	–	–	–
Switzerland	–	2208?	–	71	–	–	–	–
The Netherlands	52	25	–	8	5	–	–	–
USA	–	35	–	–	–	–	–	–

Legend: UN=unknown; LR=landrace; WS=wild, weedy; AC=agricultural cultivar; GB= genetic stock; IF=introgressed form; CU=cultivated; BL=breeding line; MT=mutation.

The International Center for Agricultural Research in the Dry Areas (ICARDA)

Wheat holdings at the Genetic Resources Unit (GRU) of ICARDA are mainly of *Triticum durum* (Table 4). The ICARDA base collection is composed of approximately 26 000 accessions, most of them (18 000, equivalent to 67%) are *T. durum*, a further 7835 (27%) are *T. aestivum* and the remainder belongs to *T. monococcum* (42) and *T. dicoccum* (338). There are no *T. spelta* accessions being maintained at ICARDA.

Germplasm of hulled wheats is distributed by ICARDA to any *bona fidae* users upon request, as is the case for any other CGIAR (Consultative Group for International Agricultural Research) centre. A total of 76 accessions of *T. monococcum* were distributed during the period 1991-95, the majority of which (30) were sent to a private plant breeder in the USA (Table 5). A larger number of accessions (213) belonging to *T. dicoccum* has been distributed by ICARDA over the last two years (1994-95) to collaborators and breeders in four countries (Table 6).

The majority of these accessions were requested by the Argentinean National Program, and some 30 were requested by the USA.

Table 4. Summary of hulled wheats accessions kept at the GRU of ICARDA.

Species	No.	No. of accessions in base collection
T. aestivum	–	7835
T. monococcum	8	42
T. dicoccum	14	338
T. spelta	–	–

Table 5. Distribution of *T. monococcum* accessions by the GRU of ICARDA.

Recipient country	Year	No. of accessions
Syria	1991	9
Egypt	1991	6
Denmark	1993	1
Lebanon	1993	25
USA	1994	30
Syria	1994	3
Ireland	1995	2

Table 6. Distribution of *T. dicoccum* accessions by the GRU of ICARDA.

Recipient country	Year	No. of accessions
Syria	1991	10
Syria	1994	3
Lebanon	1994	25
USA	1994	30
Argentina	1995	145

Germany

In total, 3211 accessions of hulled wheat species (einkorn, emmer and spelt) are being stored at the two German genebanks of Gatersleben and Braunschweig (Table 7), the largest collection (86.8%) being the one maintained at Gatersleben. The most represented species is *T. spelta* (representing 70% of the entire German collection), the accessions of which are held at Braunschweig. No information on country of origin or the status of these accessions is available.

Table 7. Holdings of hulled wheats in the German genebanks.

Species	Gatersleben	Braunschweig	Total
T. monococcum	127	199	326
T. dicoccum	189	323	512
T. spelta	106	2267	2373
Total	422	2789	3211

Italy

In total, 739 accessions belonging to hulled wheats are being conserved at the Germplasm Institute (National Research Council) in Bari. The majority of these (371) are *T. dicoccum*, followed by *T. spelta* (282), and *T. monococcum* (86). Collecting activities carried out by some of the present authors (K. Hammer and P. Perrino) have led to detection of the presence of *T. monococcum* and *T. dicoccum* in some areas of southern Italy, where these species were considered almost extinct or relic crops. The scientific data that have been gathered so far, along with ethnobotanic information on these rare wheats, have dramatically contributed to raising public awareness on the state of conservation of these crops. Today, many more farmers in Italy are growing them, and cultivation is often carried out in close collaboration with the Bari genebank, which monitors the state of genetic erosion of these species. Also worthy of note is the on-farm conservation of hulled wheats that is being successfully developed. This collaboration between the formal and informal sectors is further contributing to maintaining the evolutionary dynamics of these valuable species.

Greece

Greece is located within the broader area of origin and primary differentiation of the diploid and tetraploid wheat species. Seeds of *T. monococcum* and *T. dicoccum* were found in the Paleolithic sites of Ghediki and Argissa (ca. 6000-5000 BC), and seeds of *T. dicoccum* were also found in the Paleolithic sites in Crete (ca. 6100 BC) and other sites in Greece. These hulled wheat species were gradually displaced by the superior free-threshing tetraploid species, *T. durum*. No *T. dicoccum* cultivation has been reported in Greece this century.

Until the 1930s, *T. monococcum* was cultivated on a limited scale in the Thraki and Makedonia regions. It was found also during a 1981-88 collecting expedition launched by the Greek genebank. There is strong evidence that the species is still maintained under cultivation in the small island of Gavdos near the southern coast of Crete, and in some other inaccessible small islands of the Archipelago.

The wild progenitor if the species (*T. monococcum* subsp. *boeoticum*) was found in 27 sites during the same mission mounted from 1981 to 1988. Such material is conserved at the Greek genebank. To date, two local varieties of *T. monococcum* (named ‘Kaploutzas 1’ and ‘Kaploutzas 2’) have been maintained by the Cereal Institute of Thessaloniki, simply because there were used as border lines in experimental plots for wheat evaluations. *T. monococcum* subsp. *boeoticum,* is a rather frequent taxon in Greece. It was discovered by Link for the first time in Greece in 1833. A few years later (1844), Boissier found it in the Boeotia county and named it after this site. A total of 27 accessions of *boeticum* have been collected so far and are being maintained in the active collection of the Greek Genebank. Six accessions of the collected germplasm have been characterized together with Kaploutzas varieties for growth habit, seed germination, days to heading, days to flowering, plant height, tillering capacity and number of spikelets per spike. Kaploutzas varieties showed high uniformity for almost all traits. They are both spring types, with no vernalization requirements. On the other hand, wide variation was observed in accessions of *T. boeoticum,* which showed both winter and spring growth types.

T. spelta has never been reported from Greece.

Spain

All three hulled wheat species have been cultivated and are still being grown in some areas of Spain. The major conservation site for this material is the Centro de Recursos Fitogeneticos (CRF) of the Spanish Plant Genetic Resources Centre in Madrid. Some of the germplasm collected in Spain is also conserved for research purposes at the John Innes Institute of Norwich, England. More detailed information on these holdings is provided below.

T. monococcum

Thirteen accessions of this species are stored at CRF. However, only six of them are of Spanish origin, and two were collected during a collecting expedition to Canada del Hoyo. The remaining five accessions came from plant breeders, and probably originated in Spain, as they are referred to as 'escana', which is the common Spanish name for hulled wheats.

T. dicoccum

In total, 82 accessions are being preserved at CRF. Of these, 60 originated in Spain, while the remaining 22 have been introduced from other countries. An additional 21 accessions of Spanish origin are held at the John Innes Institute.

T. spelta

CRF holds 106 accessions of this species, 79 of which originated in Spain. A large part of the Spanish material is accompanied by passport data, with the exception of 8 accessions. The origin of 26 accessions is unknown, and these have presumably been introduced from other countries.

Hulled wheats germplasm is being stored at the CRF in two ways:

- active collection: stored at –2 to –4°C and 40-50% RH. These samples are placed in glass jars as seeds or intact spikelets
- base collection: stored in metal containers at –15 to –18°C, and 55-60% RH.

It may be useful to know that the Spanish hulled wheat material kept at John Innes is being stored at +1 C and 5% RH conditions as intact spikes in paper bags.

Turkey

Collecting and conservation activities of the Turkish plant genetic resources became well organized in 1963, after the establishment of the Plant Introduction and Research Centre in Izmir. Today, this centre is known as the Aegean Agricultural Research Institute (AARI). Its genebank (located at Menemen) houses 59 accessions of *T. monococcum*, and 16 of *T. dicoccum*. Besides this material, 45 herbarium samples are also maintained by the genebank. Furthermore, the Central Field Crops Research Institute of Ankara has also collected and stored 24 accessions of *T. monococcum* and 7 accessions of *T. dicoccum* to date. In 1995, researchers of the Institute were able to sample 78 accessions of hulled wheats during a collecting expedition in different regions of Turkey where these crops are still being grown (Table 8).

The great interest from the international community in these valuable genetic resources is demonstrated by the high number of accessions requested by researchers from different parts of the world (Table 9).

Table 8. Summary of accessions collected during 1995 and held at the Central Field Crops Research Institute, Ankara.

Species	Cultivars	Market places	Threshing grounds	Total
T. monococcum	57	3	1	61
T. dicoccum	9	2	6	17
Total	66	5	7	78

Table 9. Germplasm of hulled wheats distributed from Turkey (AARI) to other countries in the period 1971-86.

Country	Year(s)	No. of requested samples
Austria	1973-74	54
Belgium	1980	10
Germany	1974	14
India	1976	24
Israel	1979-81	30
Italy	1986	3
Jordan	1974	7
Sweden	1973	23
USA	1971	16
Total		181

Conclusions

The review of the *ex situ* hulled wheats collections has been a useful process, as it has provided valuable information on the conservation of these underutilized crops, which we feel will be useful to all who are committed to their better safeguarding and utilization. Through this exercise, we have also become aware of a number of constraints that might be serious obstacles for the fulfillment of these objectives. The following aspects of the situation regarding the species are a source of major concern at present:

- most accessions lack minimum passport data; these should be gathered urgently
- other countries such as former Yugoslavia, Albania, Algeria and Morocco are reported to be still cultivating hulled wheats; information, seed samples and passport data on such genetic resources should be gathered
- very little information, except for the Spanish material, is available on the characterization and evaluation of hulled wheats; regional or international efforts should emphasize the need for such essential activity
- very little information, except for the Italian germplasm, is available on the utilization of these hulled wheats
- no precise information is available on the level of duplication in accessions of hulled wheats conserved *ex situ*; an international effort is needed to clarify this aspect

- a database and/or a catalogue should be produced; this effort can form part of the International Wheat Genetic Resources Network
- the concept of developing a core collection for hulled wheats should be explored; this will increase interest by researchers and developers in these neglected species
- lastly, the activities undertaken by IPGRI and its collaborators should be widely publicized in regional and international newsletters and research journals.

Reference

Zohary, D. and M. Hopf. 1993. Domestication of plants in the Old World. Pp. 32-38 *in* The Origin and Spread of Cultivated Plants in West Asia, Europe, and the Nile Valley. Second Edition. Clarendon Press. Oxford, England.

In situ conservation of hulled wheat species: the case of Spain

L. Peña-Chocarro

Institute of Archaeology, University College London, London, England

History of hulled wheat cultivation in Spain

The first evidence of hulled wheat cultivation in the Iberian Peninsula comes from the archaeological record. Both einkorn and emmer seem to have been present from the Neolithic period onwards in several sites across Spain, although never as a main crop (Buxó i Capdevila 1993). Spelt, on the contrary, appears represented only from the Iron Age and in areas of northern Spain.

Much later during Medieval times, several Arab treatises recorded the different types of grains used at the time and einkorn is among them. It is particularly worth stressing the work of the Hispano-Arab writer Ibn al-Awwam. He lived most probably in the 12th century and produced a remarkable treatise on Agriculture (El Awam 1988). In this book, several varieties of glume-wheats: 'el-cali', 'el-ascaliat', 'huchaki', 'thormaki', 'tharmir', 'alas', 'colba', 'condros', 'selta' and a variety of the latter called 'lofhta' are reported, although it is rather difficult to assign to each of them a species name. According to the Spanish translator, some varieties can be identified as einkorn (e.g. 'alas').

The first historical record of emmer or spelt cultivation can be found in the Cronicón Albendense, a document dated 883 AD, in which among well-known products of Spain, the Asturian 'escanda' (a generic term for both emmer and spelt) is also mentioned. Throughout the Middle Ages escanda was used to pay rents. However, it is unfortunate that no mention of whether this crop can be identified with emmer or spelt is made. Nonetheless, considering that emmer has been – at least within living memory – the species most used for payments as it was bulkier than spelt, it may be reasonable to assume that the same happened in the Middle Ages.

During the 19th century, two eminent Spanish botanists, Clemente and Lagasca surveyed the wheat grown in Spain at that time, and among the species recorded were einkorn, emmer and spelt (Téllez Molina and Alonso Peña 1952). The presence of these species in Spain in this period was also reported by Willkomm (1852).

For the 20th century, the detailed statistical records provided by the Spanish Ministry of Agriculture since 1900 onwards allow us to follow the evolution of these crops in the different regions of Spain. The percentage of hectares devoted to hulled wheats is increasingly higher through time with an abrupt decrease during the Spanish Civil War (1936-39). After the 1930s the popularity of hulled wheats increased until the late 1950s and 1960s when the percentages dropped quickly. This is the period of agricultural mechanization in many areas of Spain. From this point onwards hulled wheats disappeared almost completely from Spanish fields (Fig. 1).

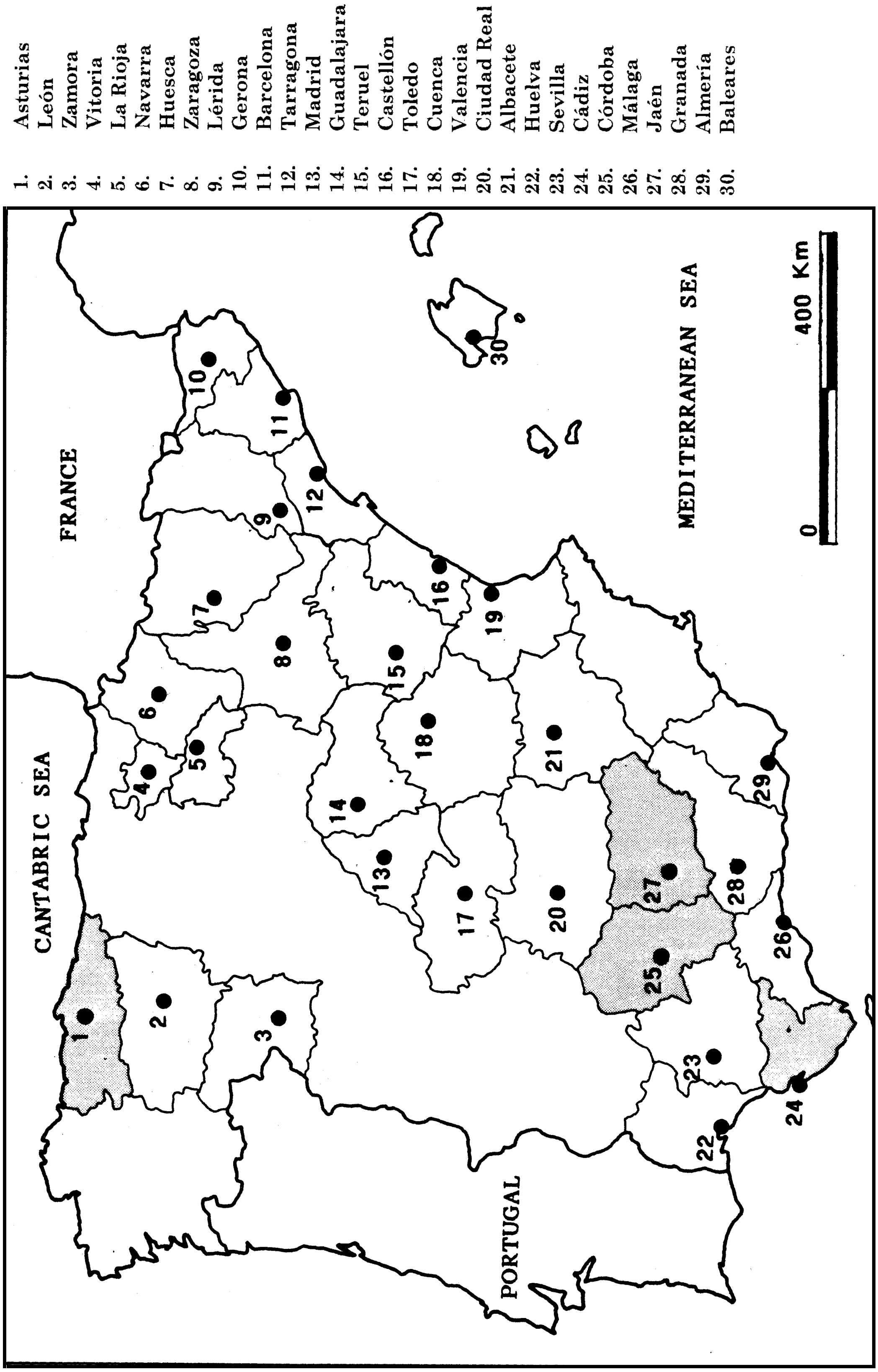


Fig. 1 Map of Spain showing the provinces where the hulled wheats (*T. monococcum, T. dicoccum* and *T. spelta*) were cultivated until the 1960s. The shaded provinces are those in which the species are still under cultivation.

Present-day cultivation of hulled wheats

Einkorn

In the last 20 years, the area grown with einkorn in Spain has enormously reduced. A drastic decrease has been observed also in the number of provinces that have been growing it. Only three Andalucían provinces (Jaén, Córdoba and Cádiz) maintained its cultivation during the 1980s (Fig. 1). Research carried out in the area (Peña-Chocarro 1992) indicates that the data provided by official sources do not reflect the present-day situation. Official records indicate 1 ha of einkorn in Cádiz and 37 ha in Jaén provinces in 1991. My research investigations conducted in this area have provided a very different picture: only one farmer maintained ca. 0.5 ha of einkorn in a remote field in the Sierra de Grazalema (Cádiz), whereas in Jaén, the 37 ha mentioned by the official source were reduced to ca. 3 ha. These studies have also found a new area planted with einkorn, which was not included in the official records. This site is a mountainous area in Córdoba province where farmers are still growing some 1.5 ha of einkorn (Fig. 2)

Four years later, in 1995, einkorn had disappeared from Cádiz and Jaén localities, and the village of Zuheros (Córdoba) is now the only place in Spain where the crop is still grown.

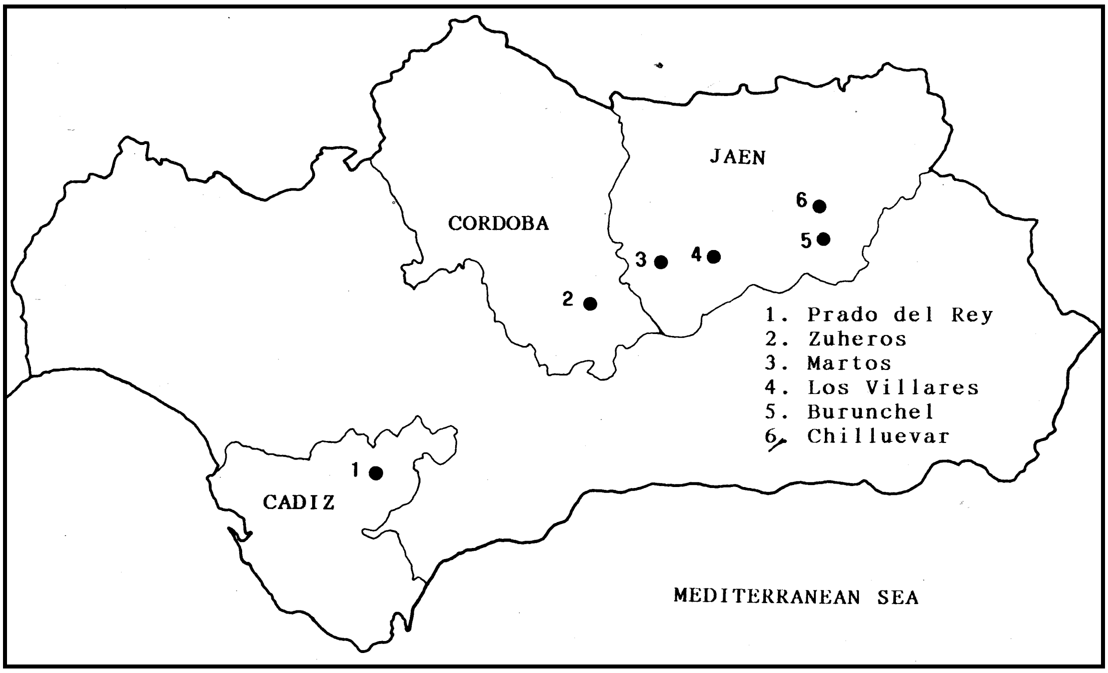


Fig. 2. Map of Andalucía province showing the location of the present-day sites where einkorn is still cultivated.

Emmer and spelt

The statistical information collected from the beginning of this century by the Spanish Ministry of Agriculture shows that in 1906 there were 300 ha sown with emmer in Navarra province. The same data indicate that the crop disappeared from this area in 1971. This date coincides with present-day information recently obtained in the region (Peña-Chocarro and Zapata Peña, in press). In Asturias, emmer has been grown until very recently in several areas; however, today its pure crop cultivation is limited to a single field in the central part of the province.

The case of spelt (Fig. 3) is a rather intriguing one. Despite the fact that the crop was used to make the most common type of bread in Asturias, official records do not make any mention of it until 1935. Asturias seems to have been the only region of Spain, at least during this century, where this crop was being cultivated.

Fig. 3. A spelt (*T. spelta*) spike from Asturias.

Ecoregional distribution

As earlier indicated, present-day distribution of these species within Spain is concentrated in mountain areas of Andalucía (einkorn) and Asturias (emmer and spelt) where traditional farming systems still survive. In the case of Andalucía, these areas can be considered as unique examples of what used to be the way of life in Spain some 40 years ago. Traditional cultivation of einkorn has been maintained in some areas where the crop still plays a role within the local agricultural economy. Here farmers are, in general, old people who still maintain a small farm with a few animals to which einkorn is given as feed. The alarming decrease of einkorn cultivation in Andalucía over the last 5 years is related to the collapse there of the traditional farming system which relied heavily on stock farming. The areas affected by this phenomenon include (see Fig. 2):

- Cádiz province. A small farm near the village of Prado del Rey at the foothills of Sierra de Grazalema (600 m a.s.l.). Cultivation stopped in 1992.
- Jaén province. Several farmers had been growing einkorn until 3 years ago but none of them have sown einkorn since. The areas included the villages of Burunchel and Chilluevar in the Sierra de Cazorla and the village of Los Villares in the Sierra Sur (400 m a.s.l.).
- Córdoba province. This is the only region of Spain where einkorn is still grown. In the village of Zuheros in the Sierra Subbética (1000 m a.s.l.), three farmers grew einkorn until 1994. In 1995 only one has sown this crop.

Information on einkorn cultivation has been also obtained from other regions such as Cuenca (Fig. 1) where einkorn played an important role in the past in its rural economy.

In all surveyed areas, einkorn types are rather homogeneous. The height of the plant is between 80 and 110 cm, although a 150-170 cm tall plant has been reported by farmers from Los Villares (Jaén province). Einkorn fields are small in size (from 1000 to 6000 m^2), either next to the farm (smallest fields) or at a certain distance from the farm (up to 1 hour walk).

In Asturias, the situation is different. Here traditional agricultural systems do survive more than in Andalucía. Apart from being a mountain area, isolation and difficult access to most areas is another factor to take into account. In these areas traditional farming systems are still common although threatened by modern ways of life.

Emmer and spelt are present in the southernmost part of central Asturias, on the border with Castille. The 'concejos' (local administrative units) from this province, in which the cultivation of these crops is still being practised, are (west to east): Somiedo, Belmonte de Miranda, Salas, Teverga, Grado, Proaza, Quirós, Morcín, Riosa, Lena, Mieres and Aller (Fig. 4).

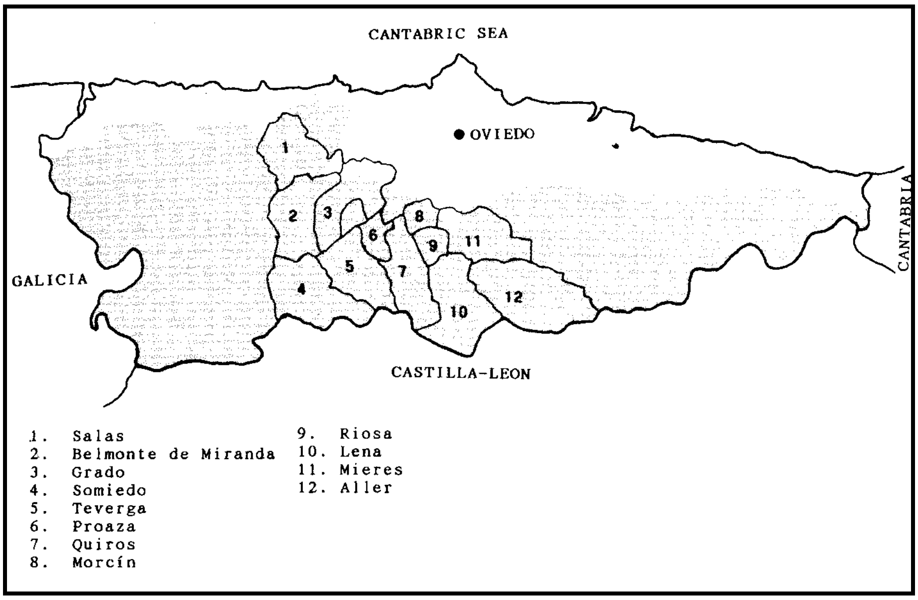


Fig. 4. Map of Asturias showing the location of the 'concejos' (local administrative units) where emmer and spelt are still being cultivated (shaded areas).

Fields are very small in size. They are situated in a diverse range of altitudes from 200 m to almost 1000 m a.s.a.l. Although spelt tends to be the main crop, emmer appears, in many cases, mixed with spelt throughout the area. Until a few years ago, emmer was cultivated as a pure stand in the western part of the present-day area of hulled wheats. As this is no longer the case, emmer is mixed with spelt in fields where it never exceeds more than a quarter of the total cultivated area. Different landraces of both emmer and spelt grow together in the fields.

The only example of emmer being cultivated in pure cultivation comes from the central unit of Proaza, where a farmer maintains just one field of this crop. This is also the only case where emmer is being sown in spring time.

The agrarian cycle

Tilling

The process of tilling is generally undertaken by using a wooden tool pulled by mules in Andalucía and by oxen or cows in Asturias. Fields are generally tilled several times, independently of the system of cultivation used.

Sowing

Hulled wheats are always sown by broadcasting the spikelets. The sowing season for einkorn ranges from mid-September to December, the latter month being considered a very late date. It is commonly accepted among farmers that einkorn can be sown on top of previous stubble and then ploughed in. Farmers recommend sowing when the soil is damp. This greatly reduces the risk of birds eating the seed because the moisture favours seed germination and birds do not eat seedlings. Hence, sowing is done soon after the rain, allowing the soil to dry for a few days.

Emmer and spelt are sown in November although sowing can be extended until December, or even as late as March depending on the area.

The quantity of seed of emmer and spelt sown, according to some authors (Caro Baroja 1972), is 250 kg/ha when broadcast. The same author also refers to 150 kg/ha when it is sown by dibbling. This system seems to have been practised in the past, although today it is no longer in use.

Handfuls of peas or broad beans (a small-seeded variety, locally known as ‘fabes negras’) are also broadcast among the spelt and/or emmer crops in order “to hold” the plants, i.e. to prevent their lodging. This is a widespread practice across the emmer and spelt cultivation area. Broad beans are also sown at the field edge, providing a border for the crop, and thus acting as a fence protecting the crop from lodging. After sowing the field is cross-ploughed again to cover the seed. In some areas, the seed is covered by harrowing.

Culling of green crops

Occasionally, emmer and spelt are grown as green fodder, at least in recent times. For instance, in some areas of Asturias the smallest spikelets, or ‘ergatos’ (usually the basal and upper spikelets in the spike) are still sown to produce green fodder. They are separated from the remaining crop through sieving and sown following potatoes in September, and then harvested in April. This is not, however, a common practice.

Weeding

Einkorn is weeded during the months of January and February, using a hoe. The uprooted weeds are piled in heaps which are used for fodder if they are abundant, otherwise they will be abandoned in the field. In April/May, einkorn is weeded for a second time by hand (Fig. 5).

In general, farmers questioned agreed that einkorn fields do not produce many weeds, primarily because of the poor quality of the fields (e.g. in Jaén). It is in fact not a coincidence that farmers grow einkorn in poor soils where this species is reported to perform better than many other crops. It was also argued that einkorn does not allow the growth of other plants (e.g. in Cuenca). However, in modern einkorn fields surveyed by the present authors, weeds were growing in abundance. It may be that in the past the fields chosen for einkorn cultivation were the worst, whereas nowadays these have been abandoned and einkorn is grown in good-quality soils close to bread wheat and barley fields.

Emmer and spelt are weeded in March. During this time women spend their time in the fields weeding the crops with 'fesorias' (a type of hoe with a short haft and wide scoop). The soil is carefully dug and weeds pulled out and thrown away. Every single wheat plant is then surrounded by new fresh soil. At the end of March, the crop is weeded a second time, although at this time women do not use any tool but their hands.

Harvesting

In the present-day areas of einkorn cultivation, the time of harvesting is heavily dependent on the climatic conditions as well as on the availability of labour. Nonetheless, the most common period for harvesting einkorn in Andalucía is July. The only tool used is a sickle (Fig. 6). The farmer starts off by cutting two bundles very low in the stem and tying them up; this is called 'atadero'. As the farmer sickles, he places the bundles on top of the atadero, one with the ears facing inwards and the next facing outwards. This is to prevent the culms from falling from the sheaf when they are transported to the threshing area, since the ears are heavier than the straw. Sheaves are left in the field to dry out for a period ranging from a few days to a few weeks.

Fig. 5. Weeding operations in a field of einkorn in Spain.

Fig. 6. Harvesting einkorn in Andalucía, Spain.

Harvesters may wear special clothing such as in the Jaén area, where this is represented by a type of apron made of thick material tied to both the waist and calves. Leather cover caps tied to the wrist are also used.

Harvest in Asturias is probably the most interesting operation of the whole cultivation period. Two slightly different systems of harvesting are applied. Late in August, or at the beginning of September, the crop is ready to be harvested. The farmer, accompanied by relatives or neighbours, goes into the field carrying 'mesorias' (reaping sticks) and 'goxas' (baskets). Mesorias is the name given to an ancient harvesting tool comprising two 50-cm-long sticks of rounded section made of yew, hazel or chestnut wood joined by a short piece of rope or leather. The name seems to have originated from the Latin *messoris* or harvester.

The first operation consists of picking up from the soild the ears that have fallen due to wind or rain. This activity is called 'apelucar'. Once finished, the 'mesoriadores' (persons using the mesorias) place themselves in pairs along one of the sides of the field with a basket between each pair, and walk across the field

(Fig. 7). The mesoriador(a) takes one stick in each hand, opening them and takes hold of a bunch of spikes together (Fig. 8) He/she then closes the mesorias tightly, moves the hands towards the centre, and slides the mesorias up to the base of the ears, and then snatches them from the straw.

Fig. 8. Harvesting operations: handling the mesorias, wooden clamps used to cut the spikes from the straws.

Fig. 7. Placing the harvested spikes of emmer in the goxa, large traditional baskets made of chestnut wood.

Because of their semi-fragile rachis, the ears break easily above the third rachis node from the base of the ear, leaving only one sterile basal spikelet or two attached to the top of the straw. The detached ears fall into the goxa, 'maniega' or 'macón' (enormous basket made of chestnut wood) which is kept near the pair of mesoriadores. Following them, women and children pick up those ears left on the culms and also those thrown to the ground. The use of mesorias for harvesting spelt in Asturias has drawn the attention of many scholars (González Llana 1889; Alvargonzález 1908; Vavilov 1926; Dantín Cereceda 1941; Caro Baroja 1972, 1975; Sigaut 1978; Ortiz and Sigaut 1980; Toffin 1983; Stordeur and Anderson-Gerfaud 1985; Buxó and Capdevila 1989; Menéndez Pidal 1993).

Another way of harvesting emmer and spelt is by plucking the ears off by hand. This method is much less common, but is still in use in some areas. It is not known whether this way of harvesting was a common one, or whether it is just a modern modification of an older practice. However, it appears to be associated with very small fields where reaping sticks might not be worth using.

History of use of harvesting clamps in other areas

The use of plucking clamps like the Asturian mesorias has also been reported in isolated areas of West, East and Central Nepal (Toffin 1983). There, the implement is called 'te-shing' or 'tep-shing' ('tep' stands for collect, and 'shing' for wood in general) and they are made of bamboo or wood hardened on the fire. The type of wood used in these particular areas is usually that of hardwood trees such as *Cotoneaster acuminatus* Lindl., *Viburnum erubescens* Wal., *V. coriaceum* Blume and

Symplocos crataegoides Buch. The te-shing are more or less of the same size and shape as the Asturian mesorias. Toffin studied their use among the Tamang of the highlands of the Ankhu Khola river in Central Nepal where he recalls they are associated with wheat and barley. The same group, however, used the sickle to harvest other cereals. Other groups in the area, living at the same altitude as the Tamang, use sickles to harvest both wheat and barley. The description of the operation is very much like that in Asturias. According to Toffin (1983), the use of this tool is perhaps connected with cultural and ethnic factors and related to the survival of past traditions. It seems that its use has been maintained in isolated areas away from southern influences. Everywhere else it has been replaced by the sickle.

It seems strange that the same group would use an implement such as the te-shing for harvesting barley and wheat and yet use the sickle for other crops. One explanation, perhaps, is that a glume-wheat is involved and therefore the semi-fragile rachis encourages the use of such an implement. However, it seems unlikely as hulled wheats are not recorded east of India in past or present times (see Nesbitt and Samuel, this volume). Nevertheless, the case of barley is a rather intriguing one, and it is possible that a wild type of barley is involved or else a semi-brittle domesticate related to *Hordeum agriocrithon*. Harvesting with plucking clamps is a tough and laborious activity, and would have been even harder if a tough rachis species was involved.

Research carried out on harvesting techniques (Sigaut 1978) also points to the use of this tool in Georgia and perhaps some other regions of the Caucasus. It is notable that several researchers (Steensberg 1943; Menéndez Pidal 1993) recorded the use of mesorias in these areas. Menéndez Pidal stated that they were used in Leuchkum (Tvshi) where they are called 'šhnakvi'. A more recent work (Bregazde 1982) describes the use of 'šamkvi', 'šankvi' or 'šnakvi in Georgia associated with glume-wheats (emmer and combinations of *Triticum timopheevi, T. palaeocolchicum* and *T macha*). Photographs in this text show the way the šamkvi were used and this matches that of the mesorias.

The history of this tool is unknown. Apart from the examples already mentioned, there seems to be a complete lack of information about its origin, past use, and even its existence in past times.

The description of agrarian implements by Classical authors includes the description of what is called 'mergae'. However, there seems to be no published suggestion as to the precise nature of the mergae. White (1967) describes the appearance of an implement called mergae in the Classical sources. Several authors (Plautus, Servius, Pliny, Columella) include the term mergae although with different meanings, but only the latter two noted their use, as follows: "Elsewhere the stalks are cut off at mid-height with the sickle and the ears stripped off between two forks" (Pliny, *Historia Naturalis* 18. 296 after White 1967); "Many gather the heads only with forks, and others with combs, an operation which is very easy in a thin crop, but very difficult in a thick one" (Columella, *De Re Rustica*, 2. 20.3. after White 1967). As has been stated (White 1967), the identity of the implement indicated in the passage from Pliny remains uncertain, because he seems to have combined two different methods of reaping: the cutting method and the use of the mergae for stripping off ears. Moreover, proof that he was not referring to an implement like the Asturian mesorias is provided by the way the mergae work. After cutting the plant, it would have been impossible to use the mergae in the same way as the 'mesorias' because in order to strip off the ears the stalk needs to be firmly secured. In the Asturian example, the stalk is still in the ground and therefore it is possible to snatch off the ears by pulling them upwards. However, both this description of the mergae as 'forks' and his account of their use to remove ears from culms which have already been cut suggest an implement of the type made from an ovicaprid's scapulae and recovered from Granj Dareh Tepe in Iran (Stordeur and Anderson-Gerfaud 1985). Columella's 'pectines' (combs) seem to be also present among certain communities in Nepal, associated with barley (Toffin 1983); however, they have not been documented in Spain.

In conclusion, while the Classical sources indicate that pectines and mergae were commonly used to strip off the ears of wheat, it seems unlikely that the mergae correspond to the Asturian mesorias.

Other methods of harvesting

In an area such as that of present-day emmer and spelt cultivation where the weather is unpredictable and it often rains, the harvest is performed even when the crop is wet. The only difference in the method of harvesting under such conditions is that the mesoriador(a) places his / her foot firmly on the base of the straw to avoid the whole plant being uprooted. In fact it is not uncommon to pull out whole plants when using mesorias.

From now on the process follows a different sequence depending on whether the crop involved is einkorn or emmer / spelt.

Field storage

In the case of einkorn, once the harvest has finished, the sheaves ('gavillas') are left in the field to dry out for a couple of days or more depending on the weather and later transported to the settlement. This operation is called 'barcinar', and it is carried out early in the morning when the dew helps prevent grain losses. The farmer, with the aid of a large wooden hook, picks sheaves up and pins them on carrying frames ('pinchos') placed on top of the back of a mule. Around 22-24 sheaves can be fitted in one load. Once the mule has been loaded the farmer drives the animal to the threshing floor.

Threshing of einkorn

This operation can be performed in three different ways:

1. **Trampling:** the most common method used for threshing einkorn. A mule or a pair of mules are driven in circles over the crop (Fig. 9). In the past, animals were shod prior to the threshing season. After a while, animals are driven away and the farmer turns up the carpet of straw, and the process starts again until the crop has been fully threshed.
2. **Lashing:** this method was only used when the straw was required for different purposes, i.e. thatching, basketry, etc. In these cases, ears were separated from the straw by beating them against a threshing sledge or the ground. After lashing, the heads were threshed with a threshing sledge fitted with discs in order to break them into spikelets.
3. **Threshing with sledges:** Three different types have been in use: one with fitted discs, a second one with rollers and a third type with fitted flint teeth. According to some farmers, the use of threshing sledges for einkorn is recommended only when finely chopped straw is required to improve its use as fodder. If this is not the case, other methods are suggested because with the use of threshing sledges spikelets tend to get lumpy and the process takes longer.

   The mixture of spikelets, awns, weed seeds, weed heads, heavy straw fragments, small stones, etc. is then heaped onto a central elongated pile called 'pez'. The 'pez' is oriented towards the best winnowing breeze. One way of heaping the crop towards the centre of the threshing floor is with the aid of a wooden plank ('arnilla') pulled by a mule. The process is carried out by two people and a mule. One person stands on top of the wooden board and holds the mule's tail while the second one drives the mule in such a way that by dragging the board the crop is piled in a central heap (Fig. 10).

Fig. 9. Threshing operations: trampling with the use of a mule.

Fig. 10. Threshing with sledges.

Winnowing of einkorn

Einkorn is winnowed when a steady breeze of the appropriate strength is blowing. Winnowing is carried out with winnowing forks. Nowadays the whole process is carried out on a small scale and therefore only one or two farmers participate (Fig. 11). While one farmer tosses the crop into the air, a second one sweeps the spikelets onto the central heap. The straw and other by-products are blown further away and the longest fragments of straw are swept off. Once most of the straw is eliminated, the winnower changes his winnowing fork for a wooden shovel and the spikelets are winnowed again. Sweeping is carried out during the winnowing process. Sieving takes place at the edges of the central pile where straw tends to accumulate (Fig. 11). The final product is measured, packed and transported back to the granaries.

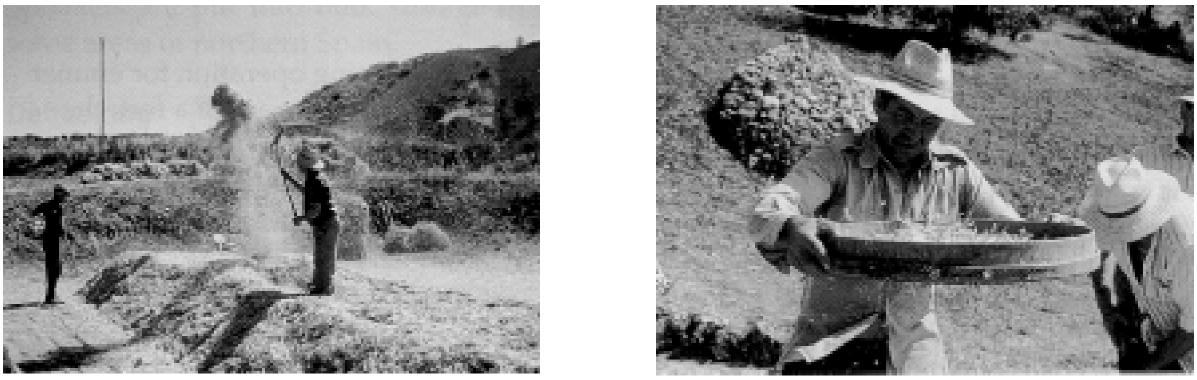


Fig. 11. Winnowing operations

In Asturias, baskets (‘goxas’) full of ears were emptied into sacks and left at one end of the field. These were transported by farmers (both men and women) on their backs or on horses and put into storage in ‘hórreos’ and ‘paneras’ (a type of aerial granary on stilts), where the crop was left for about 10 days to dry out (Fig. 12).

Cutting of straw

In Asturias, the straw left in the field is cut with a scythe and left in heaps for 2-3 days to dry. Once it is dry, the farmer either transports it back to the granaries, where it is kept to be used in winter, or it is left in the field. In the latter case straw stacks are built, and the straw taken from there when necessary.

Singeing of emmer and spelt

In Asturias, emmer and spelt ears are first scorched before threshing to remove the awns (Fig. 13). After several days in the granaries, the crop (which is usually very small) is piled in a central heap and a small fire lit at one edge. The fire may spread slowly and uninterruptedly as the burning ears get mixed up with the remaining crop, but by throwing the burning ears into the air, flames are extinguished. The whole operation is done with very quick movements which do not allow the fire to spread among the other ears. The final result is a quick burning of the awns and partial parching of some glumes. The activity was originally carried out beneath the aerial granaries (‘hórreos’ and ‘paneras’) where there was a stone slab surface specifically placed for this operation. It was also very common to remove the awns inside the water-powered mills, where there was, and often still is, a small area designed for this purpose.

Fig. 12. Granaries (‘hórreos’ or ‘paneras’) where emmer and spelt are left to dry out for about 10 days.

Fig. 13. Singeing operation for emmer and spelt. With the aid of a fork the farmer scoops up ears and shakes the fork over the fire, causing ears to fall to the ground.

Threshing of emmer and spelt

After the previous operation, the crop is ready for threshing. Three different threshing methods have been observed in Asturias:

- **trampling:** people performing a type of dance, and moving the feet rhythmically in zigzags, walking backwards, and thus breaking the ears into spikelets.
- **use of wooden mallets:** the mallet is a quadrangular piece of wood with an undulated lower surface, attached to an angled handle, which allows the crop to be beaten.
- **flailing:** the most common way of breaking ears into spikelets is by flailing the crop with wooden flails (Fig. 14). These consist of two clubs joined together by a piece of leather; the one held by the farmer is usually longer and thinner, whereas the second, the one which actually beats, is shorter and thicker.

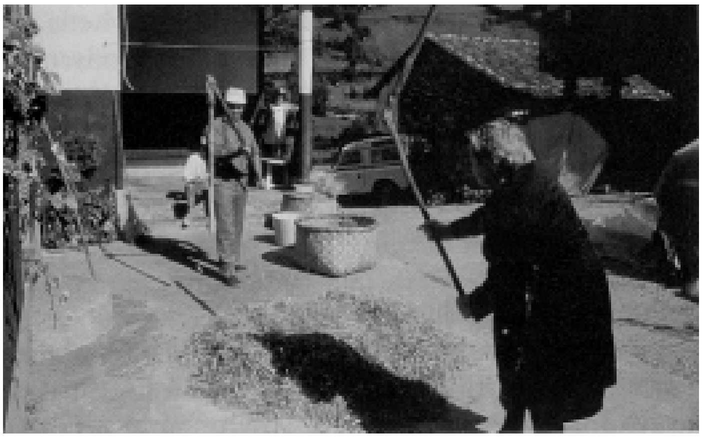


Fig. 14. Threshing emmer and spelt by flailing

Winnowing of emmer and spelt

Immediately after threshing the ears, the spikelets are winnowed with a type of winnowing drum fitted with a piece of leather, usually goat or sheep skin. On a windy day the spikelets are placed in this sieve and poured from a certain height. Dust and impurities are then selectively removed by winnowing and the spikelets piled on the floor. The spikelets can also be thrown into the air with a rhythmic movement in such a way that the lightest contaminants are brought to the surface and then scooped off by hand.

Storage of emmer/spelt spikelets

Spikelets are put into bulk storage in aerial granaries widely spread throughout some areas of northern Spain.

Dehusking

Emmer and spelt need to be further processed in order to free the grain from the husks as human consumption is the main use. Traditionally, dehusking took place either immediately after the harvest, or more commonly at Christmas time.

Spikelets are dehusked in special mills called ‘abiles’ or ‘pisones’. This is a type of mill in which the lower stone has a bigger and deeper grove than a common mill. The upper stone is set higher to allow the spikelets to pass through and the ‘poxa’ (husks) are stripped from the grain without the grains being crushed. In the traditional mill, chaff and grain were not separated during milling. However, today the chaff (‘poxa’) follows a different circuit from the grain and hence, clean grain and non-dehusked spikelets (‘ergatos’) are the final product. This type of dehusking mill was widespread in the Asturias region, although only a few examples remain still in use.

The emmer and spelt grains are then ground into flour on normal milling stones usually in the same building.

Uses

Einkorn

Einkorn is used nowadays as fodder for animals. Milled and mixed with water, einkorn makes an excellent food for pigs and cattle whereas spikelets on their own, or mixed up with barley, are fed to mules, goats, donkeys and hens. Eggs of hens fed with einkorn are said to be whiter than those from hens fed with other foods. The shell is also thought to be harder. Einkorn chaff mixed with nettles used to be given to turkeys, hens and rabbits.

Although the consumption of einkorn by humans still occurred within living memory it does not seem to have been a major component of the human diet. Most people interviewed remember that it was made into bread in lean times. Whole spikelets were milled and then sieved to separate chaff fragments.

The straw has been used in different ways in different areas. In the Cádiz province it was commonly used for thatching and there it is still possible to see huts (‘chozos’) thatched with einkorn straw. Its hardness and ability to protect against rainfall make einkorn a good straw for this purpose. Its length has been also mentioned as an important advantage over other species. But the main use of einkorn straw within people's memory is for basketry, particularly in the making of ‘tapadores’ (a type of lid for pans, to prevent insects and dust falling in the food when it is cooking) (Fig. 15). This tradition is still maintained in areas of the provinces of Jaén and Córdoba. Other uses include filling of mattresses and saddles.

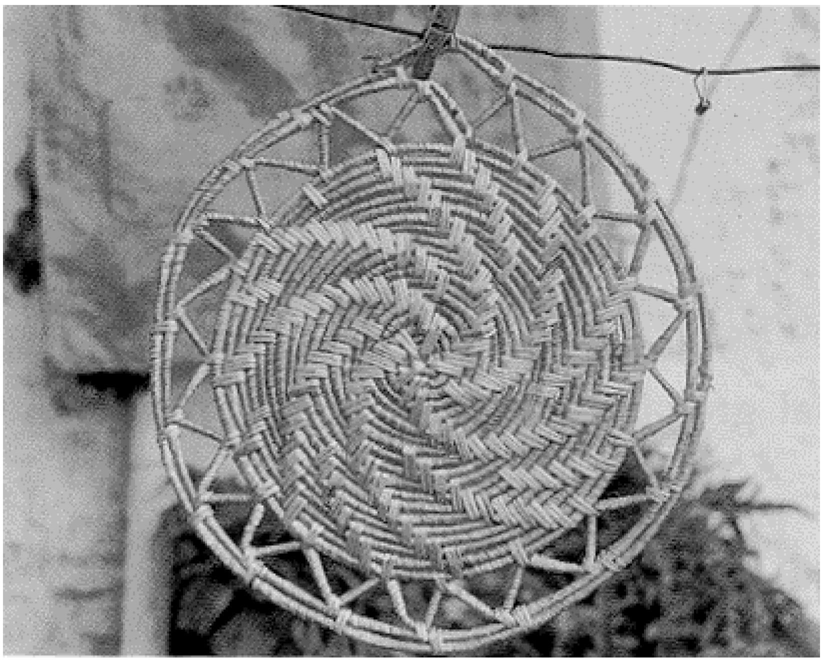


Fig. 15. A basket made with einkorn straw (‘tapador’).

Emmer and spelt

Foods prepared with emmer/spelt flour

Foods made with emmer and spelt wheats in Asturias are always produced from the flour. The most common way of consuming 'escanda' (emmer/spelt) in Asturias is as bread which has recently increased in popularity. Once milled (in water-powered mills), the flour is sieved in a series of sieve meshes ('peneras') of diminishing size. The sieved-out bran was used to feed animals (chickens and pigs) or to bake a poor-quality bread called 'fogaza' which was consumed before its higher quality counterpart. Bread is made in the traditional way following a long process of kneading and baking in ovens. 'Escanda' bread also has a special meaning, and it was and still is commonly used in religious feasts (such as Easter, the day of the village's saint, baptisms, marriages, funerals, etc).

In Aller, the westernmost area of glume-wheat cultivation, 'escanda' flour is used to make a bread which is usually consumed as a delicacy. It is called 'panchón' and is not baked in the common oven, but in a fireplace. The first step is the preparation of a dough from emmer/spelt flour, salt, water and fat. In the meantime a fire is lit, and when the fuel has been consumed, the ashes are moved aside. The dough is wrapped in *Brassica* leaves and placed on the fireplace, where it is covered by ashes and escanda chaff. The dough is then left for 6 hours to bake slowly and it is finally eaten mixed with milk and sugar.

A very common way of consuming emmer and spelt is in a kind of baby food made with flour, milk and sugar which are boiled together, and then eaten with cold milk. This mixture is called 'faricos', 'farinas' or 'farrapes' according to area. There are other ways of preparing 'escanda' foods, such as 'formigos' (bread crumbs, eggs, milk and sugar fried and sprinkled with wine), or 'freixuelos' (a kind of pancake made of a mixture of flour, eggs and milk mixed together and fried).

Use of emmer and spelt grains for animal food

Generally speaking, the grains of glume wheats (even as a whole spikelets) are not used for animal food in Asturias unless absolutely necessary. However, there are exceptions, as in some areas of Somiedo where the dehusking mill is no longer in use, impeding the use of emmer and spelt for human consumption. In these areas of generally poor communications, farmers are isolated and therefore taking the crop to the nearest dehusking mill may be costly. In these cases the crop is consumed by animals. In the past, animals were also fed with glume-wheats when taken to markets to be sold, because animals fed with 'escanda' are thought to have very shiny hair.

In Grado farmers grow 'escanda' for green fodder ('alcacer') either on its own or mixed with lucerne seeds. Here, as well as in Lena in the past, only the smallest spikelets or 'ergatos' were sown for fodder. The sowing takes place in November and the harvest in April. García Fernández (1981) mentions the use of spikelets fallen during the preceding harvest as providing the seed for growing green fodder ('alcacer') in areas of high altitude. Here the spikelets were not hand picked after the harvest, and the farmers merely added additional spikelets. The crop (ears and straw) was again harvested late in the spring to be consumed as animal food.

In Navarra, however, recent data (Peña-Chocarro and Zapata Peña, unpublished) suggest that emmer was exclusively used as animal food. The same has been observed in areas of Italy, such as Alto Molise (D'Antuono *et al.* 1993).

Uses of chaff and straw

Farmers made use of the chaff in different ways according to the area. It was traditionally used as fuel or as chicken food since it contained grains scooped off at the same time as the contaminants. Other uses were to fill up mattresses. In the most western area of glume-wheat cultivation in Asturias, chaff ('poxa') is also used in the production of a type of dessert ('panchón') (see previous section).

Straw is mainly used as bedding for cattle and pigs. Farmers agree that spelt and emmer straw are particularly warm and, therefore, most suitable for this use. Straw is sometimes consumed as fodder but, in most cases, only when there is no other food source available.

Differences between emmer and spelt according to farmers' opinions

As stated, emmer and spelt are cultivated in the same fields. In most cases, spelt is the dominant crop, and only some ears of emmer appear as contaminants. There are also cases, especially in the most western area (concejos of Somiedo and Belmonte de Miranda), where the proportion of emmer is higher, although it never exceeds that of spelt. At present, emmer is rarely found as the sole crop.

According to the ethnographic evidence, there seems to be a preference for spelt bread over emmer bread, and spelt has traditionally been considered as the richest and most valuable species for use in bread. Among the disadvantages of emmer bread which farmers mentioned is that it is flatter and darker than spelt. However, those in favour of emmer bread stressed the fact that it has a spongier texture. Spelt flour is more easily kneaded than emmer because it mixes better.

Among the differences observed in the fields, the local varieties of emmer tend to mature later (some 8-10 days) than the local varieties of spelt. Emmer is also more resistant to lodging due to wind and rain. Farmers also point out that their variety of emmer has more and bigger grains per ear than their spelt (note: the Asturias emmers are a very robust variety). This bulkiness of the Asturias emmer was greatly appreciated, at least from Medieval times, and was the species used to pay the tithe until recently. Even in the 1930s some rents to the landowner were paid in emmer. Concerning crop processing, emmer ears are harder to break into spikelets than spelt.

In conclusion, it would be proper to assume that spelt was, and still is, preferred for making bread. This preference, in conjunction with the abolition of the tithe, perhaps explains the very rapid disappearance of the cultivation of emmer wheat.

Threats to the genetic diversity of hulled wheats

The collapse of traditional farming systems due to mechanization and abandonment of agrarian activities in mountain areas is perhaps the main threat to hulled wheats.

Einkorn

The mechanization of agriculture has led to the decrease of a crop which was at some point an important element of the farming systems. Einkorn not only provided food for animals but it also produced a valuable material for thatching, basketry and other purposes. However, as the rural farming systems broke down, most of these activities also disappeared. As a consequence, the source of material required for such activities, i.e. einkorn, was no longer needed and its cultivation stopped. The few cases studied here are exceptional and should be considered as the last examples of a past way of life. During the past 5 years the few farmers growing einkorn have become older, and, in many cases, have got rid of the few animals still working in the farm. With no animals to feed, einkorn is no longer needed, and its cultivation has almost disappeared from Spain. In 1995, there is only a single farmer growing this crop in Spain.

Emmer and spelt

Emmer is still cultivated by a single farmer who maintains around 250 m^2 in central Asturias. Spelt (with some emmer mixed in) is grown by a larger number of farmers, in around 15 ha. Spelt cultivation is less endangered than einkorn or emmer as there are still farmers who grow spelt for their own consumption. There is also a small market at the local level for spelt bread which promotes to some extent its cultivation. Spelt bread is sold at high prices as a delicacy in the main towns of Asturias.

The cultivation of these two crops shows disadvantages which relate to the harvesting techniques used and the need to dehusk the spikelets to obtain the grain for human consumption.

Conservation activities

In situ conservation

The main problem in promoting conservation of these crops is the fact that these are not cash crops. In Spain, I organized funds to conserve einkorn cultivation. Funds, provided by the company Iniciativas Subbéticas since 1992, through a project supported by the European Union, cover the expenses of growing einkorn in the last village where this crop is still being grown (Córdoba province). No initiatives are available to conserve emmer and spelt cultivation in Asturiass.

Ex situ conservation

The Spanish Centre for Genetic Plant Resources (CRF) holds a collection of the three species and has agreed to be a depository centre of the germplasm of these species.

Conclusions

Today, in Spain it is still possible to find small pockets of hulled wheat cultivation which have survived in isolated areas associated with traditional agriculture and, in some cases, with very archaic practices. Research suggests that these are the last examples of the large-scale cultivation that occurred in the past. For millennia farmers have grown different crops which, in every case, were adapted to different techniques and under different cropping systems. This valuable knowledge is an intimate part of people's cultural and genetic heritage and a priceless element in any attempt to conserve and manage genetic resources. However, the changes occurring in these rural communities led to the abandonment of traditional agrarian practices and, along with it, also the interest in these crops and their cultures. There is no doubt that germplasm and traditional knowledge is highly threatened. Efforts should be made to urgently safeguard this heritage before is irretrievably lost.

Acknowledgements

For helpful criticism of this research I am indebted to Gordon Hillman, José Luis Mingote Calderón, Mark Nesbitt and Delwen Samuel. This work would not have been possible without the cooperation of many farmers in Andalucía and Asturias regions: special thanks go to farmers from Zureda (Asturias) and Zuheros (Córdoba) areas. For the assistance received in making the illustrations I am indebted to Vicente Castañeda Fernández.

References

Alvargonzález, C. 1908. La escanda. Su origen y su cultivo. Gijón.

Bregadze, N.A. 1982. Sketches on the agroethnography of Georgia. Tbilisi: Academy of Sciences, Georgian Soviet Socialist Republic. [In Russian, English summary].

Buxó i Capdevila, R. 1989. La presence de l'épeautre *Triticum spelta* L. dans l'alimentation en Espagne: les temps anciens et les temps modernes. Pp. 107-122 *in* L'épeautre: histoire et ethnologie (J.P. Devroey and J.J. van Mol, eds.). Editions Dire, Treignes.

Buxó i Capdevila, R. 1993. Des semences et des fruits. Cueillette et agriculture en France et en Espagne mediterraneennes du neolithique a l'age du fer. Unpublished PhD Thesis. Universite Montpellier II.

Caro Baroja, J. 1972. “Escanda”. Gran Enciclopedia Asturiasna. Vol. VI, 121-122. Gijón.

Caro Baroja, J. 1975. Los pueblos de España. Itsmo, Madrid.

Columella. 1941. De Re Rustica. English translation by H. Boyd Ash. Loeb Classical Library. William Heinemann, London.

Dantín Cereceda, J. 1941. Distribución geográfica de la escanda Asturiasna. Estudios Geográficos 5:739-797.

D'Antuono, F., C. Bignami and E. Mastronardi. 1993. Traditional agroecosystems and genotypes of cultivated plants inventory and conservation: case study in a Mediterranean highland Alto Molise, Central Italy. Pp. 269-286 *in* Socio-economic and Policy Issues for Sustainable Farming Systems (M.G. Paoletti, T. Napier, O. Ferro, B. Stinner and D. Stinner, eds.). Cooperativa Amicizia, Padova.

El Awam, Abu Zacaria Iahia Aben Mohamed Ben Ahmed Ebn. 1988. Abu Zakariya Yahya B. Muhammad B. Al- Awwam Libro de Agricultura. Translated into Spanish by Josef Antonio Banqueri in 1802. Madrid. Facsimile Edition by the Ministerio de Agricultura, Pesca y Alimentación, Madrid

García Fernández, J. 1981. Sociedad y organización tradicional del espacio en Asturiass. Oviedo.

González Llana, J. 1889. Manual de agricultura práctica de la provincia de Oviedo. Madrid.

Menéndez Pidal, G. 1993. España en sus caminos. Caja de Madrid, Madrid.

Ortiz, F. and F. Sigaut. 1980. La moisson de l’epeautre avec les “mesorias” dans deux villages asturiens. Bull. de la Societé d’Ethnozoologie et d’Ethnobotanique 8:2-4.

Ovid. 1989. Fasti. English translation by Sir James George Frazer. Loeb Classical Library. William Heinemann, London.

Peña-Chocarro, L. 1992. Los modelos etnográficos en arqueología: los cereales vestidos. I Jornadas Internacionales sobre Tecnología Tradicional, 21-29. Museo del Pueblo Español.

Peña-Chocarro, L. and L. Zapata Peña. (in press). The cultivation of *Triticum dicoccum* in the Basque Country: the case of Navarra.

Pliny. 1950. Historia Naturalis. English translation by H. Rackman. Loeb Classical Library.

Sigaut, F. 1978. Identification des techniques de recolte des graines alimentaires. J. d'Agriculture Traditionelle et de Botanique Appliquée 25(3):145-162.

Steensberg, A. 1943. Ancient Harvesting Implements. A Study in Archaeology and Human Geography. National Museum, Copenhagen.

Stordeur, D. and P. Anderson-Gerfaud. 1985. Les omoplates encochees neolithiques de Ganj Dareh Iran. Etude morphologique et fonctionnelle. Cahiers de L'Euphrate 4:289-310.

Téllez Molina, R. and M. Alonso Peña. 1952. Los trigos de la Ceres Hispánica de Lagasca y Clemente. Instituto Nacional de Investigaciones Agrarias, Madrid.

Toffin, G. 1983. Moisson aux baguettes au Nepal central. Objets et Mondes 23(3-4):173-176.

Vavilov, N.F. 1926. Centers of origin of cultivated plants. Bull. Applied Botany and Plant Breeding 16:2.

White, K.D. 1967. Agricultural Implements of the Roman World. Cambridge University Press, Cambridge.

Willkomm, M. 1852. Der Ackerbau in Spanien. Agronomische Zeitung 7(2):21-26.

The role of farmers' associations in safeguarding endangered populations of farro in Italy

C. Vazzana

Faculty of Agriculture, Dept. of Agronomy, University of Florence, Florence, Italy

Introduction

Triticum monococcum (einkorn), *T. dicoccum* (emmer), and *T. spelta* (spelta), some of the earliest domesticated plants commonly called 'farro' in Italy, are at present cultivated in marginal areas of several European countries, including former Yugoslavia, Spain, Turkey and Italy. In recent years, increasing interest has been given to these species because of their good potential as underutilized crops that would provide additional income to farmers while contributing to agricultural diversification. Germplasm-collecting expeditions have been mounted to collect the genetic diversity of these species, and sampled accessions are preserved in a number of genebanks around the world. Further efforts are needed to collect in areas not previously covered and to facilitate the availability to users of germplasm material already stored in genebanks.

At present, the problem being faced by farro growers in Italy is that the genetic diversity of this crop is becoming very narrow and is declining over time. Such loss of variability is closely linked to the nature of these species and the type of agroecological niches in which they are being cultivated. There is a need to gather more information on the genetic diversity of known populations and on those biotic and abiotic factors that play a role in controlling it. An important contribution towards a better conservation of these resources can be provided by socioeconomic studies. Several socioeconomic factors might be contributing to the loss of genetic diversity in farro, and we must adopt sound on-farm conservation strategies for these landraces in order to integrate these efforts with existing *ex situ* conservation initiatives.

In situ conservation goals and hulled wheats in Garfagnana

Thanks to germplasm-collecting expeditions, the ecoregional distribution of farro seems today rather well defined. This is true particularly in those European countries of the Mediterranean region. In Italy, farro occupies niches in peculiar traditional farming systems, resource-limited, located in mountain areas, where poor environment conditions represent a serious constraint for the cultivation of bread and durum wheats. In the Tuscany region, the cultivation of farro is undertaken mostly in the area of Garfagnana (Lucca province). Here, the production is sold mainly in local markets, where it is purchased for preparing popular traditional recipes.

Farro landraces are today cultivated under low-input agriculture, in integrated or ecologically oriented systems. However, high-input agriculture, with a higher technological presence, is also frequent. Especially if integrated or ecological farming systems are being used, on-farm conservation could represent an alternative and effective way to maintain the genetic diversity in these areas. This approach would contribute to increasing farmer's profits in marginal areas while allowing the dynamic conservation and the use of these resources.

An important role in this type of conservation should be played by farmers' associations, provided that *ad hoc* incentives to maintain landraces are made available to them. An aspect that should receive careful attention by policy-makers is: landraces have been conserved thanks to the crucial role played by farmers so far, but today their existence is at stake, threatened by population pressure and an unsustainable use of the environment.

The attractiveness of a crop like farro can be synthesized in the following points:

- suitability to low-input agricultural systems
- adaptation to marginal lands, scarce competition with other crops
- good competition with weeds in the field
- potential for development of new food products with high fibre content.

However, to be able to fully exploit these potentials, representative germplasm material within relevant agroecological zones needs to be carefully evaluated and studied. It is in fact based on the results from these investigations that a conservation programme for the landraces of farro will have to be built.

Although *ex situ* conservation represents an important component of the strategy for safeguarding the diversity of farro, in consideration of the implications that an on-farm conservation approach will have towards the sustainability and better use of this crop, I tend to favour much more the latter type of intervention.

On-farm is part of a wider conservation strategy, called *in situ*, which includes the conservation of natural habitats. According to Reid *et al.* (1993), *in situ* conservation is "the conservation of ecosystem and natural habitats and the maintenance and recovery of viable population of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties". According to this definition *in situ* conservation is the maintenance of landraces by farmers in the same fields in which they originated. Unfortunately, until today this method has been scarcely employed by the international community. In fact, it is more frequently applied to wild populations regenerated naturally in protected areas (habitat conservation) than used for the cultivated species (on farm). On the other hand – from a practical point of view – without the intervention of institutions, on-farm conservation of farro germplasm is *de facto* practised in different areas where farmers are actively cultivating landraces of such species (e.g. Garfagnana locality).

Attention on *in situ* conservation has been recently given by several authors; I would cite here, among several of them, Shands (1991), Swaminathan and Hoon (1994) and Brush (1995), which I found particularly interesting for this debate.

In situ reserves should be established in national parks or in other protected areas, with the condition that the objectives and special requirements like adequate sampling, management aimed at the maintenance of intraspecific genetic variation, access to reproductive materials, etc. are fully met. The adoption of an *in situ* approach has the following advantages (Palmberg 1987):

- *in situ* conservation allows evolution to continue, a valuable option for conservation of disease- and pest-resistant species which can co-evolve with their parasites, providing breeders with a dynamic source of resistance, and for continued co-evolution between associated species (for example, plants and their pollinators)

- *in situ* conservation of an economic species within an ecologically managed agro-ecosystem does conserve at the same time many subsidiary species of no present economic value, which form part of nature's heritage. Maintenance of genepools facilitates research investigations in the same habitats in which the species have evolved
- the *in situ* conservation of populations in equilibrium allows landraces to keep their internal variability and competition between genotypes. *Ex situ* conservation determines in fact the changes in gene frequency and the establishment of populations totally different from the original sampled population
- *in situ* conservation is an effective way of conserving species with recalcitrant seed which cannot be dried without rapid loss of viability and hence cannot be maintained in long-term seed storage. This is obviously not the case for farro and most cereals.

In consideration of these numerous advantages, I would say that in many cases, *in situ* is the ideal method of conserving plant genetic resources even if it is not always possible to guarantee long-term genetic integrity.

Establishment of *in situ* conservation activities: the Garfagnana example

The first step in any conservation programme is clarifying the objective and the priorities for conservation, including minimum requirements for success.

Ecological zoning of a species is an important first step towards the identification of the intraspecific genetic diversity. The simplest method relies on the measures of climatic characteristics and contiguity of populations; variation in soil and vegetation type are sometimes used as well. Where cultivated species have to be conserved, the technical management of the agro-ecosystem must be described. Sites for collection should be chosen when management requirements for conserving target populations and intraspecific variation are technically feasible, and they must be accessible for easy procurement of germplasm and for research. Sites should be chosen where protection would be the least disruptive to traditional land use. Preferred sites are the ones in which conservation can produce other benefits, such as conservation of genetic resources of associated plants and animal species, watershed protection, safeguarding of cultural and heritage values, etc.

To better understand what the role of farmers' associations could be in promoting the conservation and use of farro, I would like to report here the experience concerning farro in Garfagnana.

In 1986, the Regione Toscana (a major administrative authority in Tuscany) together with the scientific collaboration of the Department of Agronomy and Crop Science of the Agricultural Faculty of Florence University, started a programme for germplasm collecting, characterization and conservation in the region. There has been a direct involvement of myself in this project as I was called to be the coordinator from the University side.

After 2 years of collecting activities, a relevant number of germplasm samples of different species has been gathered from different ecological zones of the Region. A decision was then taken to establish a regional seedbank for conserving this valuable material. The genebank was eventually approved and it was built within the premises of the Botanical Garden of the city of Lucca. That genebank guarantees the preservations of around 500 collected samples of local varieties with the principal aim of reintroducing, as soon as possible, most of them in the local agriculture.

Twenty-seven different accessions of farro are at present preserved at the Regional Germplasm bank in Lucca, 23 of *T. dicoccum* from Garfagnana and 4 of *T. monococcum,* from the south of the region. Each of the 23 farmers from Garfagnana who provided the samples signed a contract with the Bank for the *in situ* reproduction of farro, following the protocol and the conditions indicated by the Regional Experts. At the same time, material from five selected farms is under investigation at the Florence University (Scientist responsible: Prof. Chisci) in the framework of the project 'Farro improvement' in collaboration with ARSIA (Agenzia Regionale Sviluppo e Innovazione in Agricoltura) and Comunità Montana.

One of the first problems which we addressed was related to the proper preservation of the genetic diversity of farro. The recent increase in the demand for farro (particularly in 1994), following the high demand for high-quality and healthy food, has necessitated an increase in the area cultivated with this crop. This situation is certainly beneficial for the popularity of this underutilized crop; however, a critical analysis of this phenomenon reveals that an increment in the cultivation will not necessarily bring the hoped-for benefits for the conservation of the farro diversity maintained in the Garfagnana fields. In fact, years ago, when farro was a popular crop, the diversity that could be found in its cultivated fields was very high. Unfortunately, the decline faced by the cultivation in subsequent years led to a sharp decrease of such variability. On the other hand, the return of the popularity of this crop has led farmers to again plant farro, but such new fields have been planted with largely eroded genotypes, often of the same ecotype and no longer with the same variability that was common before.

What should be done to improve this situation?

In my opinion, an important contribution in this direction could be made by capitalizing on the interest that is being felt at regional level by various organizations, including the Regione Toscana, on the cultivation of this crop.

Such interest is being used for lobbying towards the creation of a quality label (IGP – Indicazione Geografica di Provenienza – Indication of Geographic Provenance) for the farro produced in Garfagnana. Such a label would determine an increase in the profitability of the local farmers, thus encouraging them to cultivate existing local farro landraces together with those to be re-introduced through a programme of restoration of indigenous farro germplasm. The IGP, a new DOC (Denominazione di Origine Controllata = Denomination of Controlled Origin), was requested by farmers, by means of the Comunità Montana, in July 1993 following the EU 2081/92 directives. It is still under consideration at the Ministry of Agriculture and it is hoped that it will soon be approved.

The 'Farro della Garfagnana' is produced in the geographical area of 16 municipalities under the responsibility of the local Comunità Montana. Eighteen farmers from this area decided to get together to constitute an *ad hoc* Consortium which would have a specific quality label. The creation of a quality label is a necessary step for assuring consumers of the good quality of the product that would be produced here. The label of the Consortium of Garfagnana Farro Producers represents the profile of a gray mountain, a green meadow in a blue sky where the sun is shining and three farro seeds are sketched. All the technical directives to apply for the production of this labeled farro have been published and their use will be accurately controlled by experts.

In relation to this project, a recent meeting was held in Tuscany which was attended by both scientists and regional administrators. The meeting was called to discuss the feasibility and the possible implications of the creation of a 'Garfagnana farro ecotype' that would be cultivated exclusively in Garfagnana. Obviously, the point of major concern in such a project is the fact that the adoption of such ecotype throughout the region would narrow down the genetic diversity of existing landraces.

The meeting in synthesis came up with two possible options for farmers who would eventually be joining the initiative:

- work for obtaining one quality labeled ecotype which will be used for reproducing seeds having the same origin. Such a choice will determine the loss of genetic diversity and in the medium/long term will also affect dramatically the quality of the product
- to differentiate the reproductive sites where different ecotypes could be cultivated with conservation of genetic diversity, producing the component for the constitution of a multilinear variety which in the future could be labeled as a quality product of Garfagnana.

At present more research is needed to be able to make a choice between the two options: part of these research studies is the subject of the programme 'Farro improvement' here cited.

Regardless of which option is selected, it will certainly be necessary to maintain farmers in the area by assuring a significant improvement of their profitability. To this end, a significant step has been taken by proposing the establishment of a list of "agricoltori custodi" (literally "custodian farmers", i.e. farmers who would be maintaining farro landraces through on-farm conservation). These farmers, during the first phases of the conservation programme, could be financially helped by the Region, and later become self sustaining producers of farro seeds. In our case, the 23 farmers who signed the contract with the Regional genebank are acting as "agricoltori custodi" for the *in situ* conservation of farro biodiversity in Garfagnana.

This year they will receive from the Region the amount of around 250 ECU for their work in conserving germplasm resources (2078/92): it is a small support but it means that the Region recognizes their role. The role of "agricoltori custodi" also was addressed during the 'Rencontre Mediterranéennes de Manosque' in 1992, an informal gathering of NGOs, scientists and genebank managers organized for addressing the conservation of genetic resources in the Mediterranean region.

Conclusions

The debate on which would be the best way to safeguard the endangered populations of farro in Italy is still on. In fact, many Regions seem to face the same problems: biodiversity erosion, quality problems, etc. but only few specific initiatives are activate. Tuscany Region is probably the first in Italy which promoted its own programme for germplasm conservation both *ex* and *in situ*. Farro is one of the many species preserved at the Regional genebank (*ex situ* conservation) and maintained *in situ* thanks to the work of a few farmers under regional control. We think that the overall programme developed in Tuscany could be proposed to other Regions in Italy as one of the possible ways to maintain farro biodiversity for quality production. The direct consequence of this would be the creation of many regional quality labeled farro ecotypes, with possible competition and marketing problems at national level. Nevertheless, the direct involvement of farmers' associations under Regional control in the safeguarding project will surely make easier the *in situ* conservation of local landraces and allow a better income for farmers.

In the near future we must find a way to coordinate at national level all the conservation projects and IPGRI could play an important role in this. Inputs like those received through this Workshop, in which different realities at the national and international level are being addressed, will contribute towards the identification of the best strategies while speeding up the process of their implementation.

References

Brush, S.B. 1995. *In situ* conservation of landraces in centers of crop diversity. Crop Sci. 35(2):346-352.

Palmberg, C. 1987. Conservation of genetic resources of woody species. *In*: Proc. Simposio sobre Silvicultura y Mejoramento Genético. CIEF, Buenos Aires, Argentina.

Reid,W.V., S. Laird, C. Meyer, R. Gomez, A. Sittenfeld, D. Janzen, M. Gollin and C. Juma. 1993. Biodiversity Prospecting: Using Resources for Sustainable Development. World Resources Institute, Washington, DC.

Rencontre Mediterranéennes sur le patrimoine genetique domestique et le savoir populaires. 1992. Document de synthese. PAGE-PACA, Manosque, France.

Shands, H.L. 1991. Complementarity of *in situ* and *ex-situ* germplasm conservation from the stand point of the future users. Israel J. of Botany 40:521-528.

Swaminathan, M.S. and V. Hoon. 1994. Methodologies for recognizing the role of informal innovation in the conservation and utilization of plant genetic resources. Proceedings 9. Centre for Research on Sustainable Agriculture and Rural Development, Madras, India.

III. Local and Traditional Uses

The ‘farre de Montelione’: landrace and representation[1]

C. Papa

Institute of Ethnology and Cultural Anthropology, University of Perugia, Perugia, Italy

Introduction

In Valnerina, a valley situated in the Umbrian Apennines, the word ‘farro’ was still used until a few years ago to indicate *Triticum dicoccum* (emmer), a species already in use in Italy at Roman times. *Triticum monococcum* (einkorn) and *Triticum spelta* (spelt) were not known in this part of Italy and no trace of specific names that identify them have been found. Today, the name farro, as in other parts of Italy, is used to indicate collectively two species, emmer and spelt, without distinction. As a matter of fact, in recent times, the cultivation of spelt, detected only in the Valló di Nera village so far, is done mainly with material imported from elsewhere. Farmers, furthermore, are not fully aware of the difference between this species and the landrace that was once popular there. This is not the case for the territory of Monteleone di Spoleto, where an emmer landrace has been cultivated since time immemorial. Neighbouring territories had indeed a different destiny, as they went through a progressive loss of landraces. Such genetic erosion has occurred at a very fast rate from the 1950s onwards.

The introduction of *T. spelta* varieties in the area of *T. dicoccum* cultivation could produce both the introgression of alien genes in the local genetic pool of *T. dicoccum* and the substitution of *T. dicoccum* local material with more productive *T. spelta* varieties. This process is incidentally favoured by the fact that there has not yet been an identification of an emmer landrace and that measures for *in situ* conservation have not been adopted so far.

Such a process is dangerous and becomes even more so when the more farmers who practise this cultivation are unaware of these implications. Yet it is even more detrimental when the spread of improved varieties is being done in the (incorrect) belief that this will be beneficial to the existence of the local variety itself. For these reasons, the study of local culture that has developed on the basis of such a cultivation represents an important contribution towards the safeguarding of this biodiversity. This type of work does, in fact, increase awareness of the significance of this cultivation throughout its long history, and on the uses of this valuable crop.

Often, in programmes aimed at the conservation of biodiversity, an emphasis is put on the importance of the knowledge and conservation of local traditions and culture associated with it. This is done on the grounds that traditions have allowed the constitution and survival of such diversity and that the safeguarding of traditions would be beneficial to the very conservation process of the diversity that these refer to.

One cannot but agree with this point, yet further comments might be of help to clarify it.

First of all, one must not make the mistake of considering the local culture which revolves around landraces as an immutable fact, as something not undergoing transformation, characterized by oral transmission, produced and

[1] This article is partly based upon results published in Papa 1990.

preserved by popular classes, without interferences from the written culture and knowledge produced by other social classes.

By analogy we may imagine that the same cultural dynamics may be applied to the present and that the knowledge and practice that permit the *in situ* conservation of specific landraces have not only undergone changes in the past but will also in the future, due to environmental, social and cultural contexts.

This does not imply indifference with regard to their gradual disappearance, which must be avoided by recognizing the worth and meaning of such patrimony. One must be aware of the fact that this cultural heritage has its own vitality which includes a capacity for change and that it would be unwise and detrimental to destroy it.

My purpose here is to attempt to offer a diachronic perspective regarding uses and knowledge connected to emmer, with specific reference to written Roman and Renaissance sources.

Emmer throughout history

On the basis of this brief review, we can see that in the various epochs, not only has the role of emmer in food habits varied to a lesser or greater degree, but also its importance in rituals and religious ceremonies has varied, first in the Roman era and then during Christianity[2], and, more generally speaking, with the different cultural representations in which emmer has had a central role.

It is widely known that emmer was used in Italy in the Roman era. Pliny describes it as the staple food of ancient Latium. Many Latin sources refer to this species, by using terms like *far, ador, semen, adoreum, alica*[3]. These terms have also received the careful examination of Carmine Ampolo, who in a meticulous fashion has specified whether the terms in Spanish, Italian, French and English[4] are referring to *T. monococcum, T. dicoccum* or *T. spelta.*

The exact meaning of these Roman names is, however, a long-standing debate, not yet entirely resolved, between historians and naturalists. In fact, some scholars identify the above-mentioned Latin denominations with spelt, rather than with emmer, whereas for others “the terms far and adoreum refer distinctly to one and the other cereal” respectively (De Martino 1984:255). There may be many reasons for such a difficult identification. Today the Italian language leads certainly to a great confusion as the word farro is valid for both species (and for einkorn as well). Furthermore, there is a certain confusion in the Latin sources themselves, where it is possible to note an overlapping of meanings between general and more specific terms and they are used in place of each other (Aebischer 1953).

Unequivocal indications have not been found from any archeobotanic source. These have in only a few cases allowed a distinction between the two species. They are often considered in most cases as one entity in those findings which also have other cereals, especially barley, and einkorn present in lower percentages.

---

[2] There are still, however, a few Catholic ceremonies that have emmer as the central symbol. An example is the one that takes place in Monteleone di Spoleto to honour St. Nicholas (Papa 1990).

[3] The main Latin authors to use these terms are listed in Annex, along with excerpts from relevant papers.

[4] The sources that indicate the corresponding terms in the main languages of the ancient Orient, in Latin and Greek, are also Forbes (1955), Jasny (1944) and André (1956).

"The fundamental feature of paleobotanical documentation observed to date is that of bringing to light various species of cereals mixed together in findings, at times together with legumes" (Ampolo 1980:18). This mixing of the crops was done by the Romans, most probably to ward off the risk of a bad harvest for one or another cereal. Such a mixture of different cereals was called *farrago*. In the Middle Ages this continued to be a widespread practice and was called 'mestura' (Montanari 1979).

After considering the foregoing, which indicates the requirement for critical attention in the identification of the species, and keeping in mind the contexts of use and the typology of the sources, it is possible after an initial examination to detect how many of the references in the agronomic and literary sources highlight the importance of emmer in the Roman era. In order to throw light on this issue, it will be useful to review those references.

References exist on the techniques of cultivation, transformation and use, prices and ritual applications of emmer. The observations of Pliny are of particular interest. He specifically mentions emmer in his *Naturalis historia* the term *far adoreum*: "Of all the cereals, the hardest and most resistant in wintertime is emmer. It tolerates very cold and barely cultivated land, but also very hot and dry land. It was the primary food of ancient Latium, and we have proof of this in the offering of the adoria" (Pliny 1984:711) (*adoria* was the prize given to those soldiers who returned victorious from the battle). Pliny also adds that emmer was not only one of the most vigorous species together with *silig* and wheat, but also one of the most widespread crops as well.

Also according to this author, who cites Verrius Flaccus, for 300 years from the beginning of the founding of Rome (therefore to about the second half of the 5th century BC) the Romans cultivated nothing other than emmer (Pliny XVIII:11).

Calomel also confirms the widespread use of this cereal and indicates as many as four different varieties. The crop had even more ancient origins: emmer, which was already present in Neolithic Egypt, was also the "first cereal with which bread and beer were made" (Haudricourt and Hédin 1987:126-128).

The importance of this crop and its antiquity can be testified through an etymological examination. We could in fact refer to the use of the Italian term *farina* (flour), a product derived from *far* (emmer) and to the use of the Latin term *farratum*, which was used to indicate the primitive form of puls made from *far*. It may also be important to stress here that emmer had a central role in numerous rituals, which demonstrates that this cereal was the object of veneration and that it had been used, at least as a source of food, in more ancient times with considerable importance.

In a study on Roman feasts held in February together with the economic importance of emmer, Brelich also includes its importance in rituals as one of the fundamental ingredients of sacrifice: "a basic human food, emmer, had a primary function also in rites and ceremonies: the mola salsa, which was emmer mixed with raw and cooked salt, was an indispensable ingredient of sacrifice" ('immolare' the Italian word for sacrifice, means to cover with mola). Logically, therefore, its preparation was entrusted to the Vestals that guarded and guaranteed the foundations of the people's existence. These rituals occurred in three equally important festivities: Lupercalia, Vestalia and the Idus of September" (Brelich 1976:12).

Emmer was also a central component in another festivity which we can say was specifically dedicated to it and which was called the Fornacalia. According to the tradition, Numa Pompilius had instituted this festivity in order to toast emmer. It took place in February and according to Ovidius it also included a sacrifice to the Goddess Fornax, the furnace, where the toasting took place. According to historians the practice of toasting also had some specific purposes: rendering the cereal easier to digest and allowing the grain to liberate itself from the glumes. According to Brelich, the festivity also served as an offering of the first fruits to the divinity that made emmer accessible for consumption for the first time through the process of toasting. The exact date of the start of the feast was not always the same, but the celebrations ended with the Quirinalia on the 17th of February. This day was called the *stultorum feriae* (literally "feast of the absent minded") as it was the day in which the Fornacalia was celebrated by all those who had forgotten to do so on the day set aside by their own *curiae*, territorial organizations for the recruitment and celebration of collective rites.

It is no surprise that in this setting the most ancient and privileged form of Roman marriage was the Confarreatio, a ceremony where the young bride carried a loaf of emmer bread, the *farreum*.

In the Middle Ages there was still widespread use of emmer in Italy. Confirmation of this can be found in the writings of Corniolo Della Cornia, a writer from Umbria who lived between the 14th and 15th centuries. Here are some excerpts: "The ancients called emmer adore. Resistant to cold and strong winds, it supports very cold and less worked places or very hot and dry locations. It is well nourished by the hard earth, clay and red earth. It is sown at the same time as wheat, ten modius per jugar. It is of a mild constitution, good for both healthy and ill persons, astringent rather than laxative. It well nourishes and keeps. In Gallia a species of emmer is produced, called 'brace' by the inhabitants, which we call 'scandala'. It has clean grain from which more bread can be obtained than from the other emmer" (taken from Bonelli Conenna 1986:86).

By following the identification of the species provided by Ampolo, we could presume that by the term 'brace' Corniolo della Cornia was referring to spelt; and in fact, his very description confirms this. On the other hand, he does not make a clear distinction between emmer and spelt, assimilating partly the latter to the former.

Gradually the use of emmer was reduced in favour of other non-hulled wheat species. However, despite this inverse trend, the cultivation of emmer in many zones of Umbria continued until the end of the last century. This fact is confirmed by the preparatory documents made for the Jacini Enquiry (a nation-wide agricultural survey commissioned by the national authority at the end of the 19th century) on the surroundings of Perugia, Foligno and Rieti. Here there is mention of the fact that farmers were against the cultivation of this type of crop in this territory as they believed it rendered the land barren (a fact probably due to the rotation method used in that area).

Today, the Valnerina and in particular the territory of Monteleone di Spoleto, which includes the district of Rieti, is the only area in Umbria and one of the very few in the rest of Italy[5], in which the cultivation of emmer has continued ever since with no interruption and where the crop has always been used for human consumption. In fact, in the first decades of the 20th century, emmer was a staple in the diet of the local poorer classes. However, the trend in the use of emmer here reached the lowest level of consumption in the 1970s.

---

[5] In particular, until the last century the cultivation of hulled wheats occurred more or less extensively throughout Italy (Acerbo 1934). These cultivations have been successively limited to some mountainous areas of Central and Southern Appennines and the Alps (D'Antuono 1989).

Emmer was and still is mainly consumed after it is crushed and reduced to very small pieces and boiled at length in broth or water. This is a dish which is similar to the ancient Roman *puls*, a primitive meal made up of emmer (*farratum*), which was boiled in water or milk until it assumed a consistency which varied in liquid density.

Pliny (1984:713) points out the importance and the precedence of *puls* in the making of bread in Roman culture: "It is well known however that for a long time the Romans ate *puls* instead of bread, from the moment that even now some foods are called *pulmentaria* and that Ennius, the ancient poet, in order to describe the famine during a siege recalls how the fathers stole the flat loaves of *puls* from the hands of their crying children. Even today, in ancient rites and when celebrating birthdays, sweets of *puls* are made and it seems that *puls* was as unknown to the Greeks as barley flour was to Italy".

Pliny therefore points out that during his time the *puls* made of whole or coarsely crushed grain and of unrefined flour was used as ritual food, which seemed a rather archaic, poor and discriminating dish. But this idea must have come about even before, if it is true that Plautus notes that the Greeks used to call the Romans with disdain 'pultiphagonides', that is "eaters of *puls*". That *puls* was an essential component of the Roman diet in the early centuries is also testified by the term *pulmentaria* which originally was used to indicate meat dishes that were eaten together with *puls*, and as such were considered an additions to *puls*, which was the main dish. Thus, the term *pulmentaria* can be said to be the exact correspondent of the Italian 'companatico' (which refers to anything eaten along with bread). It is no coincidence that *puls*, with the growing use of wheat bread, begins to change its characteristics completely. Enriched with meat and condiment, made of better and more refined flour (André 1961), it too is transformed into 'companatico'.

But if this process of dominance and successive decline in the use of *puls* can be held, according to the historians, to have been completed within the span of the Roman era before it can be considered as completely exhausted, then centuries would have had to pass, centuries in which the *pultes*, composed of different cereals according to the era and to the geographical contexts, were an indispensable source of food with which to feed the common people of Europe.

Corniolo Della Cornia also alludes to a kind of *puls* when he speaks of a mixture of sedge hay and emmer "that appeases hunger if mixed together to take away the bitterness of the sedge hay which nonetheless causes stomach aches" (Bonelli Conenna 1986:352).

For centuries, cereal bread was an "elusive" object (Camporesi 1980) desired more than obtained by those classes which, although they produced the raw material, nonetheless had to make do with bread made with all kinds of vegetable mixtures (and with soups and corn meal), boiled at length in the fireplace.

Why emmer is cold food

For centuries in Valnerina, emmer soup has been playing the role of an essential food, which many elderly people still recall as a food eaten mainly in the evenings and more or less on a daily basis.

Eating emmer meant eating something that was **produced directly**, made by the householder. Emmer, which was not only produced by the family, but could be crushed with a domestic grinder[6] without having to be brought to the mill, began with time to acquire the connotation of a poor food for poor people.

Some informers recall a fairly simple and rudimentary tool used to crush emmer: "When I was young I remember there was a trunk of wood here in front of me, a trunk of a large tree, and in the middle of this trunk they had made a hole, then with pieces of wood, they would crush the emmer and from the hull the grain would jump out, a little damaged. The grains will be then cleaned and used" (Giovanni P. living in S. Giorgio di Cascia).

It was "necessary" to eat emmer because there was nothing else to eat, but as soon as it was possible, and this began to occur more frequently after the Second World War, one turned away from the necessity and monotony of its constant use.

In this context of changing food habits and generally speaking of changing life-styles, whoever continued to eat emmer – the symbol of a diet to which one had to succumb because of a subsistence economy dominated by stock-rearing and agriculture based on very small holdings – became an object of scorn from those who had freed themselves from hunger and poverty and who no longer made use of it. The main victims of this scorn were the inhabitants of Trivio – a division of Monteleone situated in the more mountainous part of the municipality, far from the other inhabited centres, and where the cultivation of this cereal was more extensive. It is interesting to notice that these persons, similarly to what had occurred in Roman times (the term 'pultiphagonides' applied by Greeks to eaters of the *puls*), were called with derision 'mangiafarre' (emmer eaters) and 'mangiapancotto' (pap eaters) by the inhabitants of nearby towns.

The definition of the identity of another people by referring to their eating habits – improper or of bad taste, real or presumed as it might be – in most cultures, is a means of denigration rather than designation. Designation can be made for instance in the case of an entire nation, e.g. Italians are called 'macaronis' by French and English people, or the French 'frog eaters' by the English. But within the same culture, food can become indeed a means of distinction and separation. This is the case, for instance, for the people from Veneto or Lombardy region, in Italy, who are called by the inhabitants of other Italian regions with the derogatory term 'polentoni' (corn meal eaters).

The group that is the object of the appellation is not always distant and culturally different; often, they are near and similar. In Valnerina, for instance, the inhabitants of the nearby towns call the people of Piedipaterno village the 'scocciagammeri' meaning shrimps eaters, and those of Scheggino, a village along the river Nera, are called 'ranocchiari' (frog eaters).

But if "the other" from which one wants to separate and distinguish oneself is defined by referring to oneself, then the same name can be used to designate more than one subject, and different sets.

This is what occurs with the term mangiafarre, which the inhabitants of Monteleone use for referring to the people of Trivio, a locality belonging to the same municipality, and which is used in turn by the neighbouring towns for all the inhabitants of Monteleone.

There is a two-way relationship between emmer and Monteleone. Not only is an entire community connoted by the consumption of emmer, but emmer itself is connoted with respect to the privileged area of its production and use, so that in the Valnerina this cereal is known as the 'farre de Montelione' (emmer from

---

[6] The 'macinella', a small grinder or mill, is made up of two semi-circular overlaid stones, of which the upper one supports an iron axis.

Monteleone). The existence of this term in itself implies that there is a landrace. Emmer, a poor and archaic cereal, differentiates itself from the norm. Its use and cultivation represent more than a sign of identity, it is a sign of another, specific place and its inhabitants.

With the word mangiafarre one underlines what one wants to demonstrate as most distant and different from oneself, having gone to great lengths to separate oneself from “the negative and repulsive pole of one's own identity” (Bromberger 1985:13). It is an attempt to exteriorize and reduce the other to a simple eating taboo, with which one does not want to identify or be identified. And this is because this food identity refers symbolically – in a wider sense – to another culture which automatically is also charged with other ethnic stereotypes that are consistent with it, most common being miserliness. The inhabitants of Trivio, therefore, eat emmer and are miserly or rather they are so miserly as to eat emmer.

The miserliness reinforces the meaning attributed to the fact of eating emmer and together with it in some ways modifies it: emmer is a poor food, but whoever eats emmer does so not only because he/she is poor, but because he/she is also miserly, not wanting to spend money on more costly food, and so is to be blamed for continuing a tradition of poverty.

Eating emmer was therefore seen as a deviant and blame-worthy activity with respect to the community's effort to adopt modern life-styles and eating habits in keeping with those of the city, where there was an attempt to break away from a subsistence economy, and to come out of the isolation of the mountain valley.

In the last 10 years this is no longer the case, and the situation has changed somewhat. The rediscovery of natural and macrobiotic food has underlined the value of emmer for the very reasons for which it was despised – because it is cultivated in a natural way without manipulation and without resorting to modern agricultural technology, an authentic food that does not betray its origin.

The introduction of emmer into the big city markets has brought about a modern redefinition of its traditional image which highlights its features as a dietary product, cultivated biologically and without the use of artificial herbicides and fertilizers.

Emmer, once abandoned after the war in search of more costly foods bought in the market place, is now becoming a distinctive sign of identity for the inhabitants of Monteleone di Spoleto. If in the past the term ‘mangiafarre’ had a negative connotation, now that the crop has been introduced into city markets it no longer bears this connotation, but on the contrary it is rather the source for a proud affirmation of identity. However, the generation that has this new attitude towards emmer is not the one that decided for its neglect; the latter still looks upon this recent fortune of emmer with skepticism.

Emmer was in the alimentary system of Valnerina not the rule but the exception, and also the nutritional characteristics which have been attributed to it are beyond the norm.

Emmer was, and still is today, seen as having little nutritional value with respect to other cereals. The qualities that on the other hand were attributed to it were those of ‘refreshing’ or ‘cleansing’, of being a light food for ill and elderly people, and infants being weaned, indeed a food that is easily digested.

Today the representation of the nutritional properties of emmer are consistent also with the characteristics attributed to the plant and with the methods with which it is traditionally cultivated in the area. We are dealing with a plant that adapts well to the mountain environment for the brevity of its vegetative period which takes place in spring and summer, from March to August, in this way avoiding the cold autumn and winter climate of the mountain. Furthermore, the emmer plant, is said to prefer lean, stony, impoverished, mountainous soils, that have not been fertilized; a plant grown in these type of soils (called ‘brecciole’), can tolerate heavy rainfalls during spring time. The rain is needed also for the “the firy earth, that remains red and contains iron” and “it also wants water because it is firy and if it doesn't rain it becomes hard”; on the other hand, planted in the clayey earth “a white earth without rocks or stones; emmer grows taller, tolerates drought because the soil ‘holds’ well, but here it does not tolerate heavy rainfall” (Ilario S., from Trivio, a locality of Monteleone di Spoleto).

In short, it is a plant that needs little from the environmental and climatic conditions and from the conditions of the soil, a plant of elevated rustic quality with considerable qualities of adaptation. A plant, therefore, that from poor and stony soils, offers a refreshing and light food. An internally consistent representation which is reinforced by its symbolic and ritualistic meanings.

The refreshing feature of emmer does not refer to its thermal state, but rather to its nutritive power and in itself it takes on other features to which it alludes. Emmer, like some medicinal plants, refreshes within a dichotomy in which hot and dry are identified with disease, with an altered physical state, and with sexuality.

A heat-producing food is a food that is digested with difficulty, which supplies much nutrition, which as Italians say “makes blood”, and which “has strength” and substance and therefore it is a food which also produces sexual heat. On the contrary a refreshing food is anti-aphrodisiac, humid, with little nutritional value. One can therefore point out, as Cardona does (1985:69) that “even if intuitively we feel that the opposition is one only, we are faced with difficulties when we try to define the terms of opposition semantically...we are dealing in fact with an opposition not between two single terms but between two constellations of semantic traits”. Within this polarity, cereals do not all occupy the same position, the same properties are not recognized in all of them. Corn and barley are at one pole, and are considered a heat-producing food, and emmer is at the opposite pole, and considered refreshing food. Between these two poles we have wheat, the cereal *par excellence*, the point of equilibrium between the two extremes.

Therefore, only wheat can be said to hold the place which Detienne (1975) has revealed as being where cereals in general are in the Greek codex, which at the same time deals with botany, food, sexuality and ranges from aromas, sun plants as well as hot, dry, perfumed and aphrodisiacal plants, to lettuce, a plant which is cold, humid, raw, “close to death and nasty smells”.

The properties attributed to these cereals in the local community emerge with clarity when they are listed, classified and juxtaposed in reference to a single purpose, as in the case of animal feed. An informer (Ilario S.) comments on the mixture of fodder for his sheep made of emmer, wheat and corn: "corn gives the animal more substance and keeps it fat, otherwise it gets thin; emmer refreshes it, wheat neither fattens nor refreshes". The equilibrium is guaranteed by the extremes which compensate for each other. In this case, the only component which seems of little use is wheat and in fact the informer himself sustains the practical uselessness of wheat when he states that he adds it to the fodder only because he has it and to avoid buying other cereals. Each of these cereals has a different function and it is in respect to this that it is being used: "We give wheat to the spring lambs and not emmer as these animals do not need refreshing since they are milked by their mothers; we give emmer to sheep when they have lambs because THEN they need it as they have to milk their babies" (Quinto M., from Trivio, a locality of Monteleone di Spoleto).

The category ‘fresh’ is directly associated with the category ‘humid’. Emmer favours the production of milk, an anti-aphrodisiac product, while at the same time milk substitutes for emmer as both are refreshing elements. Emmer, being ‘fresh’ and ‘humid’, is the most appropriate complement for winter animal feed based on dry fodder, which produces ‘dryness’ in the animal, this not being necessary when animals can feed on fresh grass.

The differentiated use of various cereals in human and animal alimentation clarifies the meaning that is attributed to each cereal. Wheat, which on the scale from fresh to hot is situated in an equidistant position, is unsuitable as animal feed that normally has to be rather fattening, therefore heat-producing, and in particular circumstances, refreshing. The contrary is the case for human consumption where wheat is seen as a nourishing, balanced food, at the equidistant point of an equilibrium between the excesses of hot and cold, both to be equally avoided.

In the case of emmer one can also see how the criteria of re-assignation are multiple. The caloric criterion, however, seems to have an influence in the diverse collocations of the various cereals.

In the comparison between emmer and wheat it is pointed out that "in wheat there is more flour, and in emmer there is more bran" (Giuseppe L., from San Giorgio locality near Cascia). This is why it is said that wheat is more nutritious, and "emmer does not have much strength, it doesn't have much substance" (Paola F., Trivio). In the same way, a more intense colour and a larger grain size have an influence in the consideration of corn as a caloric food in respect to wheat and emmer. The ways of cooking, in this case distinguished essentially on the basis of the fats added, in those of fatty (pork fat) or lean (vegetable oil), change the evaluation with regard to the different kinds of emmer cooked. The lean fat is more refreshing and the animal fat is more calorific, without however varying the classification of the food in itself; although it has a bearing on the assignation of the food once it is cooked, it is rather independent with respect to it.

Nevertheless these criteria do not seem the dominant ones and they are certainly not the only ones in the classification of emmer.

What one wants to demonstrate here is the place that emmer has taken historically in the classification of food, as well as its social and ritualistic aspects. That which the term emmer denotes and that which it connotes are closely linked to how it is classified in a system like the one based on the four polarities of hot, cold, humid and dry. In other words, the classificatory assignation does not only consider the traits of its semantic and encyclopaedic definition, but also its contingent semantic and encyclopaedic traits to which propositions “that do not concern the species or the genus at all times and in all places” refer (Sperber 1986:42) as for example, “emmer is an archaic food” or “emmer is not easily manipulated”.

It is worth considering at this point the concept of neutral. In the Valnerina the neutral food *par excellence*, that is a food that is neither hot nor cold, is wheat and its derivatives – bread and pasta. As Foster has already pointed out (1984), the foods that are generally considered as neutral are those foods that are found in the following conditions: foods of which the informer does not have an exact knowledge and in that uncertainty are classified as neutral, or foods that constitute the basis of a diet – what Foster calls "stable foods", basic foods that represent the standard and balance of opposites. If we apply this to the matter at hand we could say that the classification of emmer (in the specific case as refreshing food) derives not only from its intrinsic characteristics or from the ways in which it is eaten, but also from the fact that it has became a cultivated crop and food that is archaic and residual. This was not the case when emmer had a primitive widespread use as described by Pliny, where it was a "staple food". Therefore the place that a food occupies in the food system and the economic value of the cultivation (as in this case) or in other cases of breeding or production are elements which determine its classification.

The manipulative and transformative degree of a food is strictly connected to its diffusion. Among the cereals we find that the most widespread cereal is the one which is most easily manipulated.

In distinguishing between wheat and emmer, cereals that are so similar that to the untrained eye they seem identical, it is pointed out that it is from wheat (and not from emmer or from how it was used in the past) that we make bread, pasta and sweets. One can see more clearly, at this point, the level of distinction between wheat and emmer and other cereals. Wheat is the most manipulative cereal, the most easily transformed, the cereal that through human intervention goes beyond itself and distances itself from its original form. Wheat, by means of human intervention, becomes something else, it goes beyond its natural state, and appears to be the most suitable cereal for a kind of ‘culturalization’ and thus a ‘humanization’. The flour itself, a raw material which has not yet been transformed into food, is already totally different from the grain in consistency, colour and form and it too will then be transformed into food.

On the contrary, emmer, even when it becomes an edible food for human consumption, remains the same, similar to what it was originally. Thus, the name of the food is identical to the name of the plant.

Emmer is not made into flour, but is eaten in small pieces which, in colour, consistency and form, are not much different from the original grain. Sifting and winnowing, crushing, beating and cleaning make the grain edible. A ‘dirty’ grain it is said can be eaten by animals, but not by humans, and a grain with the husk and all or with ‘lu cocciu’ (the covering) is given to animals. Nonetheless despite the cleansing of the impurities the grain is still the same as it was before.

Therefore emmer can be used for human consumption, but this proximity to nature means that it is a rustic, not greatly refined or cultured food, bound to be used as feed for animals. Emmer is not a food *par excellence* as wheat. It is a food for particular categories and conditions. It is a food for the sick and the poor, an ancient and ritual food, a food for children and for animals. Emmer is not the norm, and from this point of view it represents one of the poles of a dichotomy. And it is also this particular cultural aspect which influences the classificatory attribution, thus making emmer not a neutral food, but a food which is considered, not only from a nutritive point of view, a poor and therefore, cold food.

The classification of emmer is the result therefore of the combination of several consistent criteria. These are multiple criteria because the assignation is relevant not so much to a single category (cold) but rather to a class made up of several connected categories. It becomes quite impossible therefore to identify the totality of the traits that determine the includion or exclusion in one or the other of the two classes.

It is thus insufficient to limit oneself to the consideratin of the morphological criteria as the only pertinent ones, as if one were dealing with a scientific taxonomy. However, the conceptual and symbolic definition of emmer is pertinent in its overall complexity. This means that one cannot draw with extreme detail the outlines of this definition which remain wide-ranging and vague.

The construction of emmer's image today

The progressive degradation of emmer from a food for human consumption to a food for animals is consistent with its representation: that of being a cereal with little caloric value, poor and archaic, and this, however, is consistent, even though it may seem paradoxical in purely abstract terms, with its current utilization.

After the Second World War, until the end of the 1970s, the archaic nature of emmer, the absence of industrial manipulation, the fact that it belonged to a system of subsistence farming and to a poor system of diet and that it was of vegetable origin, all these factors altogether did contribute to its automatic depreciation within a culture which was, in reaction to its past history of poverty, gradually sustaining and enjoying industrially produced foods, meat and food rich in condiments and calories.

In the 1990s, the thinking about food led to opposite conclusions: value is given to food of vegetable origin, with few calories, which has not as far as possible undergone industrial processing, and which is incorporated into diets that contain little or no fat and condiment, food also commonly known as the 'Mediterranean diet'.

This briefly outlined dichotomy, though indicating general traits of transformation, does not fully explain the current complex system, which has incorporated and given value to eating habits which belong to other systems and traditions different from the Italian tradition. This has meant that there has not been a homogeneous system and that the system has been characterized by the inter-relationship of different food cultures, rather than by a compact, autonomous system.

Despite the changes that have taken place in food habits in the last decades, emmer has kept, without undergoing variations, its place as a 'refreshing' food within the polarity hot/cold.

This analysis may appear to counter what we have maintained until now, that is, the fact that the classificatory assignation for emmer depends on the place it assumes within each single system – alimentary, social, economic – and thus it depends on relationship rather than on de-contextualised and objective factors (morphology, nutritional value, colour).

Placing an emphasis on this element of permanence, however, does not mean that the image and uses of emmer have not undergone changes. In the last 50 years at least, the use has remained, minimal from a quantitative point of view, and limited to a small geographical area and to certain social classes. And this is still the case today, though there is a process of expansion taking place. It is no coincidence that its cultivation could be defined as a 'niche' cultivation – today its consumers live in cities, rather than in the country, and are to be found over a wide area, as well as beyond the national confines, rather than in restricted geographical areas, and they are moved by different motivations, and are certainly not linked to a subsistence consumption.

What has changed radically, however, is the value that is now being attributed to it. Emmer in fact is no longer, as the old informers narrated, a food being imposed and therefore obligatory. Nor it is a food that must be abandoned because it is representative of a state of misery. Now it is a rather particular and highly valued food because of its urban re-evaluation.

This diverse evaluation is based not so much on the fact that the features pertaining to its definition have drastically changed, but rather on the fact that these features as a whole have assumed value and that everything at a food level which can be collected within the polarity ‘refreshing’ and not ‘caloric’ has also assumed value.

If permanence and transformation constitute two polarities and both are useful for the analysis of the emmer culture today, it is also true that these factors of permanence need to be understood within a context which has undergone a broad process of transformation so that the emmer eaten today by the clients of a Rome restaurant or the inhabitants of Monteleone is not identical to the emmer eaten in the past.

The way the land was worked to produce emmer in the past is not how the land is worked today with the use of modern mechanical means. The techniques used for the transformation of the product up to the 1950s when hydraulic mills and simple domestic tools, such as mortars and grinders were used, are not the same. The form of consumption has also changed. Foods containing emmer are no longer the staple diet necessary for survival. Today there is an endless choice of alternative foods. And the same landrace, the ‘farre de Montelione’ itself, is no longer the same. It too has evolved, thanks to the conscious and unconscious selection carried out by farmers and also to the changing natural environment (pedological, climatic factors, etc.).

One could analyse each of these changes objectively, but what I want to underline briefly is that the promotion of this product on the market, which its unhoped-for popularity and success have rendered inevitable, leads to manipulation of both its image and relationship with the land with the sole aim of ‘constructing’ its ‘typicality’.

The whole question of how this ‘construction’ comes about, on what basis and with what level of manipulation and falsification we are dealing and who is behind the whole operation is the object of investigation which would necessitate much more space than I have here at my disposal. However, I would try to underline at least major aspects.

In the first place, in the case of the ‘farre de Montelione, which is a landrace and therefore closely tied to the land and the local community, the protagonists involved in this ‘construction’ are not only the producers as would be the case with an industrial product, without connections to the land in which it is produced, but also several members of the community itself such as wholesalers and retailers, restaurateurs, hotel owners, pastry-makers, members of associations such as the local tourist board, organizers of local festivities, municipal and regional authorities.

The representation of the ‘typical’ product is constructed along with that of the land, the community and its more or less ancient origins and traditions. Constructing this ‘typicality’ means highlighting the permanence and indissolubility of some of the traits that are represented as belonging to a whole – man, emmer, land – and concealing, on the other hand, the variability and the reciprocal independence of other traits which are assumed to be non-typical accessories.

We are dealing with the manipulation of the image of the product on the basis of arbitrarily chosen traits.

In the first place its ancient origin as "the ancient grain of the Romans" is being reinforced by the ancient origin of the town Norcia itself. It is further reinforced by the fact that Norcia is the main town of the Valnerina – "Norcia, the ancient Sabine city Nursia" and from the iconic representation in which the Greek-Roman temple is surrounded by a crown of spikes that are presumed to be emmer (Fig. 1).

Fig. 1. Design taken from the brochure of the 28th market exhibition held in Norcia, on February 1991

The historical references, which are at times rather inaccurate and which abound in all the brochures with an advertising purpose, demonstrate that history is used in order to enhance legitimacy and social recognition.

The relationship of the product with the town of Norcia is characterized by the fact of sharing an ancient common history. The emmer of Monteleone is linked to more concrete and visible traits: pedological and naturalistic characteristics. As the brochure produced by the company owned by Renato Cicchetti illustrates "the emmer of Monteleone di Spoleto is cultivated in Umbria, in Monteleone di Spoleto, situated in the heart of the central Apennines at 1000 m a.s.l., far from highways and industrial settlements and from the big cities...for these qualities THE EMMER PLANT adapts in the best possible way to the climate and altitude of Monteleone di Spoleto, a town that with its poor lands gives a unique and inimitable characteristic to this product".

Secondly, its contemporaneous "poverty" and "richness" - "It is said of emmer that it is a poor cereal, but we know the contrary; it is a rich source of…"and here the brochure of the company Mulino del Monte continues to list its various nutritive properties. A synthesis that makes it a healthy dietetic foodstuff but at the same time nutritional and versatile: "it can be cooked with all kinds of foods... and it can be used with all kinds of recipes", the brochure explains.

Conclusions

From these few examples, to which we could add many more, we can see how the construction of the representation of emmer goes hand in hand with the construction of a ‘style’ that, in agreement with Leroi-Gourhan, could be defined as ethnic, because it has to do with the relationship between the product and the specific community that considers it to be its own specific patrimony.

Ethnologists indeed can grasp the fundamental point of this: that we are dealing with a construction based on customs and facts much manipulated and reconstructed but not invented. We are not dealing with what has been called the invention of tradition as in the well-known and widely cited case of Mulino Bianco or Barilla companies’ advertising.

Nor are we dealing with a fictitious life portrayed in a museum as happens with all de-contextualized reconstructions, with the imitation of styles, with fake antiques. There is rather a community which places itself in the public eye by those who are part of that community and who act knowingly and passionately by using a product of the land in order to construct the representation of its own identity.

Acknowledgement
I wish to thank Paul Dominici for his translation of this paper from Italian.

References

Acerbo, G. 1934. L’economia dei cereali nell’Italia e nel mondo. Hoepli, Milano, Italy.

Aebischer, P. 1953. Les dénominations des "céréales" du blé et du "froment" d'après les données du latin médiéval. Etude de stratigraphie linguistique. Essais de philologie moderne, Bibliothéque de la Faculté de Philosophie et Lettres de l'Université de Liège, CXXIX, pp. 77-94.

Ampolo, C. 1980. Le condizioni materiali della produzione. Agricoltura e paesaggio agrario. Dialoghi di archeologia anno II, no. 1 1980:15-46.

Anderson, E.N. 1984. “Heating and cooling” foods reexamined. Social Sci. Information 23(4/5):755-773.

André, J. 1961. L'alimentation et la cuisine a Rome. Libraire Klincksieck, Paris, France.

André, J. 1956. Lexique des termes de botanique en latin. Libraire Klincksieck, Paris, France.

Bonelli Conenna, L. 1982. La divina Villa di Corniolo della Cornia. Lezioni di agricoltura tra XIV e XV secolo. Accademia delle Scienze di Siena detta de' Fisiocritici, Siena, Italy.

Brelich, A. 1976. Tre varizioni romane sul tema delle origini. Edizioni dell'Ateneo, Rome, Italy.

Bromberger, C. 1985. Identité alimentaire et alterité culturelle dans le nord de l'Iran:le froid, le chaud, le sexe et le reste. *In* Identité alimentaire et alterité culturelle, a cura di Université de NeuchaTel: Faculté des lettres. Institut d'ethnologie, Neuchatel, Switzerland.

Camporesi, P. 1980. Il pane selvaggio. Il Mulino Publ., Bologna, Italy.

Cardona, G.R. 1985. La foresta di piume. Manuale di etnoscienza. Laterza Publ., Bari, Italy.

Centilivres, P. 1985.Hippocrate dans la cuisine: le chaud et le froid en Afghanistan du Nord. *In* Identité alimentaire et alterité culturelle a cura di Université de NeuchaTel: Faculté des lettres. Institut d'Ethnologie, Neuchatel, Switzerland.

D'Antuono, L.F. 1989. Il farro: areali di coltivazione, caratteristiche agronomiche, utilizzazione e prospettive colturali. L'informatore agrario 24:49-57.

D'Antuono, L.F. and A. Lucidi. 1989. L'ambiente agricolo dell' Alta Valnerina. Monti e Boschi 40(6):17-25.

De Martino, Francesco. 1984. Ancora sulla produzione di cereali in Roma arcaica. Rivista di Studi antichi July-August:241-263.

Detienne, M. 1975. I giardini di Adone. I miti della seduzione erotica. Einaudi Publ. Torino, Italy.

Eichinger Ferro-Luzzi, G. 1975. Temporary female food avoidances in Tamiland: interpretations and parallels. East and West 25(3-4):471-485.

Forbes, R.H. 1955. Studies in Ancient Technology III. J. Brill, Leiden.

Foster, G.M. 1984. The concept of "Neutral" in humoral medical systems. Medical Anthropol. 8(3):180-194.

Haudricourt, A.-G. and L. Hédin. 1987. L'homme et les plantes cultivées. Métaillé, Paris, France.

Jasny, N. 1944. The wheats of classical antiquity. John Hopkins University, Baltimore, USA.

Montanari, M. 1979. L'alimentazione contadina nell' alto Medioevo. Liguori Ed. Napoli, Italy.

Papa, C. 1990. Un segno dell' identità: il farro in Valnerina. L'Uomo. Società Tradizione Sviluppo III(1):9-29.

Sperber, D. 1986. Animali perfetti ibridi e mostri. Theoria Publ., Rome, Italy.

Annex 1. Latin sources

Cato Marcus Porcius. 1960. *De agricultura.* Hooper William Davis and Boyd Harrison, eds. Heinemann, London, UK.

p. 50, 34, 2.: *in creta et uligine et rubrica et ager qui aquosus erit, semen adoreum potissimum serito.*

Columella Lucius Junius Moderatus. 1960. *De re rustica.* Harrison Boyd, ed. Heinemann, London, UK.

Liber II:

p. 138, 6,

3: *Adorei autem plerumque videmus in usu genera quattuor: far, quod appellatur Clusinum, candidi oris et nitidi; far, quod vocatur vennuculum rutilum atque alterum candidum, sed utrumque maioris ponderis quam Clusinum; semen trimestre, quod dicitur halicastrum, idque pondere et bonitate praecipuum.*

4: *sed haec genera tritici et adorei propterea custodienda sunt agricolis, quoniam raro quisquam ager ita situs est, ut uno semine contenti esse possumus, interveniente parte aliqua vel uliginosa vel arida. triticum autem sicco loco melius coalescit, adoreum minus infestatur umore.*

p. 142, 8,

5: *magis apte tamen in eius modi agris (cioè soggetti a piogge nel periodo della semina) adoreum quam triticum seritur, quoniam folliculum, quo continetur, firmum et durabilem adversus longioris temporis umorem habet.*

p. 144, 9,

1-2: *Iugerum agri pinguis plerumque modios tritici quattuor, mediocris quinqu postulat, adorei modios novem, si ets laetum solum, si mediocre, decrem desiderat*

3-4: *Densa cretosaque et uliginosa humus siliginem et far adoreum non incommode alit.Hordeum nisi solutum et siccum locum patitur. Atque illa (i.e. SILIGO* and *FAR) vicibus annorum requietum agitatumque alternis et quam laetissimum volunt arvum: hoc nullam mediocritatem postulat, nam vel pinguissima vel macerrima humo iacitur. Illa post continuos imbris, si necessitas exigat, quamvis adhuc limoso et madente solo sparseris, iniuriam sustinent; hoc si lutoso commiseris, emoritur.*

Festus Sextus Pompeius. 1838. *De verborum significatione, quae supersunt cum Pauli Epitome.* Lipsiae, Germany.

97 : *immolare est mola, id est farre molito et sale, hostiam perspersam sacrare.*

124: *mola etiam vocatur far tostum et sale sparsum quod eo molito hostiae aspergantur.*

Ovidius. *Fasti.* Frazer J. George, ed 1959. Heinemann, London, UK.

Liber I

p. 52 693: *triticecs fetus passuraque farra bis ignem.*

Liber II

p. 94 519-32: *farra tamen veteres iaciebant, farra metebant/primitias Cereri farra resecta dabant. usibus admoniti flammis torrenda dederunt multaque peccato damna tulere suo. nam modo verrebant nigras profarre favillas, nunc ipsas ignes corripuere casas; facta dea est Fornax: laeti Fornace coloni ornt, ut fruges temperet illa suas. curio legitimis nunc Fornacalia verbis maximus indicit nec stata sacra facit, inque foro, multa circum pendente tabella, signatur certa curia quaeque nota; stultaque pars populi, quae sit sua curia, nescit, sed facit extrema sacra relata die.*

Plinius Gaius Secundus. 1984. *Naturalis historia.* Conte G.B. dir. Einaudi Publ., Torino, Italy.

Liber XVIII

2

p. 670 7-8: *Numa instituit deos fruge colere et mola salsa supplicare atque, ut auctor est Hemina, far torrere, quoniam tostum cibo salubrius esset, id uno modo consecutus, statuendo non esse purum ad rem divinam ni tostum, is et Fornacalia instituit farris torrendi ferias et aeque religiosas Terminis agrorum.*

3

p. 672 10: *quin et in sacris nihil religiosius confarreationis vinculo erat, novaeque nuptae farreum praeferebant.*

4

p. 674 ,15: L. *Minucius Augurinus, qui Spurium Maelium coarguerat, farris pretium in trinis nundinis ad assem redegit undecumus plebei tribunus, qua de causa statua ei extra portam trigeminam a populo stipe conlata statuta est* (439 a. C.).

10

p. 696, 56: *genicula autem sunt tritico quaterna, farri sena, hordeo octona.*

p. 700, 61: *in area exteruntur triticum et siligo et hordeum; SiC et seruntur pura qualiter moluntur, quia tosta non sunt. e diverso far, milium, panicum purgari nisi tosta non possunt; itaque haec cum suis folliculis seruntur cruda. et far in vaginulis suis servant ad satus atque non torrent.*

11

p. 700, 62: *Levissimum ex his hordeum raro excedit XV libras et faba XXII. ponderosius far magisque etiamnum triticum.Far in Aegypto ex olyra conficitur.Tertium genus spicae hoc ibi est.Populum Romanum farre tantum e frumento CCC annis usum Verrius tradit.*

19

p. 710, 81: *Frumenti genera non eadem ubique, nec ubi eadem sunt isdem nominibus. Volgatissima ex his atque pollentissima far (quod adoreum veteres appellavere), siligo, triticum: haec terris plurimis communia.*

p. 710, 83: *ex omni genere duriss-mum far et contra hiemes firmissimum. patitur frigidissimos locos et minus subactos vel aestuosos sitientesque. primus antiquo is Latio cibus, magno argumento in adoriae donis, sicuti diximus. pulte autem, non pane, vixisse longo*

p. 712, 84: *tempore Romanos manifestum, quoniam et pulmentaria hodieque dicuntur et Ennius antiquissimus vates obsidionis famem exprimens offam eripuisse plorantibus liberis patres commemorat. Et hodie sacra prisca atque natalium pulte fitilla conficiuntur; videturque tam puls ignota Graeciae fuisse quam Italiae polenta.*

20

p. 714, 88: *farinam a farre dictam nomine ipso apparet.*

23

p. 716-718, 97: *Pistura non omnium facilis, quippe Etruria spicam farris tosti pisente pilo praeferrato, fistula serrata et stella intus denticulata, ut, si intenti pisant, concidantur grana ferrumque frangatur. maior pars Italiae nudo utitur pilo, rotis etiam quas aqua verset obiter et mola.*

72

p. 824, 298: *far quia difficulter excutitur, convenit in palea sua condi, et stipula tantum et aristis liberatur.*

Varro Marcus Terentius. 1960. *Rerum rusticarum*. Hooper William Davis and Boyd Harrison, eds. Heinemann, London, UK.

I

p.274, 44: *seruntur fabae modii IIII in iugero. tritici V, hordei VI, farris X, sed nonnullis locis paulo amplius aut minus.*

p. 298, 63: *far, quod in spicis condideris per messem et ad usum cibatus expedire velis, promendum hieme, ut in pistrino pisetur ac torreatur.*

Agronomic practices and socioeconomic aspects of emmer and einkorn cultivation in Turkey

A. Karagöz

Central Research Institute for Field Crops, Ankara, Turkey

Introduction

Emmer (*Triticum dicoccum*) and einkorn (*T. monococcum*) cultivation has a long history in Anatolia. The crops, cultivated in Anatolia over thousands years as carbonized grain of emmer testify (see Nesbitt and Samuel, this volume), can still be found in some parts of the country. The total cultivation area of these crops was around 140 000 ha in 1964. The species is mainly cultivated in sloping and marginal lands by poor farmers, where no other crops can be economically grown. Cultivation area is rapidly declining, and if such trend continues, hulled wheats will be shortly completely wiped out from Turkey.

This group of wheats is called in Turkish the general name of 'kaplìca' which means 'covered' or 'hulled'. More specifically, the diploid species (einkorn) is called 'siyez', and the tetraploid one (emmer) is called 'gernik'.

Past and present situation of hulled wheats cultivation in Turkey

There are several records concerning emmer and einkorn cultivation in Anatolia. V. K. Kobalyev (cited in Zhukovsky 1951), who studied the expeditions conducted by Zhukovsky and his collaborators during 1925-27, states that the emmer cultivation area in Anatolia is less than 2% of all cultivated areas and it is mostly grown in Kastamonu province, where the emmer cultivation area is about 3% of the total cultivated areas. The same author describes emmer as a spring-type tetraploid wheat of secondary importance, and adds that it is cultivated in northern Anatolia over an area of little significance.

Gökgöl (1939) reports that the area sown to *T. dicoccum* is restricted to the central and western part of the Black Sea Region, northeastern part of Turkey, in the area falling into the central northern transitional zones and Ardahan and Kars provinces. Being a low-yielding type of wheat, emmer was replaced by other improved varieties of *Triticum*. Regarding einkorn, Gökgöl also reports this is cultivated in northern Anatolia, within Kütahya, Kars and even Istanbul provinces.

Today, the reasons for the cultivation of emmer, in spite of the low yields, are the high adaptability of this species to poor soils where no other crops can be grown with the same degree of success.

Because of the limited acreage of the area grown with hulled wheats in Turkey, the Turkish Statistical Institute refers to the two species as a single crop. It is therefore not possible to obtain the precise figure for the cultivation of each single species. In general, however, it is assumed that the area planted with emmer is much wider than the one planted with einkorn. Table 1 shows the hulled wheat cultivation area and corresponding yields during the period 1948-93 at 5-year intervals. As indicated in the table, hulled wheats were cultivated from 1948 to 1968 over 100 000 ha of land, and after this period there was a sharp decrease in their cultivation: in 1993; the total acreage was reduced to 12 900 ha which corresponds to about 9% of the area cultivated in 1953.

This decrease was mainly due to the widespread use of improved cultivars of wheat and the adoption of new agricultural techniques, but also to social and economic factors. In fact, hulled wheat yield did not change much in the 1948-68 period (Table 1): in 1993, wheat yielded 2040 t/ha, whereas hulled wheats yielded 1240 t/ha.

Table 1. Hulled wheat cultivation area and the yields between 1948 and 1993 in Turkey.

Year	Area sown (ha)	Production (t)	Yield (kg/ha)
1948	107,758	88,938	825
1953	137,300	129,700	945
1958	119,000	121,000	1,017
1963	132,000	137,000	1,038
1968	102,000	83,000	814
1973	65,000	80,000	1,231
1978	46,000	64,000	1,391
1983	38,000	50,000	1,316
1988	18,000	23,000	1,278
1993	12,900	16,000	1,240

Today, the area planted with this crop is limited to the forest areas of the following six provinces: Bolu, Çankìrì, Kastamonu, Samsun, Sinop and Zonguldak. All are located at the north and northern transitional regions of the country.

During germplasm-collecting expeditions carried out by the Central Research Institute for Field Crops of Ankara, it was observed that emmer is being cultivated in a few villages within Çorum province and this fact is not reported in the statistics.

Table 2 shows the cultivation area of hulled wheat in six provinces in 1992. The share of emmer and einkorn production in the overall wheat production (22 million t) is 0.0727%.

Table 2. Area of hulled wheat cultivation in each province in 1992.

Province	Area (ha)
Bolu	643
Çankìrì	20
Kastamonu	8280
Samsun	2192
Sinop	300
Zonguldak	3200
Total	14635

A case study

The Development Foundation of Turkey (DFT), an autonomous, private, non-governmental and non-profit organization established for promoting rural and agricultural development in Turkey's rural poor areas, has carried out a project for the development of seven villages located in the northern part of the country. This project was supported by FAO and was undertaken in close collaboration with the Ministry of Forestry.

The area selected for the project was a typical one for emmer cultivation. Although the project was not designed for looking in particular at the reasons behind hulled wheat cultivation, parts of the data gathered can be used for analyzing the socioeconomic aspects of this cultivation.

At the beginning of the project, household surveys were carried out by the field team of DFT in several villages. After the evaluation of the information gathered through the household surveys, seven villages were selected as pilot areas for the implementation of rural development programmes.

What follows is an analysis of the data gathered in regard to the physical, agricultural and socioeconomic conditions of the villages visited.

Social and physical characteristics

The population living in the surveyed area is 5037 people, of which 2708 are active (aged over 15 years). The most important characteristic of the population is that 72% of the active males seasonally migrate to big provinces as unskilled workers to provide for the yearly needs of their families. The average number of men leaving for the cities from each house is 1.4. Men stay in the cities (not in villages) from early spring to the end of fall. They come back only twice for a very short period of time, once for sowing and once for harvesting. During the remaining part of the year, agricultural operations are carried out by the women and children. Apart from the seasonal migration, there is a visible tendency for permanent migration, as those who can find a permanent job decide to stay in the cities. According to the survey, 53% of the households are planning to move out permanently and 29% of the population is already preparing for that. Another important element is the low level of education found for most of the people contacted (for example only 13% of the female population have had a primary school education).

Climate

The area has typical characteristics of the transitional zones. Annual average rainfall is 567 mm and its distribution is rather homogenous. Average annual temperature in the region is 10.40ºC.

Soil

The dominant soil is the Brown Forest Soil which is rich in humus. The average slope is 20%. In general, topsoil depth is rather shallow.

Distribution of farms by farm size

The land, obtained mainly through deforestation, has been partitioned into several plots over hundreds of years through the inheritance from one generation to another. As shown in Table 3, the percentage of households having more than 10 ha is only 10% and the average number of plots per household is 16. This situation is certainly responsible for the low productivity of these farms.

Table 3. Distribution of farm size by households

Size (ha)	% of households
0	5
<2	23
2-5	37
5-10	25
>10	10

Land use

The total area of the selected villages amounts to 9292 ha. Forest dominates with an average of 55%, the rest of the area is cultivated. The amount of pasture and meadow is negligible.

Altitude

Selected villages are located between 1000 and 1400 m a.s.l.

Erosion intensity, soil depth and slope

Erosion is among the most serious problems in the region: 81% of the total farm land is faced with severe erosion, whereas the rest is under moderate erosion. As a consequence of that, 81% of the land has a soil depth less then 20 cm. Another factor contributing to erosion is the land slope: almost all the farmland has a slope of over 20%.

Agricultural practices

Cereal production and animal husbandry are the main agricultural practices in the region. Since the selected villages are in the forest area, land for cultivation and animal grazing is negligible. Although the annual average rainfall is sufficient for continuous cropping, the farmers leave almost half of their fields as fallow for grazing.

Traditionally, wheat is the major source of food for Turkish villages. It appears in everyday diets as bread, cracked wheat ('bulgur'), macaroni, semolina, starch and so on. Even if some other agricultural crops such as forages can be grown more economically in the marginal areas, villagers tend to grow their own wheat instead of buying it from the market. Emmer used to be consumed as food by the peasants, but today all its production is used as animal feed, except when it is an alternative crop to wheat when enough cannot be harvested owing to unfavourable conditions.

Field crops cultivation

As a whole the cultivated area in the chosen villages is 4226 ha. About 56% (2365 ha) of the arable land is cultivated and 44% (1861 ha) is fallowed. Wheat is the major crop with 1280 ha, followed by emmer and barley with a cultivation area of 542 and 456 ha respectively. In seven selected villages, the emmer cultivated area corresponds to more than 4% of all hulled wheat grown in Turkey. The remainder of the arable land is grown with maize and vetch.

Sowing time is generally delayed in the selected villages for some reasons . Most of the active manpower is in the big cities during the sowing time. Since no soil cultivation is applied during the fallow year, soil is highly compacted and the traction power required for soil preparation is very high. For this reason, delaying the cultivation of the soil until the first rain is the farmer's common strategy to facilitate the agronomic operations in the field.

Another reason for late sowing is the lack of proper equipment. Soil is ploughed only once before seeding, using animal traction. Depending on the distance of fields from the villages and the soil conditions, 0.2-0.3 ha of land can be ploughed each day by the farmer. If ploughing cannot be completed in the autumn – as is usually the case – it is completed in the following spring. Villagers tend to sow the nearest fields first in autumn.

After ploughing once, the seeds are broadcast and covered by soil with a primitive wooden tool. The amount of fertilizer used for cereal production is generally low. The use of herbicide is very limited.

Crop yields

Owing to the poor agricultural practices and the topography of the area, cereal yields are far behind the average yields in Turkey. Average yields of wheat, barley and emmer are 847, 711 and 618 kg/ha respectively. Production is hardly at subsistence levels. Therefore in some years, peasant are forced to buy wheat from the market.

Marketing

There is no market for emmer and einkorn.

Animal husbandry

In the project area, animal husbandry is practised for two reasons: to produce meat and to have animals for traction power. Big ruminants and horse, donkey and mule are raised to be used to pull a plough, for sowing and threshing operations and for transporting the harvests. Because of the topography of the area, the full mechanization of agriculture is almost impossible. It is estimated that 44% of all animals raised here are being maintained for power traction, and thus almost half of the harvested wheats are consumed for the feeding the unproductive animals. Most livestock is represented by local races. Only 2% of the dairy cattle are crossbred individuals. Milk yield of the dairy cattle is about 400 kg/year which is lower than the yield of some goat races.

Conclusions

In Turkey, hulled wheats are grown in sloping, marginal forest areas, not suitable for field crop cultivation. Such lands are forest areas and any field crop cultivation that is undertaken without adequate soil conservation measures is likely to lead to severe soil erosion.

From the results obtained during the DFT study and observations made during surveys and collecting activities, we have concluded that in both the selected area and similar areas, the factors responsible for the abandonment of hulled wheats are several and of different nature. Crop resources are scarce and far from adequate to satisfy population needs. Natural resources have been spoiled for many years by the unsustainable use of land: severe erosion has been caused by the destruction of the forests for gaining more area for cultivation.

In regard to socioeconomic factors, the seasonal as well as the permanent migration in the region also contributes dramatically to the reduction of hulled wheat cultivation.

It is clear by looking at the fast rate of decrease in hulled wheat cultivation that, unless measures are taken to modify it, it is very likely that the crop is destined to fall into oblivion in a short time in Turkey.

References

Gökgöl, M. 1939. Türkiye'nin bugdaylarì V II. [Wheats of Turkey]. Yesilköy Tohum Islah Enstitüsü Yayìm No:14, Istanbul, Turkey.

Gökgöl, M. 1969. Serin iklim hububatì ziraatì ve ìslahì [Cool season cereals cultivation and breeding]. Özaydìn Matbaasì, Istanbul, Turkey.

Zhukovsky, P.M. 1951. Türkiye'nin zirai bünyesi [Agricultural structure of Turkey]. Türkiye £eker Fabrikalarì Nesriyatì No: 20. (C. Kìpçak, H. Nouruzhan and S. Türkistanlì, translators).

State Statistical Institution. 1993. Agricultural Statistics for the period 1959-1993. Istanbul, Turkey.

State Statistical Institution. 1992. Agricultural Structure and Production. Istanbul, Turkey.

Development Foundation of Turkey. 1993. Duragan Social Forestry Project. Household and women survey report. Ankara, Turkey.

Saltìk, A. 1994. DFT activities in relation to Sinop Duragan and Erzurum-Tortum Social Forestry Project. Proceedings of a Workshop held at Kunduz Training Center, Vezirköprü, Turkey. July 1992. FAO, Ankara, Istanbul.

Recipes made with hulled wheats

Recipes from the Roman time

Before reporting a few Roman recipes we would like to explain the meaning of '*alica*' for the Romans. Alica was obtained from spelt and was a kind of very good semolina. Three types of alica existed according to the particle's dimensions, the best one being the finest. Before being marketed, this semolina was blenched by using a special clay, rich in sulphur, coming from a hill situated between Pozzuoli and Naples. With alica it was possible to cook *puls* (another very typical Roman recipe), cream and stuffing. A kind of thin bread, called *tracta*, dried under the sun, was also obtained with alica.

- **Puls romana or farrata**

With ground seeds cooked with water or milk the Romans prepared the puls or farrata, the ancient version of today's Italian 'polenta'.

1 liter of water or milk
300 g of semolina made with farro
salt
200 g of fresh cheese
5 spoons of honey or a small quantity of aromatic herbs

In a pan with salted water or milk put the farro semolina when the water is boiling. Mix with a wooden spoon. When the farrata has swollen, reduce the heat and let the polenta boil slowly, with the pan covered, and mixing from time to time, for more than 1 hour. At the end of cooking add fresh cheese and some aromatic herbs or honey.
Using the puls, make a thin layer, wait until cold and cut it in pieces. Fry these pieces in boiling oil. Dry on paper and add brown sugar (from Apicio, *De re coquinaria*, VII.XIII.6).

- **Globi**

This was a simple recipe, made with alica and other ingredients. It is reported by Catone in his book *De Agricultura* vol. LXXIX. The modern version is the following:

800 g of ricotta (fresh Italian cheese)
200 g of farro fine semolina
1 egg
salt

Mix all the ingredients together. Take a pan and fill half with groundnut oil; using a teaspoon, let a small quantity of pastry fall into the boiling oil (two or three globi can be cooked at the same time). Take the cooked globi out of the pan, put on absorbent paper to dry the oil and dip into a dish full of sugar, or in honey plus papaver seeds.

- **Scriblita**

This is a recipe still used today as an entrée.

500 g of wheat flour
1 kg of ricotta
10 farro tracta pieces
salt

Prepare a pastry with the flour, water and salt. Alternate layers of cheese and tracta on top of the pastry. Cover the inner layers with the pastry and put the "packet" into the oven at 160°C for 30-40 minutes. Cut in slices and serve.

Modern Italian recipes

- **Minestrone di farro**

In Garfagnana farro is usually used to cook the minestrone di farro, a very flavoured soup.

300 g of farro
500 g of beans (‘borlotti’ variety)
garlic
onions
oil and fat
peeled tomatoes
sage

Wash the farro carefully with cold water. Leave farro and beans in water (twice the volume of the seeds) for 12 hours. Boil beans with salt; fry onions, garlic and some fat with oil and salt. Add a little white wine. After the wine evaporates, add tomato sauce and add the beans with their water. Cook for 10 minutes and then crush to obtain a homogeneous soup. Complete the minestrone by adding the farro seeds and cooking until the seeds are soft.

- **Farro soup**

150/200 g farro in whole grains
300 g fresh ripe tomatoes (or tinned)
50/70 g smoked bacon
mature pecorino (sheep’s) cheese
2 cloves garlic
1 onion
1-2 stock cubes
parsley, basil and thyme
olive oil, salt and pepper

Dice the bacon and fry it gently in olive oil until golden brown, together with a handful of chopped thyme, two cloves of garlic, and the onion, finely chopped. Remove the garlic and add the (skinned) tomatoes, a handful of chopped parsley, and a few basil leaves. Let the sauce reduce for a few minutes, add a litre of stock, and bring to the boil. Add the farro (which needs to have been previously rinsed to remove any dirt or other impurities, and then soaked for at least 8 hours), and cook on a moderate flame for about 2 hours, or until soft, stirring continuously. Season with salt and pepper, and remove from heat. Serve approximately an hour later, tepid, adding olive oil and a sprinkling of mature pecorino. *Serves 4*

- **Farro and chickpea soup**

150/200 g farro in whole grains
200 g dried chickpeas
1 onion
3-4 laurel (bay) leaves
olive oil
salt and peppercorns

After washing the chickpeas to remove any impurities, soak in cold water for at least 8 hours. Rinse, and cook them for about 1½ hours on a low flame, in a saucepan of water, to which a level tablespoon of salt, a few peppercorns, and the laurel leaves have been added. Finely chop the onion, and fry in olive oil in a casserole (made of terracotta, if possible). When the onion is golden brown, add the chickpeas, and the farro (previously soaked, as described above, and rinsed). Make sure the water adequately covers the chickpeas and farro, as they need to be cooked for more than 2 hours, and stirred from time to time, until a thick soup is produced. During cooking, add stock as necessary, to thin the soup. The longer the soup is left after it has been cooked, the tastier it will be. Serve tepid, with olive oil. *Serves 4*

- **Farro meatballs**

150 g farro, in whole grains or crushed
200 g minced beef
250 g milk
50 g butter
1 sausage
2 eggs
handful of crushed parsley
2 generous handfuls of grated parmesan cheese
1 slice Kraft cheese
2 tablespoons of breadcrumbs
1 clove of garlic
fresh bread, with the crusts removed
salt and pepper

Fry the breadcrumbs in the butter, until golden brown. Place the farro (previously rinsed and soaked, as described above, and with the husk removed) together with the minced beef, the sausage meat, the eggs, the grated parmesan, and the garlic (crushed), the chopped parsley, the bread (which has previously been soaked in milk, and squeezed to remove any excess liquid), and the slice of Kraft cheese. Season with salt to taste, and mix well. Mix in the breadcrumbs, and place the mixture in a greased cake tin. Bake at 180ºC in a pre-heated oven, for about 1 hour. When tepid, place in a serving dish and serve sliced, with vegetables. The same mixure may be used to make a pie. Just line a baking tin with a layer of pastry (the frozen type), sprinkle with mushrooms, garlic and olive oil, add the farro and meat mixture, cover with another layer of pastry, and bake at 180ºC, until the pastry is golden brown. *Serves 4*

- **Dolce di farro (farro dessert)**

  750 ml milk
  200 g farro
  120 g sugar
  100 g almonds
  100 g candied peel
  1 lemon
  3 eggs
  14 amaretti biscuits
  1 small glass brandy
  1 small glass Cointreau

Soak the farro for at least 8 hours and rinse to remove any impurities. Cook in the milk, with the lemon peel, add the sugar and chopped almonds, the candied peel (in small pieces), and the amaretti biscuits, soaked in brandy. Allow to cool, and add the eggs, mixing well, and put the mixture in a greased cake tin of 28 cm diameter. Cook in a moderately hot oven at 170ºC for about 1 hour. Pour the Cointreau over the pudding when it is still hot, and serve tepid. **Note:** this dessert is best eaten quickly, as the farro grains tend to harden after a while. *Serves 6*

IV. Germplasm Characterization, Evaluation, Enhancement and Utilization

Integrated approach to einkorn wheat breeding

R. Castagna[1], B. Borghi[1], M. Heun[2]* and F. Salamini[2]

[1] Istituto Sperimentale per la Cerealicoltura, S. Angelo Lodigiano, Italy
[2] Max-Planck Institut, Köln, Germany
* Present address: Agricultural University of Norway, Dept. Biotechnological Sciences, Ås, Norway

Introduction

Einkorn (*Triticum monococcum* L.) is a diploid wheat (genomic designation AA) with characteristic hulled grains and delicate ears and spikelets. Recently, Zohary and Hopf (1993) suggested considering the wild form as subspecies *boeoticum* and the cultivated form as subspecies *monococcum*. Several major ecogeographical and morphological types can be recognized within this genepool. A free-threshing form (*T. monococcum* subsp. *sinskajae*) also has been described (Filatenko and Kurkiev 1975). *Triticum urartu*, another diploid AA genome hulled wheat, is considered as a separate species since the individuals obtained by crossing it with *T. monococcum* are not all fully fertile.

Einkorn is a crop that has supported Neolithic agriculture in the Fertile Crescent region. It has been planted throughout Europe over thousands of years (see Nesbitt and Samuel, this volume). Its cultivation, however, received a dramatic reduction after the Bronze Age (Zohary and Hopf 1993).

The aim of this paper is to illustrate, through a brief survey of our activities, our approach in einkorn improvement. The final goal of our research efforts is to develop a new, low-input crop for the European market. This crop will provide raw material for food products including special diets for celiac patients as well as for industrial applications. The classification used here is that of Zohary and Hopf.

Setting up the collection

Since variability is the driving force of genetic improvement, the first step of our work consisted of setting up a large einkorn germplasm collection for assessing the level of genetic polymorphism and selecting promising genotypes by means of agronomical and technological evaluations. In 1990 we obtained from 14 international institutions a total of 1393 accessions of *T. monococcum*. The data accompanying those acquisitions specified the origin of about 950 accessions (Table 1).

Field characterization and evaluation

All the accessions were grown at two locations: in Milan, Italy and Cologne, Germany, over a period of two years (1992/93 and 1993/94 seasons). The material was characterized for several morphophysiological traits like days to heading, plant height, lodging resistance, number of spikelets per spike, kernel weight and culm and leaf hairiness.

A high level of variability was detected for most of the traits (Fig. 1). Several accessions of *T. monococcum* subsp. *monococcum* possessing useful agronomical traits like earliness, short straw, large kernels, etc. were identified for further evaluation and were included in the crossing programme (Empilli *et al.* 1995).

Table 1. The einkorn collection subdivided according to the institutions providing the samples and the geographical origin of the accessions.

Donor	**a**	**b**	**c**	**d**	**Total**	**Region**	**No. of access.**
Max Planck Institut, Köln, Germany	2				2	Not known	420
Istituto di Genetica e Sperimentazione Agraria N. Strampelli, Lonigo (VI), Italy	3				3	Europe*	112
Instituto Nacional de Tecnologia Agropecuaria, Argentina	5				5	Balkans	103
Vavilov All Union Institute of Plant Industry, S. Pietroburgo, Russia	1	1	1	2	5	West Turkey	42
Recherches Agronomiques de Changins, Nyon, Switzerland	6				6	Central Turkey	37
Istituto Sperimentale per la Cerealicoltura, S. Angelo Lodigiano (MI), Italy	17				17	Lebanon / Israel	16
Cambridge Laboratory, Norwich, England	5	10	1	5	21	Caucasus	11
Istituto del Germoplasma, Bari, Italy	25				25	Iran	40
Institut für Genetik und Kulturpflanzen Forschung, Gatersleben, Germany	21	3	2	2	28	South Iraq	40
Kansas State University, Kansas, USA	11	10		9	30	Central Iraq	200
Australian Winter Cereals Collection, Tamworth, Australia	71	5	1		77	North Iraq	128
University of Alberta, Edmonton, Canada	42	26	1	31	100	East Turkey	244
Institut für Pflanzenbau und Pflanzenzüchtung, Braunschweig, Germany	161	67			228		
National Small Grains Collection, Aberdeen, Idaho, USA	92	754			846		
Total	462	876	6	49	1393		

a: *T. monococcum* subsp. *monococcum*; b: *T. monococcum* subsp. *boeoticum*; c: *T. monococcum* subsp. *sinskajae*; d: *T. urartu*.

* Spain, England, Italy, Austria, Germany, Switzerland, Sweden, France.

Evaluation of the yield potential

Yield and yield-related traits of 21 selected lines of *T. monococcum* subsp. *monococcum* were evaluated in replicated plot trials carried out for 2 years at Cologne, Milan, Ascoli Piceno (central Italy) and Foggia (southern Italy). In addition, agronomic trials including different seeding rates (ranging from 100 to 600 kernels / m^2) and different nitrogen levels (0, 80 and 120 kg / ha) were carried out at three locations: Milan, Chieuti (Central Italy) and Foggia.

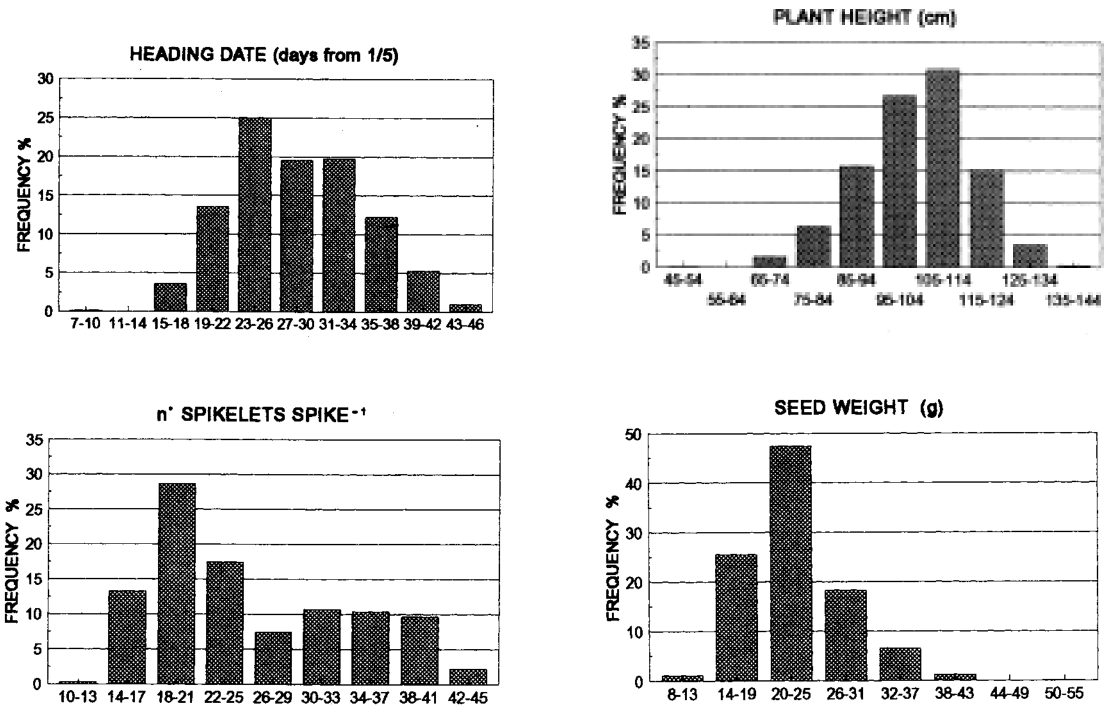


Fig. 1. Distribution of frequency for the heading date, plant height, number of spikelets per spike and seed weight measured on the Einkorn wheat collection (recorded at the Milan location in 1993) (modified from Empilli *et al.* 1995).

Results indicated that gross grain yield (i.e. the yield reported as hulled grain) differed remarkably among locations, with a maximum at Cologne (4.57 t/ha) and a minimum at Foggia (0.84 t/ha) (Fig. 2). The three nitrogen levels did not affect grain yield or plant height. The maximum gross grain yield was obtained with a seeding rate of 300 kernels/m^2.

Within the different locations, einkorn lines significantly differed for most of the recorded traits. In the southern environment, the long life cycle of einkorn wheat appeared to be a yield-limiting factor.

The observed genetic variability for important traits like earliness, plant height and kernel dimension in this germplasm sample, though of limited size, is an indication that breeding programmes could be able to produce lines better adapted to current farming systems by utilizing the useful genes found in this material (Castagna *et al.* 1995).

Qualitative characterization of the collection

In order to explore the genetical and environmental variability for qualitative traits and for the rheological properties of einkorn flours (including bread-making aptitude) seeds from the genotypes included in the agronomic trials grown at Milan and Cologne were dehulled and milled. The flour yield and the percentage of fine particles of all einkorn lines were similar to the bread wheat standard. The protein content (percentage of nitrogen x 5.7) ranged from 13.2 to 22.8% and was higher on average than in bread wheats (10.8- 13.3%). SDS sedimentation volume presented a wide variation from 11 to 93 ml. Seven einkorn lines had an acceptable gluten strength leading to good alveograph W values and to farinograph stability indices close to bread wheat (Table 2). Most accessions produced a sticky dough, but about one-third from both locations gave an acceptable dough and produced breads with a bright yellow colour and a volume similar to, or even better than, the one obtained with wheat flour (Fig. 3).

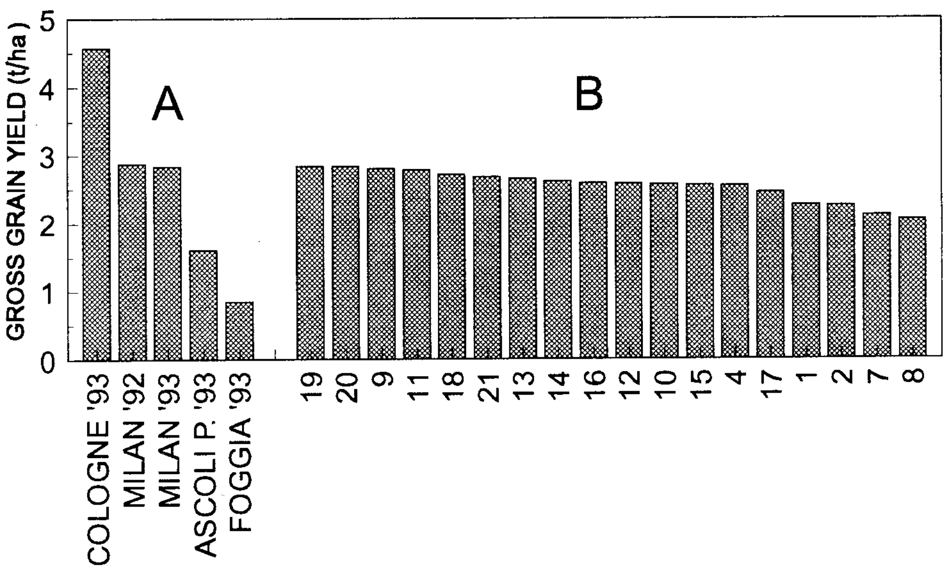


Fig. 2. Mean gross grain yield at five locations (A) and mean gross grain yield of the 18 lines evaluated at the five locations (B).

Having found a tight correlation between rheological parameters or bread volume with SDS sedimentation volume (Borghi *et al.* 1995), we screened the entire collection by means of the SDS sedimentation test (Zeleny test): about 16% of the accessions gave good SDS sedimentation volumes. In particular we found 85 accessions among the wild form (subsp. *boeoticum*) having a SDS sedimentation volume higher than 70 ml and 35 accessions among the cultivated form (subsp. *monococcum*) presenting a volume higher than 60 ml (Empilli *et al.* 1995).

From these results, it appears that einkorn could become an important crop for the production of baked foods rich in carotenoids and proteins. These findings might have an even more important impact in our society in consideration of the fact that einkorn is speculated to be non/or less toxic to patients affected by the celiac disease (Favret *et al.* 1987).

Table 2. Means and range of variation for seed, flour and bread quality traits measured for 25 einkorn lines grown in 1993 at Milan (Italy) and Cologne (Germany). Means are also given for two bread wheat (*T. aestivum*) cultivars considered as control.

Trait	Einkorn Milano mean ± SE	Einkorn Cologne mean ± SE	Range min	Range max	Bread wheat mean*
Gross grain yield (t/ha)	2.84 ± 0.10	4.63 ± 0.1	2.12	5.39	7.03
Net:gross (%)	77.0 ± 1.6	–	63.0	92.0	100
Kernel weight (mg)	23.9 ± 0.5	27.5 ± 0.8	18.3	35.3	42.7
Flour yield (%)	62.5 ± 0.2	60.6 ± 0.6	54.8	65.3	56.6
Fine bran (%)	23.5 ± 0.4	27.6 ± 0.6	20.0	36.5	29.4
Bran (%)	13.9 ± 0.3	11.8 ± 0.5	8.6	16.3	14.0
Particle size <80 µm (%)	56.9 ± 1.1	–	43.6	68.0	48.9
Carotene (ppm)	20.7 ± 0.7	–	12.7	28.3	3.2
Protein content (%)	19.6 ± 0.4	15.9 ± 0.4	14.4	22.9	12.0
Dry gluten (%)	13.2 ± 0.3	13.9 ± 0.6	9.7	16.7	10.5
Gluten/protein (%)	66.8 ± 1.0	88.2 ± 2.3	55.3	94.4	86.3
SDS Sedim. volume (ml)	50.0 ± 5.0	43.0 ± 5.7	11.0	95.0	78.0
Specific sedim. volume (ml)	2.6 ± 0.3	2.7 ± 0.4	0.6	6.6	6.4
Falling number (sec)	31.1 ± 3.6	21.5 ± 18.9	158	356	343
Alveograph W: ($Jx10^{-4}$)	68.0 ± 6.6	45.0 ± 4.4	9.0	127	235
Alveograph W: P (mm)	43.0 ± 1.5	36.0 ± 1.8	19	57	68
Alveograph W: L (mm)	76.0 ± 10.0	46.0 ± 5.7	10	205	118
Alveograph W: P/L	0.90 ± 0.1	1.07 ± 0.2	0.21	3.30	0.67
Farinograph: Water abs. (%)	57.0 ± 0.4	54.0 ± 0.4	52	60	56
Farinograph: Devel. time (sec)	98.0 ± 4.4	91.0 ± 5.1	45	135	135
Farinograph: Stability (sec)	82.0 ± 10.6	155.0 ± 31.5	25	690	600
Farinograph: Degree of soft. (FU)	186.0 ± 7.7	155.0 ± 13.6	30	265	40
Baking test: Mixing time (sec)	66.0 ± 4.4	84.0 ± 5.0	45	120	240
Baking test: Score (1-8)	3.0 ± 0.3	4.5 ± 1.5	2	7	5
Baking test: Vol. (cc)	538.0 ± 33.5	460.0 ± 11.5	325	832	687

* Mean of the two cultivars 'Pandas' and 'Centauro'. Dashes represent missing data.

Storage proteins

In polyploid wheats, good bread-making quality has been found to be determined by the presence of certain alleles responsible for the expression of some specific protein (prolamins). In order to investigate this issue, we have analyzed about 140 einkorn accessions, characterized by good or poor technological quality. The electrophoresis analyses were conducted in order to describe their genetical variability and to correlate specific electrophoretic patterns to the different rheological properties. Particular attention was placed on the search for the low molecular weight glutenin subunits (LMW-GS) of prolamins, which are known to play a major role in determining dough strength. They were extracted following a particular procedure, involving the removal of gliadins from the flour and the reduction/alkylation of the polymeric proteins present in the residue, then fractionated by SDS-PAGE. Preliminary results show the presence of about 10 different LMW-GS patterns among the accessions analyzed; in particular, those accessions with a poor technological quality seem to be characterized by a lower number of glutenin subunits.

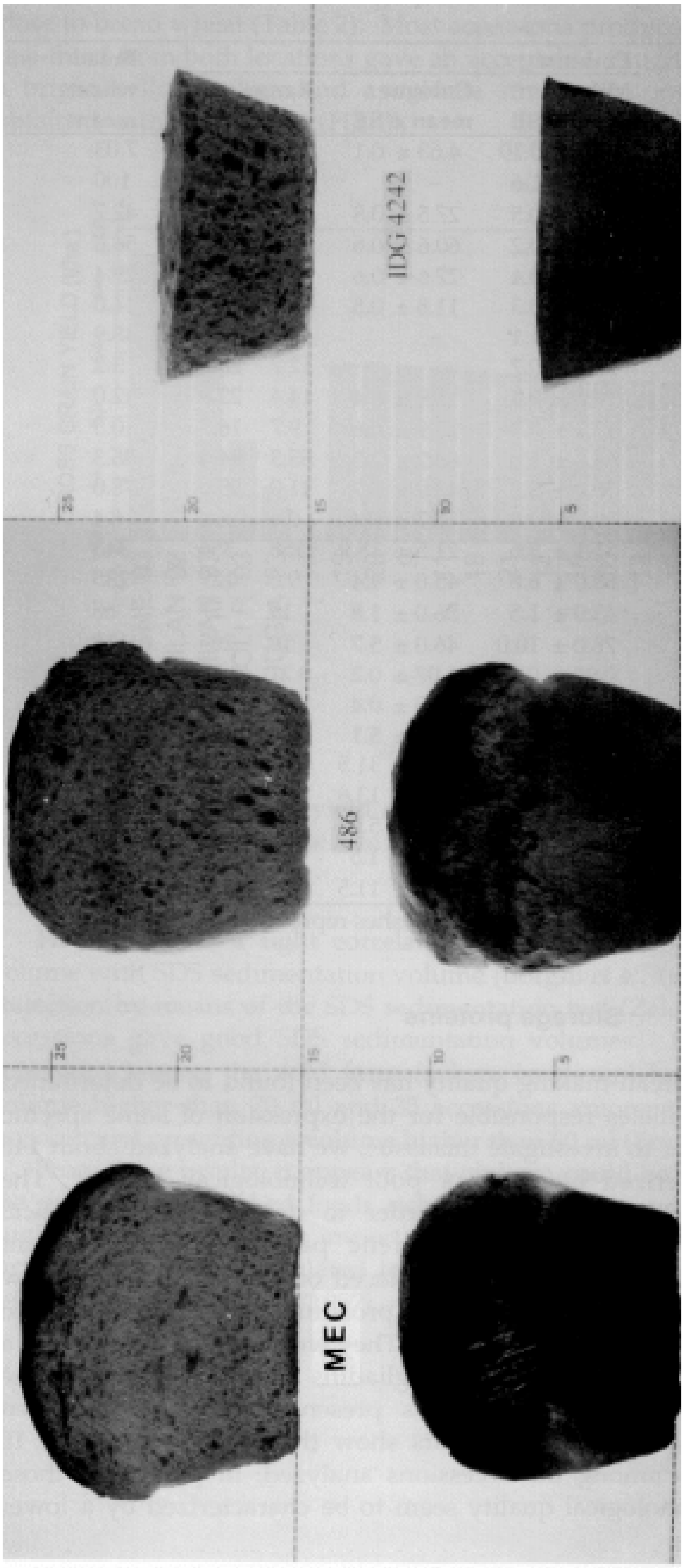


Fig. 3. Bread loaves of Mec (common wheat) and of two diploid wheat accessions

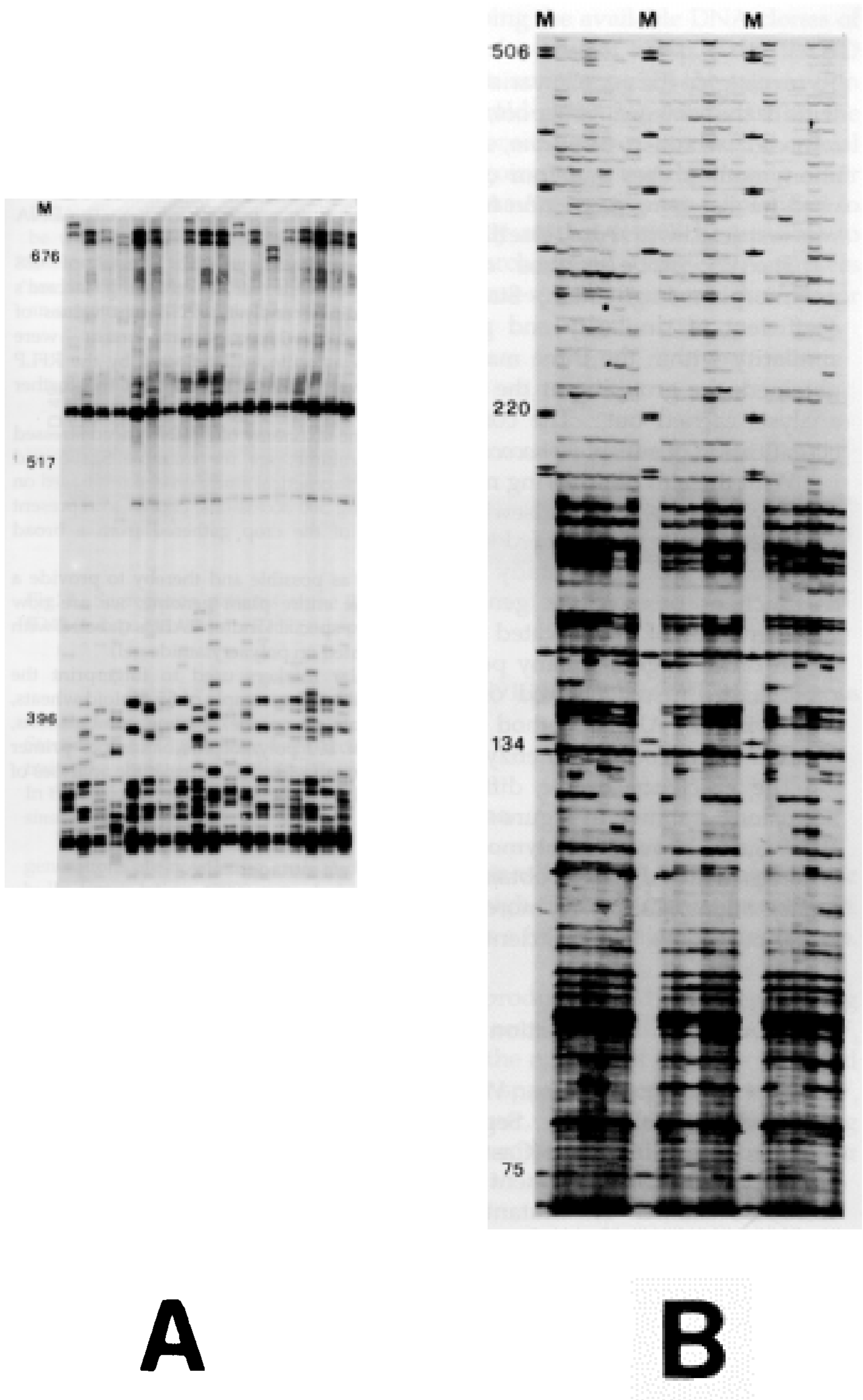


Fig. 4. RFLP patterns obtained with restriction enzyme RsaI and probe pTU1 (A) and AFLP patterns obtained with primers E42/M32 (B). M = molecular weight markers (in bp).

Molecular markers

To investigate the genetic variability and the relationships between different species within the einkorn genepool, 55 different accessions of *T. monococcum* subsp. *monococcum*, subsp. *boeoticum*, subsp. *sinskajae* and *T. urartu* were analyzed. Fifteen anonymous probes and four clones corresponding to storage protein genes were used for detecting restriction fragment length polymorphisms (RFLPs). The DNA was restricted with AluI, HaeIII, RsaI and TaqI enzymes.

The 25 probe/enzyme combinations employed yielded a total of 488 polymorphic fragments. Statistical analyses were performed using Jaccard's coefficient of similarity and principal coordinate analysis. Different values of similarity within the three main taxa – *monococcum, boeoticum* and *urartu* – were obtained; the grouping at the species level was quite well reflected by the RFLP analysis carried out. The coincidence between the RFLP data and the further classification of subsp. *monococcum* was only partial (Castagna *et al.* 1994).

With the aim of throwing more light on the taxonomy of einkorn (need stressed also by other workers elsewhere in this volume, see for example Szabó and Hammer's paper) we decided to pursue a phylogenetical study on einkorn based on DNA techniques. This study was made using 300 accessions, chosen to represent as much as possible the genetic diversity of the crop gathered from a broad representation of its cultivated area.

In order to get as many polymorphisms as possible and thereby to provide a rapid and efficient method of screening the entire plant genome, we are now employing the AFLPs method together with a special kind of RAPDs (labeled with 33P, cut with a four-cutter enzyme and separated on polyacrylamide gel).

The efficiency of the different molecular markers used to fingerprint the accessions is shown in Figure 4. In fact, on a random sample of 55 diploid wheats, RFLP gave about 20 polymorphic fragments per probe/enzyme combinations, whereas with AFLP we obtained a mean of 100 polymorphic bands per primer combinations. Therefore, more advanced methods, like RFLP, make the analyses of larger collections more efficient.

Induction of variability *via* mutagenesis

Seeds of the einkorn German Winterform population were treated with gamma rays to search for mutations. Segregating progenies were screened for chlorophyll mutants at seedling stage (Castagna 1992). Furthermore, 15 mutants with potential value for genetic improvement and for a better understanding of plant development were also isolated. The mutants were characterized through observations of macro- and microscopical traits. Some of these mutants were then used to draw a developmental model of the einkorn wheat plant body based on repeating units of growth (phytomer) (Castagna *et al.* 1993).

Description of the genetical base of relevant traits

Currently we have started a project on the construction of a map of the A genome of einkorn and to map quality and relevant agronomic traits (e.g. free-threshing, cold resistance as well as yield-related QTLs).

To get a first skeleton of the map, we are mapping the available DNA clones of the published barley RFLP map on an F_2 progeny of a cross of subsp. *boeoticum* (ID 49) x subsp. *sinskajae* (ID 69). In Figure 5 is shown an example of the segregation patterns revealed by the probe PSR 910. This would give us a good start on the mapping of the free-threshing trait which is considered an obviously crucial characteristic for new lines. The skeleton map is going to be enriched using other DNA marker techniques (AFLP, special RAPD). Our A genome map is intended to be well aligned with the H genome map of barley so that it will be possible to interact closely with the other cereal-mapping research efforts. Once DNA markers are linked to genes of interest we will generate a locus-specific marker technique for an easy testing within the breeding programme.

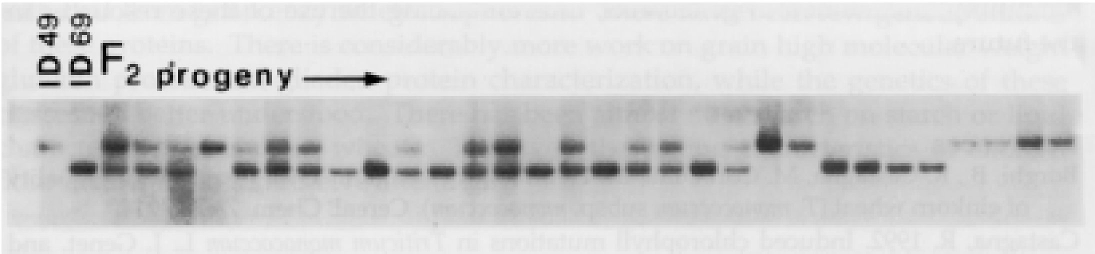


Fig. 5. Segregation patterns of the RFLP locus PSR910 in a F_2 progeny of the cross ID49 (subsp. *boeoticum*) x ID69 (subsp. *sinskajae*).

Breeding programme

Starting in 1992, we have been crossing several lines having positive agronomic traits like short straw, earliness, large kernel and high SDS sedimentation volume. In the majority of the crosses one of the parents was a free-threshing species (subsp. *sinskajae*).

To date 266 different crosses have been produced and the segregating generations are now being evaluated. In 1995 the nursery of Milan included 20 F_3 bulked populations (2000 spaced plants each) and the nursery of Cologne included 3180 F_3 head rows, 43 F_3 bulked populations (2000 spaced plants each) and 110 F_2 populations (400 spaced plants each). Moreover, more than 80 promising accessions are being multiplied at Milan (24 head rows plus 20 m^2 plot each) for further agronomical and technological evaluation.

Conclusion

Our integrated approach is expected to develop a new, alternative, low-input einkorn crop able to provide healthy and appealing food products and raw material for industrial application. We intend to breed superior genotypes with specific qualitative characteristics such as high protein content, high carotene content, high fibre content, optimal bread, biscuit or pasta-making ability.

In parallel to the applied work we are studying the genetic basis of the relevant quality and agronomic traits of einkorn, to localize the underlying genes in the genome and to create DNA markers for selecting optimized lines. We are monitoring the existing genetic variation of einkorn and its wild relatives (subsp.

boeoticum and *T. urartu*) in the centre to its origin, and we intend to relate this to the earlier cultivated European einkorn lines.

Important by-products of our work would be the generation of an A genome map and the mapping of a wide range of traits; for example, the mapping of the free-threshing form (subsp. *sinskajae*) characterized by soft glumes will not only make the tagging of the gene(s) possible, but also its (their) future isolation. The homoeology of the Triticeae genomes of wheat, barley and rye and their synteny (i.e. the conserved arrangements of genes in genomes of related plants) with other Poaceae like rice and maize is offering a wide spectrum of future research in these crops too.

Furthermore, the combined knowledge about the DNA variation and the phenotypic description of einkorn diversity will allow new insights into its variability, maintained in genebanks, thus enhancing the use of these resources in the future.

References

Borghi, B., R. Castagna, M. Corbellini, M. Heun and F. Salamini. 1995. Bread making quality of einkorn wheat (*T. monococcum* subsp. *monococcum*). Cereal. Chem. (In press).

Castagna, R. 1992. Induced chlorophyll mutations in *Triticum monococcum* L. J. Genet. and Breed. 45:373-376.

Castagna, R., B. Borghi, G. Bossinger and F. Salamini. 1993. Induction and characterization of *Triticum monococcum* mutants affecting plant end ear morphology. J. Genet. and Breed. 47:127-138.

Castagna, R., B. Borghi, N. Di Fonzo, M. Heun and F. Salamini. 1995. Yield and related traits of Einkorn (*T. monococcum* subsp. *monococcum*) in different environments. European J. Agron. 3:371-378.

Castagna, R., G. Maga, M. Perenzin, M. Heun and F. Salamini. 1994. RFLP-based genetic relationships of Einkorn wheats. Theor. Appl. Genet. 88:818-823.

Empilli, S., L. Rossetti and R. Castagna. 1995. Valutazione della variabilità genetica presente in una collezione di germoplasma di frumenti diploidi mediante marcatori morfo-fisiologici. Sementi Elette 5:21-25.

Favret, E.A., J.L. Cervetto, R.M. Solari, A. Bolondi, L.E. Manghers, A. Boffi and J.P. Ortiz. 1987. Comparative effect of diploid, tetraploid and hexaploid wheat on the small intestine of coeliac patients. [In Spanish]. Page 13 *in* Proc. 8th Meet. Latin-Am. Soc. Pediatr. Gastroenterol. Nutr. Sao Paolo, Brazil.

Filatenko, A.A. and U.K. Kurkiev. 1975. A new species: *Triticum sinskajae* A. Genetike i Selektsii 54:239-241.

Zohary, D. and M. Hopf. 1993. Domestication of plants in the Old World. Pp. 32-38 *in* The Origin and Spread of Cultivated Plants in West Asia, Europe, and the Nile Valley. Second Edition. Clarendon Press, Oxford, England.

Molecular characterization of einkorn wheat

J. G. Waines

Department of Botany and Plant Sciences, University of California, Riverside, USA

Summary

Wheat taxonomy and nomenclature are confused. There is need for a modern classification and nomenclatural study of domesticated and wild einkorn and of its relationship to other diploid and polyploid wheats, so that we can efficiently continue the molecular characterization of einkorn and the other hulled wheats. The early work with bulk seed protein extraction and electrophoresis is noted along with that from grain enzyme electrophoresis. There have been few genetic studies of these proteins. There is considerably more work on grain high molecular weight glutenin protein and gliaden protein characterization, while the genetics of these classes are better understood. There has been almost no research on starch or lipid characteristics of einkorn wheats. However, the baking characteristics of einkorn flour are beginning to receive attention.

Introduction

Domesticated einkorn, *Triticum monococcum* L. subsp. *monococcum*, is a diploid taxon with 14 chromosomes ($2n=2x=14$). The wild form is *T. monococcum* subsp. *aegilopoides* (Link) Thell. in preference to subsp. *baeoticum* Boiss. emend. E. Scheim, which is often misspelled subsp. *boeoticum* (van Slageren 1994). The domesticated form commonly has only one fertile floret per spikelet, which produces a large, laterally compressed grain. The wild form has one or two grains per spikelet, although the two-grained form is more common.

Wild einkorn should not be confused with the other wild species of diploid wheat, *T. urartu* Tumanian ex Gandilyan, which almost invariably has two grains per spikelet. The colour of *T. urartu* grain is usually red or amber, whereas the colour of subsp. *aegilopoides* is usually blue or yellow, rarely red. The grain shape of *T. urartu* looks like that of a small form of wild tetraploid wheat and differs markedly from *T. monococcum* subsp. *aegilopoides.* As far as we know, *T. urartu* was never domesticated. However, it presumably was gathered by people who inhabited the Fertile Crescent in the transition period from Paleolithic to Neolithic times. The archeological remains of wild diploid wheats need to be rechecked to see if they are more similar to reference collections of *T. urartu* than to *T. monococcum* subsp. *aegilopoides*.

There is a great deal of confusion in the taxonomic literature about the validity of these two diploid species. Where their biosystematics has been investigated, there is almost always a barrier to gene exchange between these two wheat species. The F_1 hybrid plant is largely self-sterile since the anthers do not dehisce (Johnson and Dhaliwal 1976). It is easier to obtain gene exchange between domesticated *T. monococcum* subsp. *monococcum* and *T. urartu* than between subsp. *aegilopoides* and *T. urartu* (Dhaliwal 1977; Sharma and Waines 1981).

Unfortunately, Drs Kimber, Sears and Feldman, the three Western cytogeneticists who most recently published schemes for the classification and evolution of wheats and goatgrasses, had a poor understanding of the biological species concept as it applies to these diploid wheats. They either did not read the published literature on the reproductive isolation of *T. monococcum* and *T. urartu*, or if they were aware of it, they chose to ignore it. The schemes (Kimber and Sears 1987; Kimber and Feldman 1987) consider *T. monococcum* as the donor of the male AA genome of tetraploid wheat *T. turgidum* L. subsp. *dicoccoides* (Körn. ex Asch. & Graebn) Thell., genome formula BBAA. However, there is ample evidence in the literature that *T. urartu* is the source of the AA male genome of *T. turgidum*. This includes chromosome pairing evidence (Chapman *et al.* 1976; Dvorak 1976), repeated nucleotide sequence evidence (Dvorak *et al.* 1988), and morphological evidence, namely, red grain colour (Gandilyan 1972). *Aegilops speltoides* is considered to be the source of the female BB genome (Dvorak and Zhang 1990). Since the evolutionary schemes of Kimber, Sears and Feldman were confused, much of the biochemical and molecular research that relies on these schemes for wheat ancestry is also confused. Many biochemists and molecular geneticists, even today, compare the AA genome of *T. monococcum* and the AA genome of *T. turgidum*, when they should be comparing the AA genome of *T. urartu* with *T. turgidum*. It is important that there be a modern taxonomic and nomenclatural monograph of the genus *Triticum*. A preliminary treatment is to be found in Wild Wheats: a Monograph of *Aegilops* and *Amblyopyrum* (van Slageren 1994), but this is only a cursory view, and the whole subject needs much more work.

Characterization of einkorn

Morphological characters

The morphological description of einkorn is listed by Gandilyan (1972) and Johnson (1975). The latter author also demonstrated that *T. urartu* is not an Armenian endemic, but grows all over the Near East. Moreover, many of the populations considered to be wild *T. monococcum* subsp. *aegilopoides* (usually called subsp. *baeoticum*) need to be reclassified as *T. urartu*. From the ecological studies of Valkoun at ICARDA in Syria (J. Valkoun 1994, pers. comm.), we know that einkorn requires more precipitation than *T. urartu*, and that it tends to grow in areas that receive more than 300 mm annual rain. Today, the wild diploid wheats on the margins of the Syrian desert are classified as *T. urartu*. Are the archaeological remains at Tel Abu Herrera in the Firat River Valley **really** *T. monococcum* subsp. *aegilopoides* or are they *T. urartu*? On the eastern summit of the Jebel Druz, and at other locations in north and northeastern Syria, wild wheat populations are **either** *T. urartu* **or** *T. turgidum* subsp. *dicoccoides*, **or** a mixture of the two. In wetter areas, *T. monococcum* subsp. *aegilopoides* might also be present. In central, northern and western Turkey and in Eastern Europe, wild diploid wheat populations are always *T. monococcum* subsp. *aegilopoides*.

Cytological characters

Einkorn has 14 chromosomes with median or submedian centromeres with one or two chromosomes carrying satellites (Waines and Kimber 1973).

Electrophoretic characterization

The first electrophoretic study of einkorn was by Ove Hall and his associates in Sweden (Hall *et al.* 1963) using ethanol-extracted, water-soluble endosperm proteins in starch gel electrophoresis with an aluminum lactate-urea buffer. Later, the same proteins were electrophoresed in polyacrylamide gel (Johnson and Hall 1965), and

Johnson and his students continued to use this procedure for a further 10 years for systematic studies (Waines 1969; Williams 1971). In Spain, Garcia-Olmeda and his students in Madrid also characterized these proteins as nongliadins (Aragoncillo *et al.* 1975) and as proteolipids (chloroform methanol or CM-extracted proteins; Rodriguez-Loprena *et al.* 1975). By this extraction procedure, wild einkorn has a protein profile with 0, 1, or 2 fast bands, whereas domesticated einkorn has almost exclusively a profile with 0 fast-moving bands (Johnson and Hall 1965; Johnson 1972). These studies indicated that the molecular variation in the domesticated subspecies is a subset of that found in the wild subspecies.

High Molecular Weight (HMW) glutenin proteins

The HMW glutenin subunits of *T. monococcum* were surveyed by Waines and Payne (1987). They screened 209 accessions of subsp. *aegilopoides* (called *boeoticum*) and 132 accessions of subsp. *monococcum*. The HMW subunits of all subsp. *aegilopoides* accessions have a major subunit of low mobility (an 'x' subunit) and a series of less prominent subunit bands of faster mobility with one band dominating ('y' subunits). The mobility of the 'x' subunit varies in different accessions with a range similar to those of the 1Ax and 1Dx glutenin subunits of bread wheat (*T. aestivum* L.). The 'x' subunits usually have mobilities intermediate between those of subunits 2 and 5 of bread wheat, although in 12% of the accessions, the mobility was slower, between those of subunits 1 and 2 of bread wheat. In three accessions from Greek Thrace and Kiziltepe, Mardin Province, Turkey, the 'x' subunit had the same mobility as subunit 1. At the other extreme, in two accessions from Erzurum and Ankara, Turkey, the 'x' subunit had a slightly greater mobility than that of subunit 5 (Waines and Payne 1987). The cluster of 'y' subunit bands in subsp. *aegilopoides* is reminiscent of the 1By and 1Bz subunits of bread wheat, which are often similarly subdivided into several components of similar mobilities (Holt *et al.* 1981). The range of the electrophoretic mobilities of the 'y' subunits among the 209 accessions is significantly less than the range of the 'x' subunits (Waines and Payne 1987).

An SDS-PAGE analysis of 132 accessions of domesticated subsp. *monococcum* showed the HMW glutenin subunits to be similar to those of subsp. *aegilopoides*. The range of the 'x' subunit was narrower. In two accessions of subsp. *monococcum* from Spain G1560 (PI 191146) and G1559 (PI 190940), no HMW 'x' subunits were seen, though the 'y' subunits were still present. A single accession of *T. monococcum* subsp. *monococcum* var. *sinskajae* gave an SDS-PAGE band pattern that was indistinguishable from those of several accessions of the two subspecies of *T. monococcum* (Waines and Payne 1987) even though the seed size was larger than the average for domesticated *monococcum* wheat. More recent surveys of the HMW glutenin subunits of einkorn wheat were performed by Galili *et al.* (1988) and Castagna *et al.* (this volume).

Isozyme characters

Isozymes of *T. monococcum* subsp. *aegilopoides* and *T. urartu* were compared by Yaghoobi-Saray (1979) and Smith-Huerta *et al.* (1989), but neither study characterized domesticated einkorn. We might expect there to be less genetic variation in subsp. *monococcum* than in subsp. *aegilopoides*. However, as far as I know, this comparison has not been made. Genetic diversity is low in *T. monococcum* subsp. *aegilopoides*, which had a mean number of alleles per locus of 1.22 (Smith-Huerta *et al.* 1989). The percentage of polymorphic loci was also low, with a mean of 19.71 for subsp. *aegilopoides*. These values are consistent with wild einkorn being mostly a self-pollinating species; however, this can be expected to vary with environmental conditions. A late frost that would kill anthers and pollen grains, but not eggs, would encourage outcrossing at least in cool, moist environments. *Triticum monococcum* subsp. *monococcum* var. *sinskajae*, with soft, free-threshing glumes, is a recent natural mutation. It does have a variable proportion of male sterile florets in the field at Riverside and segregation data suggest that it outcrosses more frequently than normal einkorn with tough glumes.

Characterization of gliadin proteins

Considerable research has been conducted on gliadin grain proteins in einkorn by Metakovsky and his associates (Metakovsky and Baboev 1991). Again, the patterns for the domesticated form were a subset of those found in the wild form (Metakovsky and Baboev 1992). The inheritance of the gliadin polypeptides was also studied in detail (Metakovsky and Baboev 1991).

Flour characteristics

There is almost no research on starch characteristics of einkorn wheats in the literature. Their flour is known to make good cookies or biscuits (G. Rubenthaler and J.G. Waines, unpublished), and the bread-baking and dough-mixing quality has been ascertained (D'Egidio *et al.* 1993; D'Egidio and Vallega 1994). Genetic variation in diploid wheats for seed protein and amino acids composition has received some attention (Sharma *et al.* 1981; Acquistucci *et al.* 1995). There is a need for continued research into the basic biochemical characterization of einkorn protein, lipids and starch as an aid to applied product development. At the same time, we need to be sure of the taxonomic classification and correct nomenclature of the diploid wheats and their relationship to each other and to the polyploid hulled wheat classes.

References

Acquistucci, R., M.G. D'Egidio and V. Vallega. 1995. Amino acid composition of selected strains of diploid wheat *Triticum monococcum* L. Cereal Chem. 72:213-216.

Aragoncillo, C., M.A. Rodriguez-Loprena, P. Carbonero and F. Garcia-Olmedo. 1975. Chromosomal control of non-gliadin proteins from 70% ethanol extract of wheat endosperm. Theor. Appl. Genetics 45:322-326.

Chapman, V., T.E. Miller and R. Riley. 1976. Equivalence of the A genome of bread wheat and that of *Triticum urartu*. Genetics Res. 27:69-76.

D'Egidio, M.G., S. Nardi and V. Vallega. 1993. Grain, flour and dough characteristics of selected strains of diploid wheat *T. monococcum* L. Cereal Chem. 70:298-303.

D'Egidio, M.G. and V. Vallega. 1994. Bread baking and dough mixing quality of diploid wheat *T. monococcum* L. Italian Food and Beverage Technol. 4:6-8-(20).

Dhaliwal, H.S. 1977. Origin of *Triticum monococcum* L. Wheat Information Service 44:14-17.

Dvorak, J. 1976. The relationship between the genome of *Triticum urartu* and the A and B genomes of *Triticum aestivum*. Can. J. Genetics and Cytol. 18:371-377.

Dvorak, J., P.E. McGuire and B. Cassidy. 1988. Apparent sources of the A genomes of wheats inferred from polymorphism and abundance and restriction fragment length of repeated nucleotide sequences. Genome 30:680-689.

Dvorak, J. and H.B. Zhang. 1990. Variation in repeated nucleotide sequences sheds light on the phylogeny of the wheat B and G genomes. Proc. National Acad. Sci., USA 87:9640-9644.

Galili, G., T. Felsenburg, A.A. Levy, Y. Altschuler and M. Feldman. 1988. Inactivity of high molecular-weight glutenin genes in wild diploid and tetraploid wheats. Pp. 81-86 *in* Proceedings of the Seventh International Wheat Genetics Symposium (T.E. Miller and

R.M.D Koebner, eds.). Institute for Plant Science Research, Cambridge Laboratory, Trumpington, UK.

Gandilyan, P.A. 1972. On the wild growing *Triticum* species of the Armenian S.S.R. Bot. Zh. (Leningrad) 57:173-181.

Hall, O., B.L. Johnson and R. Olered. 1963. Evaluation of genome relationships in wheat from their protein homologies. Pp. 47-54 *in* Proceedings of the Second International Wheat Genetic Symposium (J. Mac Key, ed.). Hereditas Suppl. Vol. 2.

Johnson, B.L. 1972. Protein electrophoretic profiles and the origin of the B genome of wheat. Proc. National Acad. Sci., USA 69:1398-1402.

Johnson, B.L. 1975. Identification of the apparent B genome donor of wheat. Can. J. Genetics and Cytol. 17:21-39.

Johnson, B.L. and H.S. Dhaliwal. 1976. Reproductive isolation of *Triticum boeoticum* and *Triticum urartu* and the origin of the tetraploid wheats. Am. J. Botany 63:1088-1094.

Johnson, B.L. and O. Hall. 1965. Analysis of phylogenetic affinities in the Triticinae by protein electrophoresis. Am. J. Botany 52:506-513.

Kimber, G. and M. Feldman. 1987. Wild Wheat, An Introduction. Special Report 353, College of Agriculture, University of Missouri-Columbia, Columbia, MO, USA.

Kimber, G. and E.R. Sears. 1987. Evolution in the genus *Triticum* and the origin of cultivated wheat. Pp. 154-164 *in* Wheat and Wheat Improvement, 2nd Edition (E.G. Heyne, ed.). Am. Soc. Agron. Monograph No. 13. ASA, Madison, Wisconsin.

Metakovsky, E.V. and S.K. Baboev. 1991. Polymorphism and inheritance of gliadin polypeptides in *Triticum monococcum*. Theor. Appl. Genetics 84:971-978.

Metakovsky, E.V. and S.K. Baboev. 1992. Polymorphism of gliadin and unusual gliadin alleles in *Triticum boeoticum*. Genome 35:1007-1012.

Rodriguez-Loprena, M.A., C. Aragoncillo, P. Carbonero and F. Garcia-Olmedo. 1975. Heterogeneity of wheat endosperm proteolipids (CM proteins). Phytochemistry 14:1219-1223.

Sharma, H.C. and J.G. Waines. 1981. The relationship between male and female fertility and among taxa in diploid wheats. Am. J. Botany 68:449-451.

Sharma, H.C., J.G. Waines, and K.W. Foster. 1981. Variability in primitive and wild wheats for useful genetic characters. Crop Sci. 21:555-559.

Smith-Huerta, N.L., A.J. Huerta, D. Barnhart and J.G. Waines. 1989. Genetic diversity in wild diploid wheats *Triticum monococcum* var. *boeoticum* and *T. urartu* (Poaceae). Theor. Appl. Genetics 78:260-264.

van Slageren, M.W. 1994. Wild Wheats: A Monograph of *Aegilops* L. and *Amblyopyrum* (Jaub & Spach) Eig. (Poaceae). International Center for Agricultural Research in the Dry Areas / Wageningen Agricultural University Papers 94-7.

Waines, J.G. 1969. Electrophoretic-systematic studies in *Aegilops*. Ph.D. dissertation. University of California, Riverside. Dissertation Abstract Order No. 69-19, 131.

Waines, J.G. and G. Kimber. 1973. Satellite number and size in *Triticum monococcum* L. and the evolution of the polyploid wheats. Can. J. Genetics and Cytol. 15:117-122.

Waines, J.G. and P.I. Payne. 1987. Electrophoretic analysis of the high molecular-weight glutenin subunits of *Triticum monococcum*, *T. urartu*, and the A genome of bread wheat (*T. aestivum*). Theor. Appl. Genetics 74:71-76.

Williams, D.B. 1971. Protein heterogeneity and polyploid evolution in *Aegilops* L. Ph.D. dissertation. University of California, Riverside. Dissertation Abstract Order No. 71-17, 049.

Yaghoobi-Saray, J. 1979. An electrophoretic analysis of genetic variation within and between populations of five species in the *Triticum-Aegilops* complex. Ph.D. dissertation, University of California, Davis.

Pre-breeding work on einkorn – Cooperation between genebank and breeders

***K. Hammer*[1]*, M. Neumann*[2] *and H.U. Kison*[3]**

[1] Institut für Pfanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany

[2] BAZ an Kulturpflanzen, Institut für Gemüse-, Heil- und Gewürzpflanzenzüchtung, 06484 Quedlinburg, Germany

[3] Nationalpark Hochharz, 38855 Wernigerode, Germany

Introduction

It was pointed out by Zohary in 1969 that scientists have been paying little attention to *Triticum monococcum* in regard to both wheat breeding and, in general, any research aiming at the better exploitation of this neglected crop. Almost 30 years later, we came to a similar conclusion (Hammer *et al.* 1995): apart from occasional studies, einkorn has indeed been inadequately investigated so far, particularly in regard to its potential applications in wheat improvement.

Characterization and primary evaluation of germplasm collections play a crucial role in enhancing their utilization. These activities are generally carried out by genebanks in the framework of their germplasm management. Secondary evaluations, on the other hand, do not receive the same attention from genebanks because these activities require a great number of highly specialized persons and large experimental fields, both hardly available in conservation centres.

Secondary evaluation at the Gatersleben genebank has been carried out always in close collaboration with institutions specialized in breeding research (Hammer 1991). Such cooperation has proved very fruitful so far.

This paper briefly reviews the most relevant evaluation activities that have been conducted so far on einkorn at the Gatersleben genebank.

Materials and methods

The *T. monococcum* genetic resources conserved at the Gatersleben genebank comprise around 150 accessions, of which 17 were chosen for special investigations aiming at producing basic material for wheat and triticale breeding (Neumann and Kison 1990, 1992; Kison and Neumann 1992, 1993). This material was selected on the basis of the results obtained from a broad screening of the collection in search of accessions with good raw protein and lysine contents (Lehmann *et al.* 1978).

Comprehensive biological investigations on flower morphology were also carried out by Neumann and Kison (1990).

Quality analyses of the caryopses were all carried out at the Institut für Pflanzenernährung und Ökotoxikologie of Jena, central Germany.

At this Institute, tests were also made for evaluating the resistance of einkorn to wheat brown rust and rye brown rust by means of artificial inoculations in plantlets grown in greenhouse and field conditions.

The transfer of genetic information from *T. monococcum* into triticale was achieved through direct crossing between the two species or using the hybrid *T. monococcum* x *Secale cereale* as a ‘bridge form’ (Neumann *et al.* 1985).

Results and discussion

The cultivation of *T. monococcum* is straightforward. It does not have special requirements. All accessions have been investigated in winter time exposed to Central Germany climatic conditions. The demand for vernalization is very low for einkorn; nevertheless, after autumn sowing the plants show a higher tillering rate and produce more pollen (i.e. ca 5000-6000 pollen grains/anther). Pollen production also remains fairly good under greenhouse conditions where temperature is relatively high in early spring (Table 1).

Table 1. Number of pollen grains per anther in *Triticum monococcum* accessions cultivated in greenhouse.

Accession number	**Pollen / Anther**
10	2891 ± 755
12	3008 ± 815
13	3581 ± 750
14	3203 ± 630
15	3880 ± 864
17	3307 ± 844
18	3112 ± 815
19	3398 ± 859
20	3954 ± 828
21	4674 ± 800
22	3607 ± 681
23	4219 ± 842
24	4974 ±1028
25	4062 ±1039
26	3620 ± 842
Mean	3699 ± 826
Terms of comparison with other cereals:	
T. aestivum	2236 – 3022
Secale cereale	19103 – 21434
Hordeum vulgare	2294 – 4417

Investigation of flower biology and pollen production is of great importance with regard to anthesis synchronization during crossing activities, besides providing data on the range of reaction ability of einkorn. On the basis of these results and those obtained in general on the whole reproduction system (Neumann and Kison 1990) there is evidence that *T. monococcum* represents a good basic material for increasing cross-fertilization rates (Hammer 1990). These findings could be particularly helpful in breeding programmes aiming at the development of hybrid varieties.

The protein content ranged from 16.5 to 28.5% (Table 2). It is interesting to note that peak values exceeded by far the results usually obtained in wheat (Lehmann *et al.* 1978). These data reiterate the good potential of einkorn as a basic material in wheat improvement programmes.

Similar high values in protein content are reached only by *T. baeoticum*, one of einkorn's closest wild relatives. The lysine contents also were found to be exceptionally high.

Table 2. Protein and amino acid-lysine contents in *Triticum monococcum*.

Accession number	Protein (%)	Lysine (%)
10	25.87	2.38
11	28.50	2.50
12	18.19	2.54
13	23.31	2.39
14	26.37	2.35
15	23.37	2.52
16	17.87	2.65
17	19.12	2.43
18	24.87	2.35
19	18.69	2.49
20	23.19	2.39
21	18.31	2.41
22	18.37	2.38
23	18.37	2.48
24	18.87	2.31
25	16.50	2.54
26	17.62	2.47
27	21.75	2.41
Mean	21.06 ± 1.81	2.44 ± 0.04
Terms of comparison with wheat and other closely related taxa:		
T. baeoticum	26.8	2.00
T. dicoccon	23.6	2.11
T. durum	20.2	2.22
T. aestivum	21.3	1.97

Good results also have been gathered in the area of disease resistance. Our data do confirm what was already reported in the literature, that is the high levels of resistance of einkorn to various pathogens: *T. monococcum* constantly showed 100% resistance to wheat and rye mildew. Even plants cultivated in greenhouses or under plastic tunnels located in areas where tetraploid and exaploid wheat varieties often have been found to be highly infested, showed very high level of resistance to these fungi.

Samples investigated were completely resistant to the rye brown rust, though some slight degree of variation was found among the results from the wheat brown rust screening (Table 3).

All these results that we have briefly presented here are particularly relevant in regard to the use of einkorn for the genetic improvement of triticale. Indeed these data have indicated that einkorn can be used successfully as a donor of new variability for this crop.

If we were to highlight a particular finding that in our opinion is likely to have a major impact in the breeding of triticale we would consider the results obtained on pollen (Table 4) and resistance to diseases.

Table 3. Results obtained on the evaluation trials to wheat brown and rye brown rusts carried out in *Triticum monococcum.*

Accession number	Wheat brown rust	Rye brown rust
10	0	0
11	1	0
12	0	0
13	0	0
14	1	0
15	1	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	–
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0

0-1 = resistant; 2 = moderately susceptible; 3-4 = susceptible.

Table 4. Plant character in BC1 (6x-Triticale x *T. monococcum*) x 6x-Triticale.

Accession no.	Chromosome no.	Pollen viability	Dehiscens of anthers	Resistance to mildew
I / 1	43	15.52 ± 4.32	+	–
I / 2	40	41.14 ± 7.29	++	–
I / 3	49	26.71 ± 7.20	+	–
2040 / 1669	48	32.40 ± 4.62	+	–
2040 / 1670	–	42.08 ± 7.15	++	–
II / 1	49	41.30 ± 4.11	++	–
2041 / 1671	39	–	–	(+)
Mean	43.29	34.14	–	–

+ = only a few dehiscing anthers; ++ = most dehiscing anthers; (+) = very low susceptibility.

Conclusions

Within the genus *Triticum, T. monococcum* occupies a special position because of its flowering characters, its quality and resistance characters.

Its genetic potential makes this species a suitable alternative crop – with special regard to the ecological demands in plant cultivation. But up to now *T. monococcum* has received only little interest from breeders. The reason for this might be found in its low yield: herewith a call to breeders to not neglect this aspect when trying to enhance the use of this underutilized species.

Einkorn has an outstanding potential for the improvement of wheat varieties. Its tendency towards allogamy represents a favourable ground for facilitating the production of hybrid varieties.

References

Hammer, K. 1990. Breeding system and phylogenetic relationships in *Secale* L. Biol. Zentralbl. 109:45-50.

Hammer, K. 1991. Die Nutzung des Materials der Gaterslebener Genbank für die Resistenzzüchtung - eine Übersicht. Vortr. Pflanzenzüchtg. 19:197-206.

Hammer, K., M. Neumann and H.U. Kison. 1995. Genetic resources of *Triticum monococcum*. International Symposium on Research and Utilization of Crop Germplasm Resources, Beijing, Proc., p. 7.

Kison, H.U. and M. Neumann. 1992. Hybridization between hexaploid triticale and *Triticum monococcum* L. I. Progamic reaction. Hereditas 116:285-289.

Kison, H.U. and M. Neumann. 1993. The Introgression of Genetic Information from *Triticum monococcum* L. into Hexaploid Triticale by Hybridization with a *T. monococcum* x *S. cereale* Amphiploid. Plant Breeding 110:283-289.

Lehmann, C.O., A. Rudolph, K. Hammer, A. Meister, K. Müntz and F. Scholz. 1978. Eiweißuntersuchungen am Getreide- und Leguminosensortiment Gatersleben,Teil 1: Gehalt an Rohprotein und Lysin von Weizen sowie von Weizen-Art-Yund Gattungsbastarden. Kulturpflanze 26:133-161.

Neumann, M. and H.U. Kison. 1990. Introgression genetischer Information von *Triticum monococcum* L. in 6x - Triticale. Dissertation B, Berlin, 206 + 32 S.

Neumann, M. and H.U. Kison. 1992. Hybridization between hexaploid triticale and *Triticum monococcum* L. II. The F1 generation AuAbBR. Hereditas 116:291-294.

Neumann, M., W. Sodkiewicz and K. Skiebe. 1985. On possibilities of genetic information transfer from *Triticum monococcum* to triticale. Gen. Polonica 26:209-215.

Zohary, D. 1969. The progenitors of wheat and barley in relation to domestication and agricultural dispersal in the old world. Pp. 47-66 *in* The Domestication and Exploration of Plants and Animals (P.J. Ucko and G.W. Dimbleby, eds.). Proc. Meet. Res. Seminar Arch. Rel. Subj., London.

Technological and nutritional aspects in emmer and spelt

R. Cubadda and E. Marconi

University of Molise, Faculty of Agriculture, Dip. Scienze e Tecnologie Agroalimentari Ambientali e Microbiologiche, Campobasso, Italy

Introduction

Organic agriculture and health food products have been gaining increasing popularity lately and this has led to a renewed interest in hulled species, whose utilization dates back to Roman times.

In Italy, hulled wheat species are known by the name farro. In this country, farro is still being used in rural areas to prepare traditional dishes. The whole grain or broken, clean grain – 'farricello' – is still used mainly in soups as in ancient Rome. As Pliny commented, among Romans *pulte* (hulled wheat broken and boiled in water or milk) was more popular than bread. Old and new recipes based on farro are numerous. Among these products the most popular are the 'focaccia' (a type of flat bread), cakes, biscuits, confectionery and fresh pasta (such as 'tagliatelle' which were and still are called 'sagne'). Recently, a type of dry pasta produced industrially from emmer and durum wheat blends along with an artisanal type made entirely with farro are being marketed with success.

In Europe, particularly in Germany, Belgium and Switzerland, spelt flour is largely used in bread-making and other bakery products (Defrise and Jacqmain 1984; Graber and Kuhn 1992; Boller 1995). According to Ranhotra *et al.* (1995) farro bread and pasta are being produced and marketed also in Michigan and Ohio States, USA.

In light of the increased demand, evaluation of the composition and technological characteristics of farro, particularly in those products traditionally manufactured from durum wheat and/or soft wheat or in other foods designed for special diets, is of paramount importance.

The aim of this work is to describe the technological characteristics of some emmer and spelt ecotypes, and review and compare the results available in the literature on the functional properties and nutritional composition of these species.

The variability of these characteristics in relation to the genotype and to the environmental conditions will also be examined.

Protein content and gluten quality

The functional properties of different species of wheat for bread-making or pasta-making strictly depend upon protein content and gluten quality.

The few data available in the literature on protein content and gluten quality of *T. dicoccum* and *T. spelta* are given in Table 1. The data show a great variability of these parameters: for example, Perrino *et al.* (1993) found high mean values of 17.1% d.m. in 50 emmer accessions and 16.1% d.m. in 50 other spelt accessions cultivated in the same experimental field, whereas other researchers, on the contrary, found very low values (<10%) in three Italian emmer populations (from Garfagnana, Leonessa and Trivento) cultivated in three different locations (Galterio *et al.* 1994).

Table 1. Whole meal protein content (Nx5.70)% d.m. and gluten quality (SDSS ml) of emmer and spelt accessions, ecotypes, landraces or populations reported by different authors.

	Emmer					Spelt				
	Sample	Protein		SDSS		Sample	Protein		SDSS	
Reference	no.	range	mean	range	mean	no.	range	mean	range	mean
Perrino *et al.* (1993)	50	14.2-20.2	17.1	24-66	33	50	14.4-17.7	16.1	36-127	90
Blanco *et al.* (1990)	50	8.7-18.0	12.5	25-53	34	–	–	–	–	–
Cubadda and Marconi (1994)	2 (1x2)*°	20.6-21.9	21.3	–	41	2 (1x2)*	18.5-19.9	19.2	–	75
Graber and Kuhn (1992)	–	–	–	–	–	19	12.3-16.2	14.4	9.-23	18
Belitz *et al.* (1989)	–	–	–	–	–	3	12.8-14.2	13.4	–	–
Galterio *et al.* (1994)	9(3x3)**	7.9-10.4	9.3	20-26	22	–	–	–	–	–
Galterio *et al.* (1994)	6 (3x2)***	9.6-10.1	9.7	20-26	22	–	–	–	–	–
Ranhotra *et al.* (1995)	–	–	–	–	–	1	–	12.7	–	–

* = 1 entry x 2 theses (years); ** = 3 entries x 3 theses (locations); *** = 3 entries x 2 theses (nitrogen fertilization levels).

Table 2. Rheological characteristics (alveograph and farinograph) of flours from bread wheat (control), spelt and emmer grown in Apulia in 1992 and 1993 (adapted from Cubadda and Marconi 1994).

	Bread wheat		Spelt		Emmer	
Characteristics	1992	1993	1992	1993	1992	1993
Alveograph						
G	23.0	25.7	34.3	28.0	21.9	18.9
W	173	190	181	116	78	118
P/L	0.43	0.38	0.16	0.25	0.39	0.95
Farinograph						
Water absorption (%)	49.4	–	54.3	–	58.0	–
Development time (min)	1.30	–	5.00	–	1.30	–
Stability time (min_	10.00	–	6.30	–	4.00	–
Mixing tolerance index (BU)	30	–	30	–	50	–

In the accessions investigated by Perrino *et al.* (1993) evaluated by the SDS sedimentation test (SDSS), gluten quality was high, with mean values of 33 ml and peak values of 66 ml for emmer and 90 and 127 ml for spelt, respectively. These findings are in conflict with those obtained analyzing the three emmer varieties, which showed a particularly low content in gluten quality, SDS sedimentation values being 20-26 ml (Galterio *et al.*1994).

Such high variability in protein content and in gluten quality has been further confirmed by other workers. Blanco *et al.* (1990) found in 50 emmer accessions a protein content ranging from 8.7 to 18% d.m. and SDSS of 25-53 ml whereas Graber and Kuhn (1992), for 19 spelt varieties cultivated in Germany, reported a protein content range of 12.3-16.2% and SDSS values of 9-23 ml. Moreover for another three German spelt varieties (‘Rouquin’, ‘Oberkulmer’ and ‘Steiners roter Tiroler’), Belitz *et al.* (1989) have reported a protein content of 12.8-14.2%, whereas a spelt sample grown in Canada showed a value of 12.7% (Ranhotra *et al.*1995).

Still on this issue, assessments carried out by Cubadda and Marconi (1994) over two years (1992-93) on emmer and spelt landraces cultivated in Apulia (southern Italy) revealed mean protein contents of 18% and 22% d.m., respectively. Gluten quality appeared higher for spelt (SDSS 75 ml) and lower for emmer (SDSS 41 ml) in comparison with the soft wheat control (‘Centauro’ cultivar).

The investigations carried out by Graber and Kuhn (1992) on two spelt varieties (‘Schwabenkorn’ and ‘Rouquin’), grown in two locations in Germany under different cultivation conditions (seeding times and nitrogen fertilization levels), highlighted protein contents ranging from 14 to 17.5%. Since the degree of nitrogen absorption from the soil and its conversion into proteins were greatly dependent on the genotype and on cultivation conditions, the authors stressed the need to compare samples grown under the same conditions. This fact is in contrast with the observations of Galterio *et al.* (1994) for which the nitrogen fertilization (50 kg/ha) is reported to have not modified the protein content which was 9.7% d.m. in the three emmer populations, with or without fertilization.

Rheological properties, baking and pasta-making

Information in the literature on the rheological properties, baking and pasta-making tests is scarce.

In Table 2 are reported some rheological data (alveograph and farinograph), that the present authors gathered on the flours of the emmer and spelt landraces mentioned above.

The alveograph parameters of spelt are lower than those of the control wheat (‘Centauro’); nevertheless the 1992 harvest sample shows fairly good alveograph indexes even though dough extensibility seems to be excessive (P/L=0.16).

According to Rahnotra *et al.* (1995), the mixograph data of Canadian spelt flour compared with wheat flour, had a much shorter dough development time and less mixing tolerance which are indicative of inferior baking characteristics.

Bread-baking data showed a lower specific volume for spelt bread and also a lower total score. Spelt bread had a rather open grain and coarse texture compared with the control (white wheat bread). According to the authors spelt bread would probably be more acceptable if promoted as a speciality bread for which white wheat bread scoring standards would not be applied.

Results obtained by Legros and Castille (1972) and Castille (1982) using six Belgian spelt varieties (‘Albin’, ‘Altgold’, ‘Ardenne’, ‘Hercule’, ‘Lignee 24’, ‘Renval’ and ‘Rouquin’) indicated that spelt flours had good rheological and bread-making properties (in particular ‘Rouquin’) and produced bread with a very distinctive taste. This is in agreement with the results of panel tests the present authors carried out on emmer and spelt farro bread loaves, baked according to the procedure reported by Cubadda and Pasqui (1984): these results (Table 3) indicate that spelt and emmer flours produce voluminous loaves which have better flavour, taste and crust colour than the control. In addition, bread loaves of farro had a relatively fine and uniform texture and a distinctive light-dark colouration of the crumb.

Table 3. Bread characteristics of fours from spelt and emmer landraces grown in Apulia in 1993 compared to bread wheat (adapted from Cubadda and Marconi 1994).

Bread characteristics	**Bread wheat**	**Spelt**	**Emmer**
Specific volume (cm^3/g)	2.0	2.6	2.1
Loaf quality:			
Volume	Good	Very good	Good
Symmetry	Regular	Regular	Light irregular
Break and shred	Good	Good	Mediocre
Crust colour	Fair	Good	Mediocre
Texture	Regular	Regular	Irregular
Crumb colour	White	Cream	Gray
Taste	Fair	Good	Good
Flavour	Fair	Very good	Very good

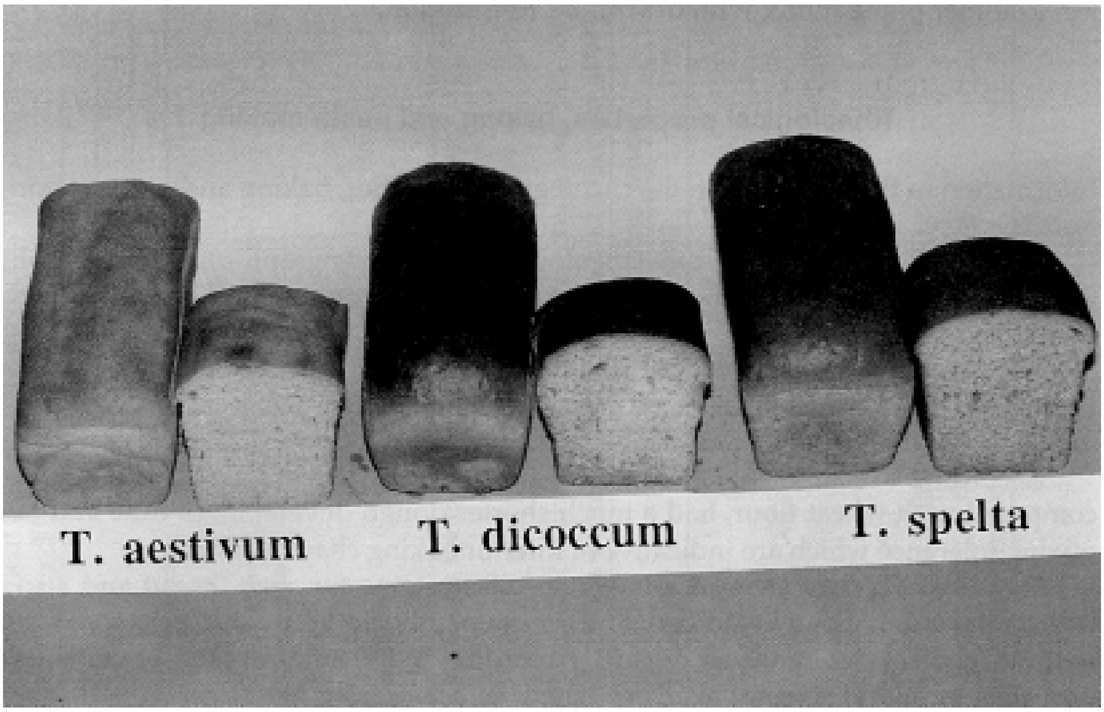


Fig 1. Bread loaves manufactured with flours from bread wheat (Centauro), *dicoccum* and *spelta* landraces grown in Apulia in 1993

With regards to the pasta-making potential of farro, Galterio *et al.* (1994) gave a very negative organoleptic judgment on the cooking quality of the pasta obtained from three emmer landraces cultivated in three different locations in Central and Southern Italy.

In addition, the same researchers noted that, during mixing, the doughs were sticky, thus confirming the low alveograph values (W< 50) of the meals; W parameter in fact is closely correlated to the dough's gluten strength.

This conclusion, however, is not supported by the data collected in our study, carried out by comparing the pasta-making potential of emmer grown in Garfagnana (Tuscany) with the durum wheat (cv. 'Simeto'), as a control. For the compositional and technological studies, both wheats were first ground into semolina in an experimental Buhler pneumatic mill equipped with a laboratory semolina purifier, with three breaking and three regrinding stages. An experimental pasta-making apparatus (Pavan) composed of a press and a dryer was used for turning semolina into pasta (spaghetti). The operating conditions were as follows:

Mixing time (min)	15
Temperature of added water (ºC)	40
Extrusion pressure (Bar)	120
Maximum drying temperature (ºC)	90 (for 50 min)
Total drying time (min)	390

Pasta cooking quality was evaluated by an organoleptic procedure, as determined by Cubadda (1988) and by the method based on the determination of the total organic matter released by cooked pasta (D'Egidio *et al.* 1982).

The semolina characteristics, pasta colour and cooking quality of emmer and durum wheat samples are shown in Table 4. Compared with durum wheat, the gluten quality and alveograph W parameter were low, indicating inferior pasta-making characteristics. Emmer pasta colour was light dark. However, the cooking quality of emmer pasta was fair and more than acceptable, if considered as a specialty pasta.

Table 4. Semolina characteristics and pasta cooking quality of emmer landraces grown in Garfagnana in 1994 compared with durum wheat (var. 'Simeto').

Characteristics	Emmer	Durum wheat
Semolina		
Protein (Nx5.70)% d.m.	12.3	11.9
Ash% d.m.	0.99	0.88
Gluten Index	37	87
SDSS ml	26	52
W alveograph	67	187
Pasta		
Colour	Light dark	Yellow
Cooking quality		
Stickiness	Rare	Almost absent
Firmness	Sufficient	Good
Bulkiness	Rare	Almost absent
Total score*	65	80
Total organic matter	1.8	1.3

(TOM)**

* 40 = poor or mediocre quality; >40-50 = not completely satisfactory; >50-70 = fair; >70-80 = good; >80 = excellent.
** >1.4 = good or excellent quality; 1.4-2.1 = average; <2.1 = low.

Nutritional quality

Spelt and/or emmer are often claimed to be higher in nutrient content and more easily digested than common bread wheats. Furthermore, with no support of substantiated scientific investigations, spelt has also been also recommended for the treatment of colitis ulcerosa, neurodermitis and other allergies as well as for high blood cholesterol (Strehlow *et al.* 1994; Italiano and De Pasquale 1994).

We must remark here that, indeed, scientific data on the nutritional properties of both species are rather few and inconclusive. The only work that might in our opinion be used as a valid reference on this issue is that of Ranhotra *et al.* (1995), which examines only one spelt landrace in comparison with a hard red winter (HRW) wheat variety.

In our opinion, the differences Ranhotra found between various nutrients (proteins, fats, carbohydrates, thiamin, riboflavin, niacin, calcium, phosphorus, magnesium, etc.) were minimal and certainly within the biological variability between the different genotypes of the same species. If the only significant difference, zinc content, which is 91% more in spelt than in wheat, is validated in more comprehensive studies, the nutritional significance may be of importance.

Grela *et al.* (1993), on analyzing barley, wheat, triticale, rye and spelt samples for alpha, beta, gamma and delta tocopherols (vitamin E), found that spelt had the highest gamma tocopherol value (21.6 mg/kg), the lowest delta tocopherol value (2.5 mg/kg) and intermediate values for alpha and beta tocopherols.

In order to assess protein quality, Rahnotra *et al.* (1995) undertook animal studies to determine the protein efficiency ratio (PER) and apparent protein digestibility (protein intake minus fecal protein loss). No significant differences were noted in PER nor in digestibility data between spelt and HRW wheat.

An indirect evaluation of protein quality can be obtained through the determination of the amino acidic composition, taking into account particularly the essential ones.

Table 5 shows the composition in amino acids we determined on flours of two spelt and emmer landraces grown in Apulia in 1993 referring to the control wheat (*T. aestivum*) and on meal and whole meal of an emmer landrace grown in Garfagnana, in 1994. Amino acids were determined by ion-exchange chromatography after protein hydrolysis with 6N HCl at 110°C for 24 h and 72 h in vacuum-sealed tubes (Moore *et al.* 1958). Performic acid oxidation, followed by acid hydrolysis, was used for cysteine and methionine determinations (Schram *et al.* 1954).

Refined flour should be used in evaluating amino acid composition rather than whole meal because cereals are generally eaten, more or less, as sieved flour. It is well known that the milling and the subsequent sieving often leads to a substantial loss of nutrients, including essential amino acids.

The amino acid composition of emmer and spelt was analogous to that of common wheats (Table 5) which was also reported by Belitz *et al.* (1982), Ranhotra *et al.* (1995) and Galterio *et al.* (1994).

In spelt and emmer, as well as in other cereals, lysine is the limiting amino acid, followed by threonine. The lysine content in spelt is slightly higher but is almost the same in emmer as in the control wheat. The higher lysine value found in whole meal emmer could explain the assertion that farro is high in lysine content, since farro is mainly consumed as whole or pearled grain meals.

The domestication and the improvement programmes of modern wheat species, in order to increase their yield, could have brought about an unintentional diminution of some of the antinutritional factors responsible for resistance to biotic and abiotic stresses. For these reasons, it could be very useful, from a nutritional point of view, to examine wild and primitive wheats for the possible presence of these antimetabolic compounds (tannins, protease inhibitors, phytic acid, lectins, etc).

Since no data are available on farro antinutrients, we carried out some preliminary investigations on phytic acid and trypsin inhibitors in two emmer and spelt landraces. Phytic acid (PA) was determined according to Harland and Oberleas (1986) and trypsin inhibitors according to Hamerstrand *et al.* (1981). PA forms insoluble complexes with minerals such as calcium, iron and zinc, causing their low bioavailability. We found slightly higher phytate values in emmer and spelt flours (236 and 313 mg/100g d.m., respectively) than in soft wheat (‘Centauro’) flours (142 mg/100g d.m.). The higher PA values of farro (analogous to those reported currently in other wheat flours) could be attributed to a lower degree of refinement of farro flours, since PA is located mainly in the bran and aleuronic layer.

Table 5. Amino acid pattern (g/100 g protein) of emmer, spelt and bread wheat (Centauro) grown in Apulia in 1993 and of emmer landrace grown in Tuscany in 1994.

Amino acid	Bread wheat Apulia 93 meal	Spelt Apulia 93 meal	Emmer Apulia 93 meal	Emmer Tuscany 94 meal	Emmer Tuscany 94 whole meal	Pattern FAO (1985)
Threonine	2.75	2.63	2.83	2.62	2.95	3.40
Valine	3.92	4.16	4.01	4.12	4.36	3.50
Methionine	1.51	1.58	1.51	1.43	1.40	-
Cysteine	2.34	2.03	1.92	2.21	2.25	2.50
Leucine	6.68	6.76	6.44	6.85	6.91	6.60
Isoleucine	3.22	3.54	2.91	3.47	3.66	2.80
Tyrosine	3.07	2.94	3.45	2.52	2.54	-
Phenylalanine	4.82	4.78	5.45	5.03	4.59	6.30
Lysine	2.09	2.25	2.14	2.13	2.47	5.80
Aspartic acid	4.26	4.20	4.76	4.16	4.72	-
Serine	4.85	4.57	4.61	4.72	4.65	-
Glutamic acid	34.20	34.37	33.20	34.23	31.05	-
Proline	10.86	10.92	11.60	10.54	10.02	-
Glycine	3.29	3.08	2.87	2.95	3.30	-
Alanine	2.96	2.78	3.08	2.54	2.99	-
Arginine	3.78	3.98	3.47	4.10	4.92	-
Histidine	2.00	2.04	2.10	2.21	2.47	-
Chemical score	0.36	0.39	0.37	0.37	0.43	-
Limiting AA	Lysine	Lysine	Lysine	Lysine	Lysine	-

The trypsin inhibitor content of farro landraces was very low (trypsin inhibitors units <0.5 mg dry flour), similar to that of common soft and durum wheat meals.

Such preliminary results should be completed by assessing the other antimetabolic compounds and a larger number of accessions.

Conclusion

In brief, the data reported in the present work clearly show that the information on chemical composition, milling, baking, pasta-making and the nutritional characteristics of emmer and spelt wheats is incomplete and frequently divergent. More investigation is therefore needed to support the claims that these species have significant advantages over common bread wheat.

Food market demands sound products for good health. Cereal-based foods from emmer or spelt wheats, particularly if grown under the conditions of organic agriculture, could represent an answer to the request of many consumers. Furthermore, in order to promote the utilization of these underutilized crops for baking and pasta-making purposes, an evaluation of the qualitative characteristics of a large number of genotypes should be undertaken with priority.

In this context, collaborative research projects aiming at shedding light on genetic, agronomical, technological and qualitative aspects of emmer and spelt and hulled wheat species in general, would be highly recommended.

Acknowledgements

The authors wish to thank Prof. F. Basso and Dr M. Pisante of University of Basilicata (Potenza, Italy) for providing Apulian emmer and spelt samples and Prof. A. Stefani (Scuola Superiore e di Perfezionamento Sant'Anna, Pisa, Italy) for providing emmer material from Garfagnana.

References

Belitz, H.D., W. Seilmeier and H. Wieser. 1989. Proteins of spelt wheat (*Triticum spelta*). Zeitschrift-fuer-Lebensmittel-Untersuchung-und-Forschung 189:1-5.

Blanco, A., B. Giorgi, P. Perrino and R. Simeone. 1990. Genetic resources and breeding for improved quality in durum wheat. Agricoltura Ricerca 12:41-58.

Boller, S. 1995. Conservation and promotion of spelt by breeding and research in Switzerland, oral presentation given at the Workshop "Farro: promoting the conservation and use of a valuable underutilized crop", IPGRI, 21 July 1995, Castelvecchio Pascoli (Lucca), Italy.

Castille, J.P. 1982. Technological characteristics of spelt of the 1980-1981 harvest. Note-Technique, Centre de Recherches Agronomiques et l'Etat, Gembloux N 6/35.

Cubadda, R. 1988. Durum Wheat: Chemistry and Technology. AACC, St Paul, Minnesota, USA, pp. 217-228.

Cubadda, R. and L.A. Pasqui. 1984. Risultati di una sperimentazione quadriennale sulle caratteristiche tecnologico-qualitative della produzione nazionale di frumento tenero. Monografia dell'Istituto Nazionale della Nutrizione, Roma, pp. 15-16.

Cubadda, R. and E. Marconi. 1994. Aspetti relativi all'utilizzazione e alla caratterizzazione tecnologica e nutrizionale del farro. Atti del Convegno "Il farro un cereale della salute", Potenza 18 giugno 1994 (P. Perrino, D. Semeraro e G. Laghetti, edd.): pp. 82-88.

Defrise, D. and D. Jacqmain. 1984. Determination of spelt content of bread by electrophoretic analysis of gliadins. Revue des fermentations et des Industries Alimentaires 39:123-136.

D'Egidio, M.G., E. De Stefanis, S. Fortini, G. Galterio, S. Nardi, D. Sgrulletta and A. Borrini. 1982. Standardization of cooking quality analysis in macaroni and pasta products. Cereal Foods World 27:367-368.

FAO/WHO/UNU. 1985. Energy and protein requirements. WHO Tech. Rep. Ser. Nl724 World Health Organization, Geneva, Switzerland.

Galterio, G., M. Cappelloni, E. Desiderio and N.E. Pogna. 1994. Genetic, tecnological and nutritional characteristics of three Italian populations of "farrum" (*Triticum turgidum* subsp. *dicoccum*). J. Genetics & Breed. 48:391-398.

Graber, S. and M. Kuhn. 1992. Evaluation of the baking quality of different varieties of spelt. Getreide, Mehl und Brot 46:102-108.

Hamerstrand, G.E., L.T. Black and J.D. Glover. 1981. Trypsin inhibitors in soy products: modification of the standard analytical procedure. Cereal Chem. 58:42-45.

Grela, E., M. Baranowska, R. Krusinski and H. Skornicki. 1993. Tocopherol contents of legumes and cereals. Przemysl Spozywczy 47:311-312.

Harland, F.H. and D. Oberleas. 1986. Anion exchange method for determination of phytate in foods: collaborative study. J. Assoc. Off. Anal. Chem. 69:667-670.

Italiano, M. and A/ De Pasquale. 1994. Il farro: Nuove acquisizioni in ambito preventivo e terapeutico. Atti del Convegno "Il farro un cereale della salute", Potenza 18 giugno 1994 (P. Perrino, D. Semeraro e G. Laghetti, edd.): pp. 67-81.

Legros, R. and J.P. Castille. 1972. Use of spelt (*Triticum aestivum* var. *spelta*) in breadmaking. Revue de l'Agriculture 25:725-732.

Moore, S., D.M. Spackman and W.H. Stein. 1958. Chromatography of amino acids and sulphonated polistyrene resins. Analytical Chem. 30:1185-1190.

Perrino, P., S. Infantino, P. Basso, A. Di Marzio, N. Volpe and G. Laghetti. 1993. Valutazione e selezione di farro in ambienti marginali dell'appennino molisano. L'Informatore Agrario 43:41-44.

Ranhotra, G.S., J.A. Gelroth, B.K. Glaser and K.J. Lorenz. 1995. Baking and nutritional qualities of a spelt wheat sample. Lebensm.-Wiss. u.-Technol. 28:118-122.

Schram, E., S. Moore and E.J. Bigwood 1954. Chromatographic determination of cystin as cysteic acid. Biochem. J. 57:33-37.

Strehlow, W., G. Hertzka and W. Weuffen 1994. Aspetti nutrizionali. Le caratteristiche dietetiche del farro nel trattamento di malattie croniche. Atti del Convegno "Il farro un cereale della salute", Potenza 18 giugno 1994 (P. Perrino, D. Semeraro e G. Laghetti, edd.): pp. 52-66.

The quality of *Triticum monococcum* L., in perspective

V. Vallega

Istituto Sperimentale per la Cerealicoltura, Rome, Italy

Developing commercial cultivars of diploid wheat, *Triticum monococcum* L. (einkorn) seems a most interesting venture (Vallega 1979, 1992; Waines 1983), and may ensure a durable future for this ancient crop. Einkorn's high agronomic potential is well documented (Vallega 1992). Conversely, assessment of its quality attributes proceeds at a slow pace owing to dehulling difficulties and because of the need to investigate a very large number of quality traits and aspects. At present, discussions on this topic are also rather complex, because of factors related to the abandonment of *monococcum* cultivation (prejudices, breeding gaps, marketing problems, etc.) and because of the opportunities offered by einkorn's diploid nature in the exploitation of novel endosperm mutants (Vallega 1978; Waines 1983).

During the past two decades, einkorn has been examined for disparate quality traits by breeders, cereal technologists and medical researchers. This paper summarizes the results so far obtained in the light of genetic, historic and marketing considerations; its main objectives are to highlight a few issues concerning the quality of *T. monococcum*, and to promote further research contributions from experts in different fields. Data on various quality traits of einkorn are also addressed elsewhere in this monograph (Borghi *et al.* this volume).

Available germplasm

Triticum monococcum L. comprises a wild subspecies, *T. monococcum* L. subsp. *boeoticum* Boiss. (with hulled grains and brittle rachis), a domesticated, hulled subspecies, *T. monococcum* L. subsp. *monococcum* (with tough rachis), and two domesticated, free-threshing subspecies recently identified in germplasm collections: *T. monococcum* L. subsp. *sinskajae* Filat. et Kurk. and *T. monococcum* L. subsp. *clusii* (Filatenko and Kurkiev 1975; Szabó *et al.* 1994). Hybrids between these taxa are fully fertile, whereas those with *T. urartu* Tum. (also a diploid wheat) are sterile (Dhaliwal 1977). In practice, the amount of genetic variability readily available for breeding einkorns of better quality is very scarce. In fact, (1) crosses involving subsp. *boeoticum* accessions are very difficult to manage owing to the negative traits transmitted by these wheats (seed dormancy, brittle rachis, small grain size, etc.), and (2) seedbanks hold only about 150 unduplicated accessions of domesticated einkorns and one genetically improved, free-threshing population (PI 584654, Vallega 1991).

It should be noted that practically all the domesticated forms of *T. monococcum* preserved in seedbanks were collected from relic cultivations in mountainous areas during the last 60-70 years, when the races formerly grown in the fertile areas were no longer available. Therefore, the results of variability surveys conducted on these wheats should be interpreted with caution.

Hulled grains

The grains of hulled wheats are enclosed by tenacious glumes, which cannot be removed with the procedures normally utilized to thresh those of common wheat (*T. aestivum* L.) and durum wheat *(T. durum* Desf.). Hulled forms of domesticated einkorn are markedly more difficult to thresh than spelt and dicoccum wheats, and wild einkorn strains pose even greater dehulling problems owing to their smaller and more slender-shaped seeds (Harlan 1967; Vallega 1992). Tenacious glumes do not affect any quality attributes except, perhaps, grain shape and size (Millet 1988).

Removal of tenacious glumes entails enhanced costs as well as greater technology and energy inputs, yet this has not impeded the success of typically hulled cereals such as rice, nor the long-term survival of tenacious-glumed wheat crops. Cultivation and/or breeding of hulled einkorns seems nevertheless anachronistic owing to the availability of free-threshing strains (Kurkiev and Filatenko 1981; Multani *et al.* 1992; Szabó *et al.* 1994) and because of the need to improve this crop for many other characteristics. Indeed, the preponderance of hulled einkorns in germplasm collections is hindering quality surveys and the selection of improved progenies in breeders' fields.

Hulled wheats are traditionally de-glumed either by exposure to fire, strong pounding or with millstones (Harlan 1967; Aykroyd and Doughty 1970); nowadays this operation is generally performed by specialized machinery, such as decorticators. In general, the dehulling experience gained with other tenacious-glumed cereals has been little exploited. Past use of roasting as a means of dehulling has been questioned (Nesbitt *et al.* and Peña-Chocarro, this volume).

Einkorn’s diploid nature

Einkorn (genome A'A', 14 chromosomes) has attracted the attention of researchers mainly because of its diploid nature. This feature, in fact, renders it ideal for the identification and direct utilization of variants (particularly recessive endosperm mutants) that are unavailable in durum wheat (genome AABB, 28 chromosomes) and common wheat (genome AABBDD, 42 chromosomes) because of masking interactions between homoeologous *loci* (Vallega 1978; Waines 1983). Owing to this peculiarity, einkorn appears of greater interest for satisfying special demands by the chemical and food industries than for producing the foods currently made with durum and common wheats (D'Egidio *et al.* 1993). To date, few and rather unsuccessful efforts have been made in this direction (Johnson and Mattern 1975; Vallega 1978; Kantaki and Noda 1988; Multani *et al.* 1992; Acquistucci *et al.* 1995), mainly because of the scarcity of einkorn germplasm and the predominance of hulled accessions. At present, mutagenic treatment of free-threshing einkorn strains seems the only means for producing the wide array of endosperm mutants (for high-lysine, high amylose, etc.) detected in maize, rice and other diploid cereals.

Wheat uses and quality requirements

Commercial wheat crops are utilized to manufacture comestibles, alcoholic beverages (whiskey, ‘bouza’, etc.), and a few industrial products (starch, paper, alcohol, etc); use as animal feed has become relatively common during the last few decades. Wheat-based foodstuffs comprise whole-grain aliments (frekeh, muesli, farro soups, kibe, 'pastiera', 'trigo perlado', 'frumenty', 'graupen', 'grünkorn', etc.), breakfast cereals (flakes, puffed wheat, etc.), cracked grain aliments (burghul, couscous, etc.), flat bread (chapati, baladi, matzoh, tortillas, etc.), dry pastes (macaroni, noodles, vermicelli, bihon, etc.), and a wide range of leavened products (bread, cakes, cookies, biscuits, pizza, crackers, croissants, waffers, etc.) (Aykroyd and Doughty 1970). Leavened foodstuffs can be made only with wheats and rye; all the other kinds of aliments, including some dry pastes, can be made from any cereal (i.e. rice dishes, polenta, tortillas, etc). In general, hulled wheats are used to produce whole or cracked grain aliments, common wheats for leavened foodstuffs, and durum wheats for dry pastes and cracked grain aliments.

The quality requirements of each of the aliments listed above are multiple and often contrasting, particularly in regard to gluten strength and grain texture. Indeed, because this highly diversified demand, breeders have developed quality-specialized polyploid wheat cultivars, and this seems mandatory also in the case of *T. monococcum*. Generally speaking, at least three einkorn quality types are needed: (1) soft-textured with weak gluten (for biscuits, cookies, etc.), (2) soft-textured with strong gluten (for leavened bread, croissants, etc.) and (3) hard-textured with strong gluten (for macaroni, couscous, etc.). Soft-textured accessions of domesticated einkorn with either weak or strong gluten are available; hard-textured forms have been found within *boeoticum* germplasm. Breeding *T. monococcum* strains with shorter cooking time requirements and devoid of grain stickiness after boiling also seems important, so as to facilitate consumers' acceptance of whole-grain einkorn foodstuffs.

Einkorn's domestication for quality traits

Einkorn was domesticated in the Middle East some 10 000 years ago, together with or at about the same time as tetraploid wheats and barley (Harlan 1981; Nesbitt 1995). The quality of the wild progenitors of these cereals was poor, by modern standards, yet good enough for integrating the diet of prehistoric man and for grazing. Stands of wild *T. monococcum* are still grazed today (Jancovic 1975). Prehistoric man, haunted by early tooth decay, may have soon learned to appreciate einkorn's soft grain texture.

Grain size was most probably the first quality trait subjected to selection; the kernels of domesticated einkorns weigh about twice as much as those of wild strains (10 mg / seed) and are much less slender-shaped (Waines *et al.* 1987; Blanco *et al.* 1990). Einkorn's grain protein content diminished drastically as its grain yield augmented during the course of domestication; the grain protein content of subsp. *boeoticum* is about 6 percentage points higher than that of cultivated einkorns and about one and a half times greater than that of modern polyploid wheat cultivars (Harlan 1967; Villegas *et al.* 1968; Waines *et al.* 1987; Blanco *et al.* 1990). According to one report, the grain proteins of wild and domesticated einkorns contain nearly the same amount of lysine (Waines *et al.* 1987).

In prehistoric times, subsp. *boeoticum* and other wild wheats were harvested prior to plant maturity, to avoid losses due to rachis fragility. We know little about the ways in which the harvested material was subsequently processed and utilized. Most probably, the grains, still green and invested, were exposed to fire, separated from unwanted plant materials, and then eaten as whole kernels or ground into meal to be consumed in the form of porridge or as unleavened 'cakes' and flat bread

(Harlan 1967; Aykroyd and Doughty 1970). Presently, free-threshing polyploid wheats are harvested and processed in this way in parts of the Near East and North Africa to produce ‘frekeh’, i.e. green, parched wheat (Williams and El-Haramein 1985). Roasted grains are today consumed also in restricted areas of Central Europe (‘grünkorn’), Tunisia (‘zoumita’), and Tibet. Parboiled (burghul) and cooked wheat grains (‘trigo perlado’) are consumed in parts of the Middle East and Peru, respectively. Flat bread consumption is much more widespread, especially in North Africa, the Middle East and the Indian subcontinent (Faridi 1971).

Consumption of roasted wheat grains has been most important in ancient times, and may be of interest also in the future, particularly for einkorn and hulled wheats in general. Roasted grains are reasonably palatable, distinctly aromatic and not difficult to masticate; moreover, they keep well, are easy to carry, and can be eaten without further cooking. Also, roasting requires little fuel, prevents pregermination and destroys certain storage insects.

Domesticated *T. monococcum* and the other hulled wheats were consumed over thousands of years in the same ways as most other cereals, i.e. in the form of whole or cracked grains and as flat bread (Aykroyd and Doughty 1970). In general, the present trend towards the use of wholemeal (‘health’) aliments and unconventional foodstuffs is in line with these traditional forms of consumption. Recent records (Tellez Molina and Alonso Peña 1952; Schiemann 1956) indicate that einkorn has been utilized, to an unknown extent, also to produce leavened bread.

The variable and relatively low quality level of the old landraces of polyploid wheat grown at the beginning of this century suggests that the quality of wheats improved little from the time of early domestication to the advent of modern breeding methods. This is not surprising because, until recently, wheats were for the most part considered general purpose cereals, utilized to produce disparate foodstuffs, and often destined to fulfill contingent needs; bread, for instance, was generally made from wholemeal, often substantially diluted with other plant sources, and baking results were quite unpredictable (Aykroyd and Doughty 1970).

Diffusion and decline of einkorn

Cultivation of hulled wheats and barley diffused very rapidly from their centre of origin, probably as a result of and in parallel with the demographic expansion induced by their domestication (Cavalli-Sforza 1993). At the time of its greatest expansion, *T. monococcum* was grown from the Caucasus to the Iberian Peninsula, and from North Africa to Sweden. We know this for sure because einkorn fields could still be found and sampled throughout this area in modern times (Miège 1930; Vavilov 1957; Hjelmquist 1963; Vallega 1979; Perrino and Hammer 1982; Sakamoto 1987; Ohta and Furuta 1993; Szabó 1994). As a matter of fact, several hundred hectares of einkorn are still grown in southern France (Mt. Ventoux and Sault) and Turkey (Sakamoto 1967; Karagöz, this volume).

Widespread use of naked wheats and leavened bread commenced only in historical times, towards the end of the Roman kingdoms in Europe, probably earlier in other regions (Aykroyd and Doughty 1970; Harlan 1981). Prior to this, *T. monococcum, T. dicoccum*, and the culture they represented had the opportunity to dominate the agricultural landscape of a vast region for thousands of years and to diffuse very deeply, even into the remotest mountainous farmlands. Cultivation of hulled wheats subsequently declined, but at an extremely slow pace, probably because of strong cultural barriers and owing to a deep-rooted human preference for diversity; perhaps also because of the initially poor agronomic performance of free-threshing types outside of their centres of origin. Culinary habits and post-harvest processing techniques were presumably determinant in retarding the acceptance of novel foodstuffs and wheat types; it should be noted that grain roasting, for instance, destroys the enzymes for the necessary leavening process.

Recent uses of einkorn

In this century, the cultivated *T. monococcum* has been utilized mainly to feed monogastric animals (in the form of hulled grain), and to produce whole or cracked grain foodstuffs (i.e. 'puches' in Spain; burghul in Turkey; 'grünkorn', 'graupen', muesli, and porridge in Northern Europe); use of einkorn straw for roofing, binding, bedding, filling, hat-making and basketry has been frequently reported (Tellez Molina and Alonso Peña 1952; Schiemann 1948, 1956; Borojevic 1956; Vavilov 1957; Yamashita and Tanaka 1960; Hjelmquist 1963; Kuckuck 1970; Szabó 1981; Karagöz, this volume; Peña-Chocarro, this volume). Production of leavened bread (in Spain and ex-Yugoslavia), sweets (ex-Yugoslavia), dry pastes (Spain) and beer (Spain) has been recorded more rarely (Tellez Molina and Alonso Peña 1952; Borojevic 1956; Schiemann 1956). The end-use quality of these einkorn foodstuffs has been described very vaguely, if at all. Interestingly, in a treatise on Spanish wheats compiled around 1830, Lagasca and Clemente suggested that einkorn bread should be made utilizing recently harvested grain, warmer water and a greater amount of yeast; they also recommended to mix doughs energetically, and to ferment and bake them for a relatively short time (Tellez Molina and Alonso Peña 1952).

As far as we know, in this century einkorn has been grown only for home or local use, except in southern France (Mt. Ventoux and Sault), where a few quintals of rather expensive whole-grain foodstuffs (flake-like products, and precooked grains for soups, muesli and salads) are marketed as specialties.

Nutritional and medicinal value

The aminoacid composition of the grain proteins of domesticated einkorns, well as its nutritional adequacy and association with total seed protein content are analogous to those of durum and common wheats (Acquistucci *et al.* 1995), and the same holds true for the ratios between grain protein solubility fractions (D'Egidio *et al.* 1991). Interestingly, the seed protein content of domesticated *T. monococcum* seems to be somewhat higher than that of the polyploid wheats at comparable grain yield levels (Vallega 1979, 1992).

Einkorn flours contain 3-5 times more carotenoid compounds than those from modern polyploid wheat cultivars (D'Egidio *et al.* 1993). This may be of interest for improving egg yolk colour (Lanari and Mordenti 1983), and also in the field of bowel cancer prevention, owing to of the antioxidant properties of these substances. Einkorn's high carotenoid content does not necessarily entail a high amount of pro-vitamin A. Extended studies have in fact shown that this vitamin, earlier supposed to exist as carotene in wheat, occurs in minimal amounts, if at all (Fortmann and Joiner 1971).

Recent studies suggest that einkorn flours might be non-toxic in coeliac disease or markedly less toxic than the flours of polyploid wheats (Auricchio *et al.* 1982;

Favret *et al.* 1984, 1987; Frisoni *et al.* 1995), but the evidence so far collected is far from conclusive. In any case, owing to its simpler genetic make-up, einkorn is undoubtedly the ideal wheat species for identifying the toxic fractions responsible for coeliac disease (Frisoni *et al.* 1995); *T. urartu*, the donor of the A genome of durum and common wheat (Nakai 1983; Kerby and Kuspira 1988), is also of interest in this respect.

Monococcum grains are devoid of certain anti-nutritive substances, i.e. α–amylase inhibitors that are present in *T. urartu* Tum. and in the polyploid wheats (Vittozzi and Silano 1976); einkorn feeds and foodstuffs should therefore be easier to digest and assimilate, but this also awaits experimental demonstration.

Grain and milling characteristics

The grains of domesticated einkorns are typically flat, oblong and relatively small (15-35 mg/kernel) compared with those of modern polyploid cultivars (30-50 mg/kernel); grain and flour ash content are relatively high, as in *dicoccum* and spelt wheats; yellowberry incidence is extremely low (LeClerc 1918; Forlani 1954; Pavicevic 1975; Waines *et al.* 1987; Vallega 1992; D'Egidio *et al.* 1993). *Monococcum* germplasm collections have been found to be extremely variable in regard to most quality traits; moreover, recent studies indicate that types producing larger and more oval-shaped kernels, low in ash content, could be easily obtained utilizing the breeding experience gained with the polyploid wheats (Vallega 1992; D'Egidio *et al.* 1993).

The grain texture of domesticated einkorns is typically soft (Williams 1986; D'Egidio *et al.* 1993), and flour yields are high, possibly because *monococcum* grains lack the deep crease typical of polyploid wheats (D'Egidio *et al.* 1993). The flour particle size of some accessions is decidedly small (Schiemann 1948; Williams 1986; D'Egidio *et al.* 1993) and hence of interest for producing ice-cream cones, for instance. Einkorn flours have a strong yellowish tinge (Schiemann 1948; D'Egidio *et al.* 1993), a feature favoured in semolina of durum wheats, and in flours of common wheat consumed in the Near East. Einkorn's characteristic kernel shape and flour colour may prove useful as distinctive marketing traits.

Rheological and end-use quality

The end-use quality of domesticated einkorns has been studied little, and only with reference to leavened foodstuffs. Generally speaking, einkorn's bread-baking quality seems excellent: most accessions, including some having weak gluten and low protein content, produce loaves of decidedly high volume and with a relatively fine and uniform crumb texture; crumb colour is typically yellowish; crust colour and conformation are variable (Yamashita *et al.* 1957; D'Egidio and Vallega 1994; Borghi *et al.* this volume). Einkorn possessing rheological characteristics analogous to those sought for biscuit and cookie-making has also been identified (D'Egidio *et al.* 1993).

Einkorn's gluten strength, as estimated by mixograph, farinograph, alveograph and SDS sedimentation tests, is extremely variable among accessions, and analogous to that of wild einkorns (Blanco *et al.* 1990; D'Egidio *et al.* 1993; Borghi *et al.* this volume). Interestingly, einkorn gluten seems to be stronger in regard to gas retention capacity than with respect to mixing requirements. Einkorn gluten also seems to have a relatively low water retention capacity and a marked tendency to retain appreciable amounts of non-proteagenous materials (D'Egidio *et al.* 1993; D'Egidio and Vallega 1994).

T. monococcum doughs are reportedly sticky, difficult to handle and to model (Yamashita *et al.* 1957; D'Egidio *et al.* 1993; D'Egidio and Vallega 1994). Thus far, this is the only important negative quality trait attributed to einkorn; investigating this aspect seems to be a priority because sticky doughs are extremely difficult to process mechanically.

Concluding remarks

Einkorn crops are rapidly vanishing and so are many of the traditions associated with their usage. This tendency is not necessarily irreversible. Indeed, various researchers opine that, owing to its diploid nature, *T. monococcum* may very well be the wheat species best suited for satisfying the multitude of continuously changing demands posed by modern industries and consumers (Waines 1983; Vallega 1992; D'Egidio *et al.* 1993). Breeding commercial cultivars of einkorn should also allow us to rebuild part of einkorn's former genetic variability and favour the use of some of the food stuffs traditionally made with hulled wheats. Needless to say, research on *T. monococcum* is also expected to augment the amount of genetic variability available for the improvement of polyploid wheat species (Vallega 1992). Presently, the future of *T. monococcum* as a crop seems to rely almost entirely on a more or less accidental discovery (i.e. in the fields of coeliac disease, mutation research, hybrid seed production, etc.), but its prospects could change rapidly if public funding were made available to conduct reasonably sized breeding programmes and more systematic variability surveys.

References

Acquistucci, R., M.G. D'Egidio and V. Vallega. 1995. Amino acid composition of selected strains of diploid wheat, *Triticum monococcum* L. Cereal Chem. 72:213-216.

Auricchio, S., G. De Ritis, M. De Vincenzi, P. Occorsio and V. Silano. 1982. Effects of gliadin-derived peptides from bread and durum wheats on small intestine cultures from rat fetus and coeliac children. Pediatr. Res. 16:1004-1010.

Aykroyd, W.R. and J. Doughty. 1970. Wheat in human nutrition. FAO Nutritional Studies, Rome, Italy, p. 123.

Blanco, A., G. Giorgi, P. Perrino and R. Simeone. 1990. Genetic resources and breeding for improved quality in durum wheat. [In Italian]. Agricoltura e ricerca 12:41-58.

Borojevic, S. 1956. A note about the "New dates for recent cultivation of *Triticum monococcum* and *Triticum dicoccum* in Yugoslavia". W.I.S. 4:l.

Cavalli-Sforza, L., P. Menozzi and A. Piazza. 1993. Demic expansions and evolution. Science 259:639-646.

D'Egidio, M.G., S. Nardi and V. Vallega. 1991. Quality of diploid wheat, *Triticum monococcum* L. Pp. 205-208 *in* Proc. Cereals Intern. Conf., Brisbane (D.J. Martin and C.W. Wrigley, eds.). Royal Australian Chemical Institute, Parkville, Australia.

D'Egidio, M.G. and V. Vallega. 1994. Bread baking and dough mixing quality of diploid wheat, *Triticum monococcum* L. Italian Food and Beverage Technology 4:13-17.

D'Egidio, M.G., S. Nardi and V. Vallega. 1993. Grain, flour and dough characteristics of selected strains of diploid wheat, *Triticum monococcum* L. Cereal Chem. 70:298-303.

Dhaliwal, H.S. 1977. Origin of *Triticum monococcum* L. W.I.S. 44:14-17

Faridi, H. 1971. Flat bread. Pp. 457-506 *in* Wheat Chemistry and Technology (Y. Pomeranz, ed.). Am. Assoc. Cereal Chem., St. Paul, MN.

Favret, E.A., J.L. Cervetto, R.M. Solari, A. Bolondi, H. Nuñez, L.E. Manghers, A. Boffi and J.P. Ortiz. 1984. Influence of wheat ploidy on the induction of coeliac disease. [In Spanish]. P. 116 *in* Proc. Seventh Meeting Latin-American Soc. Pediatr. Gastroenterology and Nutrition, Buenos Aires, Arg.

Favret, E.A., J.L. Cervetto, R. Solari, A. Bolondi, L. Manghers, A. Boffi and J. Ortiz. 1987. Comparative effect of diploid, tetraploid and hexaploid wheat on the small intestine of coeliac patients. [In Spanish]. P. 13 *in* Proc. Eight Meeting Latin-American Soc. Pediatr. Gastroenterology and Nutrition, San Paolo, Brazil.

Filatenko, A.A. and U.K. Kurkiev. 1975. A new species - *Triticum sinskajae* A. Filat. et Kurk. [In Russian]. Trudi po Prikladnoi Botanike, Genetike i Selektsii 54:239-241.

Forlani, R. 1954. Wheat. [In Italian]. Monogr. Genet. Agr. 1:1-305. Pavia, Italy.

Fortmann, K.L. and R.R. Joiner. 1971. Wheat pigments and flour colour. Pp. 493-522 *in* Wheat Chemistry and Technology (Y. Pomeranz, ed.). Am. Assoc. Cereal Chem., St. Paul, MN.

Frisoni, M., V. Vallega, M.G. D'Egidio, G.R. Corazza and G. Gasbarrini. 1995. *In vitro* toxicity of gluten of three wheat species on the intestinal mucosa of coeliac patients. P. 8 *in* Abstr. ICC Conf. "The role of cereals in future nutrition". Vienna, Austria.

Harlan, J.R. 1967. A wild wheat harvest in Turkey. Archeology 20:197-201.

Harlan, J.R. 1981. The early history of wheat: earliest traces to the sack of Rome. Pp. 1-19 *in* Wheat Science - Today and Tomorrow (L.T. Evans and W.J. Peacock, eds.). Cambridge University Press, Cambridge, U.K.

Hjelmquist, H. 1963. Zur Geschichte des Einkorns und des Emmers in Schweden. [In German]. Botaniser 116:487-494.

Jankovic, M. 1975. Properties of the local Yugoslav wheat population. Pp. 145-152 *in* Proc. Second Intern. Winter Wheat Conf., Zagreb, Yugoslavia.

Johnson, V.A. and P.J. Mattern 1975. Improvement of the nutritional quality of wheat through increased protein content and improved amino acid balance. Report of research findings 1 Jan. 1973 - 3 Mar. 1975. USDA-AID, Washinton D.C. 191 pp.

Kantaki, K. and K. Noda. 1988. Glutinous (waxy) endosperm starch mutant *of Triticum monococcum* L. Jpn. J. Breed. 38:423-427.

Kerby, K. and J. Kuspira. 1988. The philogeny of the polyploid wheats, *Triticum aestivum* (bread wheat) and *Triticum turgidum* (macaroni wheat). Genome 30:722-737.

Kuckuck H. 1970. Primitive wheats. Pp. 249-266 *in* Genetic Resources in Plants - Their Exploration and Conservation (O.H. Frankel and E. Bennett, eds.). Blackwell Scientific Publications, Oxford and Edinburgh.

Kurkiev, U.K. and A.A. Filatenko. 1981. diploid naked-grained wheat. [In Russian]. Pages 116-120 *in* Botan. i genet. resursy flory Dagestana. Markhala, U.S.S.R

Lanari, D. and A. Mordenti. 1983. Il mais nell'alimentazione dei monogastrici. [In Italian]. Pp. 514-540 *in* Il mais (M. Bonsembiante, ed.). Liviana editrice, Padova, Italy.

Le Clerc, J.A., L.H. Bailey and H.L. Wessling. 1918. Milling and baking tests of Einkorn, emmer, spelt and polish wheat. J. Am. Soc. Agron. 10:215-217.

Miège, E. 1930. Contribution a l'étude morphologique des blés. étude de quelques caracteres secondaires de l'épi. Annales Direction Générale de l'Agriculture, Rabat, Vol. I, 111 p.

Millet, E. 1988. Grain weight is largely determined by genes for spike morphology. Pp. 593-596 *in* Proc. Seventh Intern. Wheat Genet. Symp., Cambridge, England (T.E. Miller and R.D.M. Koebner, eds.). Bath Press, Bath, Avon, UK.

Multani, D.S., S.K. Sharma, H.S. Dhaliwal and K.S. Gill. 1992. Inheritance of induced morphological mutants in *Triticum monococcum* L. Plant Breeding 109:259-262.

Nakai, Y. 1983. Morphological characteristics and izozyme variation of esterase in wild wheats collected from Anatolia, Turkey. Seiken Siho 31:1-13.

Nesbitt, M. 1995. Plants and people in ancient Anatolia. Biblical Archeologist 58:67-81.

Ohta, S. and Y. Furuta. 1993. A report of the wheat field research in Yugoslavia. Wheat Inf. Service 76:39-42.

Pavicevic, L. 1975. Diploid and tetraploid wheats in Montenegro and neighboring regions. Acta Biol. 7:3-8.

Perrino, P. and K. Hammer, K. 1982. *Triticum monococcum* L. and *T. dicoccum* Schübler (syn. of *T. dicoccon* Schrank.) are still cultivated in Italy. Genet. Agric. 36:343-352.

Sakamoto, S. 1987. Origin and phylogenetic differentiation of cereals in Southwest Eurasia. Pp. 1-45 *in* Domesticated Plants and Animals of the Southwest Eurasian Agro-pastoral Complex (Y. Yani and S. Sakamoto, eds.). Kyoto University.

Schiemann, E. 1948. Wheat, rye, barley: systematics, history and utilization. [In German]. G. Fischer Verlag, Jena, Germany, 102 p.

Schiemann, E. 1956. New dates for recent cultivation of *Triticum monococcum and Triticum dicoccum* in Yugoslavia. W.I.S. 3:1-3.

Szabó, A.T. 1981. Problems of genetic erosion in Transylvania, Romania. Kulturpflanze 29:47-62

Szabó, A.T., E. Nagytoh and T. Lelley. 1994. Studies on Triticeae IX. Strategies for the enhancement of diploid wheats (*Triticum* sect. Urartu and sect. Monococcum). Amplicon 4:4-15.

Tellez Molina, R. and M. Alonso Peña. 1952. Los trigos de la "Ceres Hispanica" de Lagasca y Clemente. [In Spanish]. I.N.I.A., Madrid, 516 p.

Vallega, V. 1978. Search of useful genetic characters in diploid *Triticum* ssp. Pp. 156-162 *in* Proc. Int. Wheat Genet. Symp., 5th (S. Ramanuyan, ed.). Indian Society of Genetics and Plant Breeding, Indian Agricultural Research Institute, New Delhi, India.

Vallega, V. 1979. Field performance of varieties of *Triticum monococcum*, *T. durum*, and *Hordeum vulgare* grown at two locations. Genet. Agric. 33:363-370.

Vallega, V. 1991. *Triticum monococcum*. Ann. Wheat Newsl. 37:74-77.

Vallega, V. 1992. Agronomical performance and breeding value of selected strains of diploid wheat, *Triticum monococcum*. Euphytica 61:13-23.

Vavilov, N.I. 1957. World resources of cereals, leguminous seed crops and flax, and their utilization in plant breeding. Acad. Sci. U.S.S.R., Moscow, 442 p.

Villegas, E., C.E. McDonald and K.A. Gilles. 1968. Variability in the lysine content of wheat, rye and triticale proteins. CIMMYT Res. Bull. No. 10. CIMMYT, Mexico.

Vittozzi, L. and V. Silano. 1976. The phylogenesis of protein α-amylase inhibitors from wheat seed and the speciation of polyploid wheats. Theor. Appl. Genet. 48:279-284.

Waines, J.G. 1983. Genetic resources in diploid wheats: the case for diploid commercial wheats. Pp. 115-122 *in* Proc. Int. Wheat Genet. Symp., 6th. (S. Sakamoto, ed.) Plant Germplasm Institute, Kyoto University, Kyoto.

Waines, J.G., B. Ehdaie and D. Barnhart. 1987. Variability in *Triticum* and *Aegilops* species for seed characteristics. Genome 29:41-46.

Williams, P.C. 1986. The influence of chromosome number and species on wheat hardness. Cereal Chem. 63:56-58.

Williams, P.C. and F.J. El-Haramein. 1985. Frekeh making in Syria - a small but significant local industry. Raquis 4:25-27.

Yamashita, K., M. Tanaka and M. Koyama. 1957. Study on the flour quality of *Triticum* and *Aegilops*. Seiken Ziho 11:20-26.

Yamashita, K. and M. Tanaka. 1960. Exploration results of the BMUK 1959. W.I.S 11:26-32.

The hulled wheats industry: present developments and impact on genetic resources conservation

L.F. D'Antuono[1] and R. Bravi[2]

[1] Department of Agronomy, University of Bologna, Bologna, Italy
[2] Ente Nazionale Sementi Elette, Bologna, Italy

Introduction

Over the last few years we have been witnessing at the fact that traditions and habits of our culture are being more and more associated to the launching of 'new' products. This is also true in the case of agricultural products.

The case of farro (Italian name for hulled wheats) in Italy represents this situation. A staple food in the Romans' diet, farro was progressively abandoned in favour of white, easily threshed bread wheat. As a result, its cultivation survived only in marginal mountain areas, mainly as a fodder crop. Its use for human food was almost completely unknown by the majority of people until about 15 years ago, although it remained well established in the local tradition of two production areas (Garfagnana and Valnerina areas in Central Italy).

This rather static situation started to change as a consequence of several factors: the spreading of general welfare that increased the consumption of specialty foods, the growing attention of the public towards old traditions and the search for 'naturalness'' a concept with which the image of farro became more and more associated.

To this regard, it is interesting to point out that an important role in promoting the use of spelt was played by non-Italian farmers, involved in the 'green' movement, who had encouraged their cultivation in Central Italy.

Today farro production is greatly affected by rapid changes that have been occurring in the market over the last few years, which are far from stable. Components related to traditional and modern life have an impact on this fluid process and it is rather difficult to predict how these forces contribute to the conservation and use of farro genetic resources.

In view of these facts, the need was clearly felt for more information on trends of crop exploitation to foresee possible new uses and on-farm conservation initiatives regarding native landraces. A survey was therefore carried out by submitting a questionnaire aimed at obtaining information on the cultivated genotypes, cropping techniques, areas in cultivation, on-farm transformations and kinds of products, to those involved in farro production: farmers, manufacturers and traders. Most of those who gave an answer were then contacted and visited to obtain more direct details on main steps of the farro production chain.

Cultivation areas and genetic material

Three hulled wheat species are currently indicated as farro in Italy: einkorn wheat (*Triticum monococcum* L.), emmer wheat (*T. dicoccum* Schubler) and spelt (*T. spelta* L.). Only the last two, however, are presently of commercial interest in the country.

Interesting germplasm material of emmer has been cultivated since time immemorial in all the Italian traditional farro-growing areas: Garfagnana, upper

Valnerina and Leonessa plateau, the upper valleys of the Tronto and Aniene rivers, the upper Molise region, the Daunian and the Basilicata Apennine regions (Perrino and Hammer 1982, 1984; D'Antuono 1989, 1994; D'Antuono and Lucidi 1989; D'Antuono *et al.* 1993; D'Antuono and Pavoni 1993; Mariani 1994).

Spelt was introduced about 20 years ago by German and Swiss amateurs, mainly in restricted stations of central Italy, with the two varieties 'Altgold Rotkorn' and 'Roquin'.

The expansion of hulled wheats cultivation genetated a rather intense exchange of self-reproduced seeds of both native emmer landraces and spelt varieties that did not occur in the past. Seeds of different origin were also mixed by new producers and these mixtures spread very quickly in several parts of central Italy. As a result of this process we could identify the following types of cultivations in Italy:

- native emmer landraces in traditional areas
- native emmer landraces outside traditional areas
- spelt varieties, often multiplied on-farm
- mixtures of genotypes that often include both emmer and spelt.

The raw material: traditional and modern uses and processing

Harvest

The traditional sequence of reaping and threshing is today completely abandoned, except in some marginal areas. Modern machinery (combines) used for wheat are easily adapted to harvest hulled wheats, with a minimum of experience.

Cleaning the product

The product from the combine generally cannot be further processed without additional manipulation, as it is normally contaminated by straw residuals, soil and weed seeds (particularly when herbicides are not used). As it cannot be marketed, preliminary selection, mainly by sieving and winnowing, is therefore needed; this operation is done both on farm or in small-scale plants.

Dehulling

Clean, whole spikelets represent the real, primary raw material which will undergo the most typical farro processing: the removal of the glumes. Although basically simple, this procedure still represents the major bottleneck of farro production and processing. As a matter of fact until a few years ago, the kind of end-product obtained (Table 1) in different areas was strictly dependent on the way this operation was performed.

Table 1. Steps of farro dehulling in two traditional areas compared with an updated scheme.

Scheme	Initial material	Process	End-product
Garfagnana	whole spikelets	stone dehulling	pearled grain
Valnerina	whole spikelets	mill crushing	'farricello'
Modern	whole spikelets	dehulling machine	whole grain

In any case, but particularly in the first two processing schemes, a certain amount of flour is also produced, as primary output or as a product of the subsequent milling of the wastes. In the traditional process, flour was therefore only a by-product, mostly used to feed animals.

The use of primary products of dehulling

All three end-products of the dehulling process are still being used today. Traditionally, in Garfagnana, in neighbouring Lunigiana and in the provinces of Lucca and La Spezia (Liguria region), pearled grain of the local emmer wheat population was used in the preparation of soups (e.g. the 'mesciua' of Liguria) and salty cakes. At present, pearled grain is also obtained outside Garfagnana and it is sold packed in different ways or by weight.

In central Italy (Umbria and Lazio), soups were prepared with coarsely broken seed (farricello), whereas a limited amount of whole meal was mixed with durum wheat at a rate of about 1:3 and employed for the preparation of 'sagne', a kind of home-made pasta. The further milling of farricello gives a kind of semolina, also resulting as a by-product of dehulling, mainly used for the preparation of gruel ('polenta di farro').

Whole grain is a relatively new product, used more or less in the same way as pearled grain. Vacuum packaging is the most common way in a modern commercialization of all the above-mentioned products.

Besides being sold as pure products, pearled, whole grain and farricello are often marketed in mixture as basic ingredients for soups, together with other cereals and dried legumes. More elaborate preparations include dehydrated vegetables (tomato, onion, celery. etc.) along with farro. A pre-cooked mix of farro and legumes is a more recent release in the market

'Pop farro' and other similar breakfast products are also prepared from whole grain.

Products from farro flour

Although meal is the less traditional among primary farro products, it has certainly given a strong impulse towards the manufacturing of new products and to the widening of the market.

Several formats of pasta-like products (in the Italian legislation the term 'pasta' is reserved exclusively for 100% durum wheat products) are prepared with both pure farro flour and mixtures with durum wheat meal.

A similar situation exists for cookies, where the other component of meal blends is soft wheat. The technologies of biscuit production vary a lot, ranging from conventional industrial procedures (use of hydrogenated fats, natural-like flavours, etc.) to specialized, small-scale processing schemes, in which only selected natural ingredients are used, resulting in rather unconventional and really original products.

The production of farro bread has started in northern and central Italy, but is at a very initial stage, since the market of perishable products is not yet mature. Farro pastry and pies are being manufactured on a very small scale as well. Kinds of pizza bases, packed in controlled atmosphere, are newer and more technologically advanced products with an intermediate shelf-life. Whole farro meal is available for domestic use as well.

The market

The farro market is not yet stable in Italy. In fact, wide fluctuations from year to year usually occur, causing cyclic surplus and shortage of raw material. Seed prices on the free market are therefore fluctuating as well. However, the amount of grain employed for all of the above-mentioned uses can be roughly estimated as 1200-1500 t/year and indicated as ‘user-linked’. This amount refers to the amount of product that satisfies the actual market demand. On some occasions, an almost equivalent amount has been produced, without any preliminary estimation of the market potential, which has caused a heavy negative impact on price stability and quality.

Almost all those involved in farro production agree in forecasting an expansion of the market, although its instability makes the distinction between trend and cyclic fluctuations a difficult task.

The players who increase farro’s value

Farmers

Without any doubt farmers of two traditional areas of production (Valnerina and Garfagnana) have been the real actors of farro resumption. Today, the role of farmers is very different, according to the way they organize the production. Farmers who sell raw hulled grain directly on the market are probably a minority. In fact, their earnings are conditioned by fluctuating prices and they cannot take advantage of any added value of the product. The situation is slightly better for those who make preliminary agreements with the purchasers.

Many small-scale producers try to be self sufficient for the processing, so that they can sell the on-farm packed whole grain, farricello or meal with their own label. On the other hand, some of them, although having their own commercial label, commit all post-harvest operations to third parties.

Other growers are also involved in the commercialization of more elaborate products such as pasta or cookies, the manufacturing of which is, however, committed to external specialized plants. In this case, they occupy an intermediate position between farmers themselves and traders. Italian laws require farmers engaged in this activity to apply for a special licence to carry out this commerce.

Whatever their activity, it is important to stress here the important role played by small-scale farmers in promoting of innovative farro products.

Manufacturers

This is a quite a heterogeneous category. The basic processing of farro is dehulling. Until a few years ago this process was performed in non-specialized industrial plants, mainly in northern Italy. Recently, intermediate-scale plants, more specialized in farro, started to operate in central Italy. Milling is generally done in non-specialized plants.

Producers of more elaborate end-products are normally independent from dehulling plants. In general, these operators are not specialized in farro processing but they do successfully apply to the farro chain their knowledge and expertise. Probably the most original farro products are those made by operators who are in close contact with advanced farmers.

Until recently most transformation plants worked on behalf of third parties (farmers or traders). Because of the increasing popularity of farro, a growing number of them are now commercializing the product with their own trademark.

Small scale traders

The only operation that traders sometimes do on their own is packaging. Otherwise they buy and sell the product obtained at different stages of the processing. With respect to the trademark, the situation is similar to the one explained for manufacturers, with a growing number of traders operating with their own label.

The big food industry

Farro is a fashion nowadays. As a consequence, some multinational industries have become interested in it. Pasta, packed seed, crackers and a frozen soup with farro and legumes are already being marketed by some famous firms. However, for the big industry, farro still represents more an effective tool of advertisement, based on the 'image of naturalness' attached to it, rather than a relevant source of income. It is interesting to note that, in fact, the quantities of raw material absorbed by these industries probably amount to less than one-fifth of the global market.

Public-supported players

The activity of the above-mentioned subjects is more or less self supported, being based on the equilibrium of market demand and costs of production. However, the potential of farro for solving agricultural problems of disadvantaged areas has been overestimated sometimes and used as an opportunity to set up development projects entirely based on public support. In this situation, the equilibrium with the market has obviously failed to hold.

A particularly significant case occurred in central Italy, where a big plant for farro processing, the potential of which largely exceeded twice the present amount of user-oriented farro production, was built entirely with public funds. In the area there was no tradition of farro production and no preliminary activity was set up. The commitment to farro farmers for an amount equivalent to the total national production caused a surplus of product that had to be sold at a low price during a relatively long period of time.

Quality of raw material

Farro quality can be distinguished on the basis of the following aspects: technological, commercial, dietary and health qualities.

An easy definition of any of them conflicts with the very limited amount of available knowledge. Moreover, it is clear that the term farro is too generic, indicating three different species, each with its own variability, also subject to the influence of environment. As happens for all other agricultural crops, any further investigation intended to be scientifically sound should therefore refer to well-defined species, genotypes and site conditions.

Technological quality

The wide range of products manufactured from farro could suggest the need for well-differentiated properties of raw material. However, the definition of farro's technological characters and their variability is at an initial stage.

The native Italian populations of emmer differ with respect to several characteristics (D’Antuono and Pavoni, 1993 1995), among which the observed variation of endosperm structure seems to be connected with growth habit. In fact, winter and alternative landraces differ for having floury and vitreous endosperm respectively. However, this character is also subject to environmental influences. In traditional processing it is well known how only the vitreous types yield good ‘farricello’ and semolina, whereas floury types are suited for the production of pearled grain. On the contrary, these differences were not appreciated at all in the manufacture of more elaborate products, such as pasta, cookies etc., until a few years ago. The situation is not still substantially changed, although manufacturers have started to distinguish a ‘soft’ emmer type (floury), often confused with spelt, from a ‘hard’ type (vitreous), with slightly different optimal utilization. Unfortunately, the present structure of the production, characterized by a high level of confusion in the genetic material, cannot guarantee the supply of one type or the other.

Preliminary technological analyses of native emmer landraces (D'Antuono and Pavoni 1995) yielded average values of W=30.3 x 10-4 J, P/L=1.29 and falling number=432s, indicating rather poor quality, at least taking as a reference the commonly accepted standards of wheats. The variation among landraces was very low as well. Other results (Cubadda and Marconi 1994) seem to indicate slightly different characteristics, but the uncertainty about the original material excludes any possibility of generalization.

In any case, the detected analytical traits are typical of flours yielding very weak dough, with scarce aptitude to leaven. The complex of these technological characters is well represented by the crumbling texture of the present farro products and their easy breaking when handled without care. These traits can be well viewed as fundamental elements of typicality with respect to other cereals: as a matter of fact, farro producers and manufacturers never complained about them. Appropriate mixing with other meals can effectively attenuate the excess of friability.

Finally, it must be stressed how, at present, the milling process is rather empirical and that whole meal only is being almost exclusively used. It is therefore likely that the improvement of milling technologies and differential sieving could contribute to widening the range of flour rheological and technological characteristics.

Commercial quality

This is probably a weak point of the whole production chain. Despite the popularity of farro, the market is substantially immature: the demand is strongly influenced by fashion and the discrimination capacity of the consumer is still scarce. These facts, coupled with the absolute lack of marketing regulations, make commercial frauds rather frequent. Very common, for example, is the case of packed seed products, in which emmer is mixed with other cereals.

Besides these facts, the low commercial standards often depend on the very confused situation of the cultivated material. Taking as an example a simple article, such as ‘pop farro’, the difference between the rather uniform size and texture of the product obtained from a sufficiently homogeneous native population and the heterogeneity determined by the use of mixed seed can be easily appreciated.

Dietary and health quality

Almost everything and its opposite have been said on farro dietary qualities, whereas almost none has been experimentally or analytically verified. From the scientific side, therefore, skepticism dominates, despite folk knowledge which indicates that emmer wheats have positive effects on intestinal regulation and are useful components of the energy part of the diet for young animals. The constancy with which common ideas recur in almost all the traditional areas of emmer cultivation should stimulate an interest in more critical investigation.

Recent studies have focused mainly on protein content characterization (Galterio *et al.* 1993; Perrino *et al.* 1993; Cubadda and Marconi 1994; Piergiovanni and Bianco 1994), indicating interesting variability among populations. However, the results were somewhat contradictory, confirming once more the need for having proper identifications of the material used and more information on the environmental effects on the quality of the crop. Furthermore, a better understanding of the supposed healthy properties of farro, however, could come from the analysis of secondary metabolites such as fibres, gums, mucilage, etc., on which further studies should perhaps also be carried out.

In any case, farro is already used in some practices of unconventional medicine (Italiano and De Pasquale 1994; Strehlow *et al.* 1994) and as a complementary health food by Italian dietary centres in the treatment of obesity-affected patients.

Other healthy aspects depend on the strong connection of farro to its image of a biological product. A relevant percentage of the national product is biologically grown and certified by some of the officially recognized associations. The farro from traditional areas, even if not certified, is virtually biological, since no chemicals have ever been used by farmers for its cultivation.

Preliminary synthesis and indications

At present, farro production is in a rather dynamic phase, with the co-existence of traditional and new factors both determining its growth . A preliminary synthesis of the overall situation will therefore help to better focus on the possible impact of utilization on the evolution and conservation of its genetic resources.

The initial situation

The following traits characterized the initial phase of resumption of *T. dicoccum* cultivation in Italy:

- farro production was addressed to a well-differentiated niche market
- farmers were actively involved in transformation and commercialization. Some of them enjoyed a very good interaction with small-scale manufacturers, a situation that normally does not occur for mass production
- the production volume was perfectly suited to processing in small-scale plants
- the production was well calibrated to the demand; avoiding any surplus was a key point to keep satisfactory income levels
- in the beginning, raw material sources were well individuated: a few spelt varieties from abroad and the local native emmer wheat populations, mostly cultivated within the limits of traditional areas
- the above-mentioned aspects are not substantially changed in traditional production areas.

The present

Many traits of a transitional phase characterize the market and can be summarized as follows:

- an evolution towards a wider market and use for farro is probably taking place; the cultivation is expanding outside traditional areas
- the commercial and industrial sectors are more and more interested in hulled wheats
- the supply of raw material from the traditional areas probably cannot meet these new needs
- the expansion of farro consumption is linked to fashion, but the level of public information and awareness is still rather low
- public support obtained by some subjects determined the production of surplus material, with a consequent lowering of prices and commercial quality; the market is therefore unstable from year to year
- demand for a constant supply of seed of known characteristics is building up
- the genotype situation is extremely confused because of the mixing of seed that has frequently occurred; spelt cultivars and emmer landraces in the native areas are the only propagation material with definite characteristics
- the lack of analytical information and the absence of any rule do not allow discrimination between products of different quality.

The future

Future developments will depend a lot on the size that the market will reach; at present this is not an easy guess. However, basic economic principles and similarities to what has happened for other productions allow to envisage the possible following evolution:

- farro will have a tendency to become a mass production and leave the niche market of specialty foods
- traders and manufacturers will occupy an increasing share of the market; most of the transformation processes will occur outside of agricultural farms
- prices, at least the ones of raw material, will go down
- marginal farmers will find it more and more difficult to maintain the profitability of the crop, unless they succeed in differentiating it from mass production
- the farro market could evolve into two segments: (a) the production from native areas, based on the use of landraces, in which farmers could take advantage of the added value through a partial control of the transformation processes; (b) the wider scale production, which should rely on raw material at low cost and with constant quality characters
- differentiated genotypes should be required for these two different markets
- basic quality characters should be more and more appreciated by purchasers.

In any case, further evolution will probably depend a lot on the qualification of raw material, a key factor of which seems to be the role of the genotype employed. The proper utilization of hulled wheats genetic resources therefore represents a priority in any future strategy.

Conservation and economic exploitation

Perspectives for a 'farro' seed industry

Seed production and commercialization are regulated by law in the European Union. Historically, the introduction of a legislation on seed trade was promoted by the professional organizations of seed producers. The basic element of the European seed legislation is the compulsory registration of varieties in the EU Variety Catalogue, in force for all the major agricultural crops. Commercialization is allowed only for seeds of registered cultivars, subject to official certification and control. To obtain registration, varieties must adhere to the requisites of distinguishability, uniformity and stability and represent real improvement with respect to the existing ones.

The regulation of seed production had a strong effect on the increase in average yields of major crops, in a period in which self-sufficiency for food was not reached in most parts of the world. In fact, it encouraged the use of improved genotypes and high-quality seed with good germinability, specific and varietal purity, seedborne disease resistance, etc. However, beyond the advantages for farmers and food supply, the spreading of improved varieties was also certainly promoted by the protection of breeders' rights.

Among hulled wheat species, a varietal register has been established only for spelt. Seed production and trade of this species are therefore subject to official legislation. Four varieties are registered in the European catalogue and a few others are available from third ??countries. Commercial spelt cultivation is almost exclusively based on selected varieties.

The situation is very different for *T. dicoccum*. In fact, not only does an official emmer varietal catalogue not exist, but the species is not even mentioned in the more general regulation of commercial seed. Seed exchanges are therefore characterized by a total absence of rules and reference parameters.

The cultivation of this species at a commercial scale is exclusively based on the use of local populations, the seeds of which sometimes have been badly mixed outside traditional areas. Its expansion in recent years stimulated the interest of breeders (Perrino *et al.* 1991, 1993; Bozzini *et al.* 1994) and perhaps the first selected varieties could be available in short times. However, at present, their registration is not possible and therefore only public-supported breeders can be interested in their commercialization.

The institution of a compulsory register for emmer has been advised (Castagna *et al.* 1993, 1994). However, for all agricultural crops the introduction of improved varieties protected by law almost invariably determined the loss of local populations: it is very likely that this could also happen for emmer. The basic present legislation therefore does not seem suited to guarantee the matching of breeding with the on-farm preservation of local landraces.

The institution of a voluntary register is also possible. That would allow the evaluation and classification of the propagation material presently available (local populations, landraces, breeding lines) and the certification of selected varieties, whenever supported by adequate market demand. In the long term it seems that the institution of any kind of official register according to the present rules would probably exclude from certification the local populations, because of the likely lack of homogeneity of morphological characters.

At present, however, the aspects of plant breeding connected with the assurance of food supply are perhaps less important than in the past, at least in industrialized countries. In particular, specialist niche crops like farro do not play any function in solving global nutritional problems. In the case of emmer, varietal certification would therefore have little meaning as a means to improve yields and its function would be reduced to the protection of breeders' rights.

Lately the interest in the use of old and local types of farro has grown among farmers and amateurs. The present seed legislation *de facto* excludes the possibility of certifying this genetic material, the use of which, besides not interfering with the market of selected varieties, could contribute to the agricultural differentiation and on-farm preservation of genetic diversity. A possibility to create the juridical basis for the commercial exploitation of local genetic resources within an improved seed legislation may perhaps come from the updating and extension of the current rules of ecotype certification.

This possibility presently applies only to some fodder species, like lucerne, clovers, etc. Ecotypes are populations that evolved in equilibrium with the environment and are therefore particularly suited to the conditions of native areas. They are not subject to artificial selection and their genetic equilibrium is dependent on local climate and soil. Base seed must therefore be obtained in selected farms within the native areas and cannot be further multiplied outside these limits.

Certification of ecotypes is subject to criticism, since the lack of genealogical control, leaving space for commercial frauds, cannot guarantee the main goal of the ecotype legislation, which is to increase the value of local material. Ecotype certification is no longer allowed in some EU countries. In Italy, the possibility of certifying fodder crops ecotypes is going to be abolished in favour of selected varieties by the year 2003.

However, to meet the needs of preservation of local resources, the European legislation (dir. 66/401) introduced the possibility of certification of "local varieties" on the basis of appropriate genealogical seed control. The main steps of this process are: (1) the identification of local varieties; (2) the identification of farmers who have cultivated them for a long time and could produce base seed; (3) the establishment of effective genealogical control of base seed production. The opportunities of this directive are still largely unexploited.

The case of Italian emmer landraces seems quite similar to that of fodder ecotypes. In fact, they are adapted valuable material, on which most of the present production is based. Increasing their value would require the elimination of all the mixed material presently on the market. The native cultivation areas are few and well known and the identification of farms for base seed production should also be easy.

The extension of the legislation on local varieties to hulled wheats could therefore be an effective way to increase the value of local emmer populations as well as of the few einkorn and spelt landraces still grown in Europe. Coupled with the introduction of an official register, it would allow the full exploitation of genetic resources without limiting any potential economic subject.

Other conservation opportunities

The EU regulation 2078/92, among other actions, includes financial support for the cultivation and multiplication of crops suited to local conditions and threatened with genetic erosion. The local administrations must establish the appropriate criteria for their individuation. The opportunities given by this regulation, however, are presently mainly exploited for the parts dealing with the support to biological agriculture, but are scarcely applied in the field of genetic resources conservation.

The regulation 2081/92 deals with the denomination of origin of agricultural and food products. It is substantially aimed at protecting typical productions from the improper use of geographical specifications. Increasing the value of local products is not pursued through direct financial support, but by means of the certification of their origin and ways of production. The IGP label (protected geographic origin) certifies the production or transformation of the crop in a certain region, whereas DOP (protected denomination origin) requires that both production and transformation are carried out in a specific area. Neither of these two specification refers directly to the use of local genotypes. However, the use of a local landrace can be explicitly mentioned in the documentation for obtaining the origin denomination. This regulation leaves the producer free to decide the rules to adopt and seems therefore more suited than the previous one to stimulate self-supporting initiatives.

Regulation 2082/92 is somewhat complementary to the previous one. In this case, in fact, the specificity certification cannot be based on the geographical origin, but must be founded on a complex of intrinsic characteristics of both raw materials and end-products. It could apply to the protection of hulled wheats genetic resources when distinctive traits of end-products are determined by genetically determined quality of raw material.

In any case it must be stressed how the application of EU regulations is sometimes bureaucratically cumbersome. It generally requires the assistance of consultants, with consequent additional costs for farmers. It could therefore represent a useful tool for hulled wheats only if viewed as an honest, complementary marketing tool aimed at increasing information and public awareness on the value of local products.

Conclusions

As can be seen from this review, the utilization of farro can have both positive and negative implications for the on-farm conservation of local types.

Traditional farmers played an outstanding role in recovering the cultivation of native landraces. This process was initially completely market-led, since no subsidy to production was introduced. The function of new producers is a lot more uncertain. In fact, awareness of genetic erosion problems is often completely lacking for most of them, including those that, being linked to the biological agriculture movement, sometimes claim to be more sensitive to conservation aspects.

In any case, commercial strategies of small-scale producers are extremely differentiated, leaving space for any kind of solutions among which the proper use of local populations can be certainly pursued. In this context two factors must be recalled:

- Public support up to now had a basically negative impact in several respects. In fact, causing an artificial expansion of the cultivation, it indirectly favoured seed mixing. Moreover, direct supports determine the lowering of raw material prices, to the advantage of traders and transformers. In the long term, farmers are therefore no longer stimulated to practise the on-farm transformation that was one of the milestones for the resumption the utilization of native landraces.

- The market is presently very confused, with good and poor quality material being valued more or less the same because of lack of information. An effort is needed to qualify production, several aspects of which are closely connected to the genetic material used.

A limited number of simple rules should therefore be useful to pursue the goal of conservation through utilization. They should not discourage individual initiatives, but should be mainly addressed from one side, at allowing the possibility of the full exploitation of landraces and, from the other, at increasing the interest of consumers through honest and scientifically based information.

Landrace growers should overcome their individualism, since the additional cost implicit in certification, although limited, should be better sustained by associated producers.

Researchers and other public subjects can give positive contribution provided they will avoid any dirigistic approach. Their role can be fundamental in the characterization of local populations, in spreading information and supporting the introduction of seed regulations that do not exclude local material from certification and commercialization.

References

Bozzini, A., U. Francia and P. Iannelli. 1994. Farro "Basian". L'Informatore agrario 50(37):48.

Castagna, R., C. Minoia, L. Rossetti and P. Codianni. 1993. Produttivita' del farro in diverse condizioni di coltivazione. L'Informatore agrario 49(35):52-55.

Castagna, R., L. Rossetti, O. Porfiri and G. Rocchetti. 1994. Farro: prove di concimazione azotata e di densità di semina. L'Informatore agrario 50(35):44-46.

Cubadda, R. and E. Marconi. 1994. Aspetti relativi all'utilizzazione e alla caratterizzazione tecnologica e nutrizionale del farro. Pp. 82-88 *in* Il farro, un cereale della salute. Potenza, 18 giugno 1994 (P. Perrino, D. Semeraro and G. Laghetti, eds.). CNR, Institutodel Germoplasma, Bari, Italy.

D'Antuono, L.F. 1989. Il farro: areali di coltivazione, caratteristiche agronomiche, utilizzazione e prospettive colturali. L'informatore agrario 45(24):49-57.

D'Antuono, L.F. and A. Lucidi. 1989. L'ambiente agricolo dell'Alta Valnerina. Monti e Boschi 40(6):17-25.

D'Antuono, L.F., C. Bignami and E. Mastronardi. 1993. Traditional agroecosystems and old genotypes of cultivated plants inventory and conservation: case study in a Mediterranean highland (Alto Molise, Central Italy). Pp. 269-286 *in* Socio-economic and Policy Issues for Sustainable Farming Systems (M.G. Paoletti, T. Napier, O. Ferro, B. Stinner and D. Stinner, eds.). Coop. Amicizia, Padova.

D'Antuono, L.F. and A. Pavoni. 1993. Phenology and grain growth of *Triticum dicoccum* and *T. monococcum* from Italy. Pp. 273-286 *in* Biodiversity and Wheat Improvement (A.B. Damania, ed.). Wiley-Sayce, UK.

D'Antuono, L.F. 1994. Obsolete wheats in Italy: an overview on cultivation, use and perspectives for their conservation. Pp. 41-48 *in* Report of the IPGRI workshop on conservation and use of underutilized Mediterranean species, Valenzano, Bari, 28-30 March 1994 (S. Padulosi, H. Ager and E. Frison, eds.). International Plant Genetic Resources Institute, Rome.

Galterio, G., A. Belocchi and C. Lintas. 1993. Un delicato equilibrio tra moda consumistica e convenienza economica: il farro. Molini d'Italia 1:17-19.

Italiano, M. and A. De Pasquale. 1994. Il farro: nuove acquisizioni in ambito preventivo e terapeutico. Pp. 67-81 *in* Atti del Convegno "Il farro, un cereale della salute". Potenza, 18 giugno 1994 (P. Perrino, D. Semeraro and G. Laghetti, eds.). CNR, Instituto del Germoplasma, Bari, Italy.

Mariani, G. 1994. Il farro di Garfagnana a confronto con le altre realta' produttive. L'Informatore Agrario 50(38):39-43.

Perrino, P. and K. Hammer. 1982. *Triticum monococcum* L. e *T. dicoccum* Schubler (sin. di *T. dicoccon* Schrank) are still cultivated in Italy. Genet. Agric. 36:343-352.

Perrino, P. and K. Hammer. 1984. The farro: further information on its cultivation in Italy, utilization and conservation. Genet. Agric. 38:303-311.

Perrino, P., S. Infantino, G. Laghetti, N. Volpe and A. Di Marzio. 1991. Valutazione e selezione di farro in ambienti marginali dell'Appennino molisano. L'Informatore agrario 47(42):57-62.

Perrino, P., S. Infantino, D. Basso, A. Di Marzio, N. Volpe and G. Laghetti. 1993. Valutazione e selezione di farro in ambienti marginali dell'Appennino molisano (II nota). L'Informatore agrario 49(43):41-44.

Piergiovanni, A.R. and M.G. Bianco. 1994. Primi risultati di una valutazione bromatologica di linee selezionate di farro. Pp. 89-95 *in* Atti del Convegno "Il farro, un cereale della salute". Potenza, 18 giugno 1994 (P. Perrino, D. Semeraro and G. Laghetti, eds.). Officine Tipographica, Bari, Italy.

Strehlow, W., G. Hertzka and W. Weuffen. 1994. Aspetti nutrizionali. Le caratteristiche dietetiche del farro nel trattamento di malattie croniche. Il farro, un cereale della salute. Pp. 52-66 *in* Atti del Convegno "Il farro, un cereale della salute". Potenza, 18 giugno 1994 (P. Perrino, D. Semeraro and G. Laghetti, eds.). Officine Tipographica, Bari, Italy.

Checklist for recording the cultivation and uses of hulled wheats

M. Nesbitt[1], G. Hillman[1], L. Peña-Chocarro[1], D. Samuel[2] and A.T. Szabó[3]

[1] Institute of Archaeology, University College London, London, England
[2] McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, England
[3] Department of Botany, Berzsenyi College, Universities of Western Hungary, Hungary

Introduction

A wide range of topics concerning the hulled wheats were discussed at the farro workshop held in Castelvecchio in July 1995. During the meeting it became clear that very few data have been recorded on the traditional husbandry, crop-processing or uses of the hulled wheats, and that this kind of information is potentially useful to a wide range of specialists. This guide aims to assist researchers in all fields to accurately and fully record all aspects of hulled wheat cultivation.

The most common hulled wheats are einkorn (*Triticum monococcum*), emmer (*T. dicoccon*) and spelt (*T. spelta*). During prehistory these taxa were among the staple crops of much of Europe, the Near East and temperate Asia. Today they are largely restricted to scattered mountainous enclaves. Even in these areas cultivation of hulled wheats continues to decline each year. The case of einkorn cultivation in Spain, reduced from an official figure of 48 ha in 1990, to one field in 1995, is not unusual. Although increased consumer demand for hulled wheat products in continental Europe has led to the spread of cultivation in some areas, this is doing little to ensure the preservation of local landraces and knowledge of their husbandry and uses. We believe that now is the last opportunity to record traditional practices before they are extinct.

Much earlier work on hulled wheats is of limited usefulness, either because an account is too short or does not cover the topic of interest to the researcher, or because of fundamental misunderstandings about the differences between the free-threshing wheats such as macaroni wheat (*T. durum*) and bread wheat (*T. aestivum*) and the hulled wheats. In this paper we aim both to give a comprehensive guide to the questions that should be asked, and also to briefly explain the techniques of crop-processing that are specific to the hulled wheats.

Importance of the hulled wheats

Hulled wheats are of strong interest to a diverse range of research areas, including germplasm conservation, plant-breeding, rural development, archaeobotany and ethnography. While each of these research areas has different goals, they share a common interest in accessing the fullest possible records of traditional cultivation and uses of hulled wheats. For example, knowledge of farmers' perceptions of factors such as relative yield, response to inputs and marketability is essential for understanding why hulled wheats are declining, and thus creating viable on-farm (*in situ*) conservation strategies. Such information is equally essential for modeling decision-making of prehistoric farmers and thus explaining past agrarian change.

Knowledge of agronomic practices such as time and density of sowing both assists genebanks in efficient multiplication of holdings, and will be useful to those selecting breeding material. Knowledge of crop-processing techniques, for example pounding in mortars and grinding in mills, is useful to archaeobotanists who need to understand how food-processing artifacts were used, and also to those involved in rural development who wish to support the infrastructure for processing hulled wheats. As a final example, knowledge of food uses is of interest both to the ethnographer for its cultural significance, and to the plant breeder or grain merchant seeking new uses or markets for hulled wheat products.

It is clear that no one person will be able to collect all the information from a given region is such a way as to satisfy all possible users. However we believe that data recording can be significantly improved by using this guide, which represents a consensus view from a number of different research viewpoints. Wherever possible, fieldwork should be planned in collaboration with researchers from different areas. The hulled wheats are disappearing too quickly to allow an approach in which different researchers only collect the information that seems immediately relevant to them.

Collection and publication of data

In the checklist below we suggest a series of points about which data should be collected, arranged by the agricultural year. We must stress that despite its format, this is not intended as a questionnaire. Farming is a complex operation and simply asking a series of questions is likely to induce puzzlement or extract misleading answers. However, even on the most hasty germplasm collecting trip, there is time to sit and talk with small groups of farmers. Under these conditions, and in the course of general discussions about farming, most of our points can be raised and answers collected.

As usual in ethnographic fieldwork, we must beware of asking “leading questions” which result in us getting the answer we expect, and we must recognize that there will be some questions to which the answers are either contradictory or ambiguous. These must be recorded as such. Some hints on dealing with particularly complex areas, such as yields, are given at the appropriate points.

Once information has been collected and organized in written form, it must be published. Large amounts of information on hulled wheats were written in germplasm collectors’ notebooks in the 1960s and 1970s, but this work resulted in just a few paragraphs of publication and is now effectively lost for ever. Written reports on germplasm collecting trips usually do not have space for extended discussion, but there are numerous other opportunities for publication. These include specialized journals of agricultural ethnography and ethnobotany, such as Tools and Tillage or Economic Botany, agronomic and plant breeding journals such as Genetic Resources and Crop Evolution and, of course, a host of regional ethnographic and scientific journals. Given the rate of decline in the opportunity to study traditional cultivation of hulled wheats, we would stress the necessity for rapid publication of fully descriptive accounts.

Understanding the processing of hulled wheats

Dehusking

Most of the agricultural sequence of husbandry, processing and food use of hulled wheats (Fig. 1) is similar to that for the better known, free-threshing macaroni and bread wheats. However, both ancient and contemporary accounts of hulled wheat use often show basic misunderstandings of the difference between hulled wheats and free-threshing wheats. Simply put, a free-threshing wheat will break up into grains and chaff on threshing. After threshing, all that is required to obtain clean grain is a series of winnowings and sievings to remove the chaff. In contrast, the spikes of hulled wheats break up into their component spikes on threshing. The grains are trapped inside the spikelets by tough glumes. An extra step is therefore required after threshing, to break open the spikelets and release the grain. After this, removal of the chaff is again a matter of winnowing and sieving.

Two techniques are widely used for extracting grain from spikelets of hulled wheats:

1. **Pounding.** Spikelets are placed in a mortar and pounded with a pestle or hammer. The husks rub against each other and slide off the grains. The buffering effect of the husks means that grains are removed intact and are usually not broken. If broken grain or flour is to be produced, this is usually a separate, subsequent step in processing.
2. **Milling between rotating millstones.** This is usually carried out in a water mill or similar apparatus, using circular millstones with a relatively high gap between them. As in pounding, this produces a mixture of intact grain and torn husks. Usually this mixture is removed from the millstones and the husks are winnowed out, before any further processing.

Decisions on planting
↓
Manuring
↓
Tilling
↓
Sowing
↓
Raking/Harrowing
↓
Weeding
↓
Harvest
↓
Threshing ➔ *straw*
↓
Winnowing ➔ *light chaff, straw*
↓
Coarse sieving ➔ *straw nodes, weed heads*
↓
Fine sieving ➔ *weed seeds and some chaff*
↓
spikelets

Fig. 1. Simplified sequence of crop husbandry and processing from sowing to spikelets (adapted from Hillman 1981:fig. 5, fig. 7).

Once clean whole grain has been obtained, it can then be prepared for food use in a variety of forms – as whole grain, cracked grain, or flour. At various stages in the preparation of these foodstuffs grinding or pounding will be required. In studies of modern and ancient hulled wheat processing the process of dehusking has often been confused with the process of grinding or cracking clean grain. A common example of this confusion is the suggestion that spikelets are placed in a mortar and pounded directly into flour. Ethnographic and experimental studies show that the removal of the husks (glumes, palea, lemma) from the grain is usually a distinct first step in preparation of foodstuffs. Only after clean, whole grain has been obtained are further steps such as bran-stripping, cracking or grinding carried out.

When processing of hulled wheats is being observed, it is therefore essential to fully understand what each step of the processing sequence is doing. This requires detailed observation and, equally importantly, collection of samples of the different products of processing from each stage.

Parching

There is a widespread assumption that spikelets of hulled wheats should be heated ("parched") in order to facilitate removal of the husks by pounding. This seems to be largely based on comments by Pliny (*Historia Naturalis* xviii, 7-8; xviii, 97). However, there is virtually no ethnographic evidence for parching of spikelets for this purpose, and experimental work in both dry areas such as Egypt (Samuel 1993) and damp areas such as Germany (Meurers-Balke and Lüning 1992) indicate that parching is unnecessary prior to pounding.

Cereal grains and spikelets are sometimes heated, for a wide range of reasons including drying of damp grain prior to storage (van der Veen 1989), or singed to remove awns as in Asturiass, Spain (Leonor Peña-Chocarro, this volume). If evidence for the use of heat in cereal processing is found, it is essential that the reason for this, as well as the means, are fully documented.

Checklist for traditional husbandry and processing of hulled wheats

Our outline of the operations involved in growing and processing hulled wheats closely follows Hillman's (1981, 1984, 1985) classic papers, to which readers are referred for more details, especially with regard to Turkey and the rest of the Near East. Operations are discussed in their approximate order through the agricultural year.

General socioeconomic information on the farming community

- Community size, economic status, ethnicity and religion.
- For each farmer or informant:
    - Name, age, gender
    - Family structure, relative economic status, ethnicity, religion.
    - Do farmers from other communities have any opinions regarding those growing or using hulled wheats; how do the latter view themselves in regard to nearby farmers growing free-threshing wheats?

Which crops are grown?

Cereals grown.

- Common names: local names often vary between villages, and even between villagers. Rather than asking for crops by name, we recommend carrying samples of the different hulled wheats and asking if they are recognized – and then seeking local names. Are hulled wheats regarded as being wheats by farmers, or as a different kind of cereal?
- Are distinct landraces recognized within each of the hulled wheats?
- Amounts of each cereal cultivated and change through time: these questions should not be restricted to hulled wheats. Changes in hulled wheat cultivation are linked to changes in other cereals.
- Factors that are changing the cultivation and uses of hulled wheats and other cereals: response to fertilizers, irrigation or pesticides; local or centralized markets; culinary uses; access to crop-processing facilities.
- Any special customs relating to the hulled wheats.

Decision-making on areas and amounts to be sown

- Number of farmers in village growing hulled wheats; area sown by each: less, same or more than previous years? Estimates of area should be recorded for each farmer, as local units and square meters, and for the community as a whole (hectares).
- Reasons why this amount of land was sown.
- Any special type of landform or soil chosen: hulled wheats are often (but not always) planted on poorer soils.
- Grown as pure crops, or as deliberate or tolerated mixtures? If grown as a mixture, for improved food value or for other reasons (for example, supporting the wheat plants)?
- Comparison of husbandry practices – especially manuring, weeding and irrigation – with other cereals.
- Villagers' perceptions of hulled wheats: old-fashioned? low / high prestige?
- Market for product: in household, village, market town.
- Expected uses of product. What are the approximate proportions of each hulled wheat used for each purpose?
- What do farmers suggest to improve their varieties, processing techniques or quality? Are there special problems with hulled wheats?

Sowing

Job distributions

- age, sex, hire of labour – should be noted for all the operations concerned with husbandry and processing.

Origin of the cultivated seed (location, persons, years)

- Fallowing and rotation
    - Place of hulled wheats in rotation / fallowing systems.
    - Reasons for adoption of these systems

Time of sowing

- Sowing dates for hulled wheats.

- Variation between different landraces, or from year to year.
- Factors affecting decision on when to sow.
- Differences in yield between cereals sown at different dates.
- How is the actual day of sowing chosen: for example, after first rain, when snow melts?

Manuring

- Timing and number of applications.
- Use of chemical or natural manures (dung, ashes, etc).
- Preferences for particular manure types.
- Types of chemical fertilizers.
- Prices of chemical fertilizers; date of introduction; government subsidies.
- Responses of hulled wheats and other cereals to different types and levels of fertilizer/manure. In addition to yield, these may include responses such as lodging.

Tilling

- Preparation of the fields: by ploughing with mouldboard plough or ard; spade; hoe.
- Harrowing of soil before or after sowing.
- Fineness of tilled soil required for sowing.

Sowing

- Spikelets sown by broadcasting, or dibbled into channels, or sown with a seed-ard? Note: hulled wheats are almost always sown in the spikelet owing to the difficulty in removing grains from the spikelet without some damage to the embryo.
- Density of sowing: this is usually difficult to discover by direct questioning. Number and weight of spikelets/unit area is probably the best way to present these data. This may have to be obtained by asking how much was planted in a field of known area. Spacing between plants in the field should also be recorded.

Raking or hoeing

- Coverage of the seeds after sowing.
- Depth of seeds after coverage.

Husbandry of the growing crop

Weeding

- Associated weeds; local/scientific names and herbarium vouchers if possible.
- Frequency and timing of manual weedings or application of weedkiller.
- Use of weeds for fodder or human food.
- Presence of tolerated weeds or of weeds with undesirable characters that must be removed.

Irrigation

- Frequency and timing of irrigation.
- Source of water and mode of distribution in fields.

- Choice of crops and fields for irrigation.
- Effect on yield; comparison of irrigated and unirrigated crops.

Drainage

- As above

Stone clearing

- As above

Harvest

Harvesting

- Timing of harvest in relation to other crops.
- Basis of decision on exact harvesting date.
- Part of plant harvested: whole plant by uprooting, harvest of spike and straw together, or harvest of spike only.
- Tools and procedures used. While the sickle and scythe are most common in traditional agriculture, other procedures include hand-plucking of spikes and trapping of spikes between reaping sticks. The semi-brittle rachis of hulled wheats makes their spikes particularly suitable for this kind of harvesting, and it is therefore possible that harvesting techniques may differ for free-threshing and hulled wheats. Sickles are often used in conjunction with harvesting claws or wooden hooks.

From spikes to spikelets

Collection of sheaves and temporary field storage

- Use of tools to move cut sheaves into stocks: simply for convenience in transport, or to allow the crop to dry out?

Transport of threshed crop to farmstead or threshing yard

- In carts, panniers or nets.

Threshing

During threshing the spikes will be separated from the straw and broken up into their constituent spikelets. Five different methods are described below. For whichever method is used, the following should be noted:

- Is the whole of the harvest threshed at once, or is it processed piecemeal through the year?
- Does processing take place in a special area (for example, a threshing yard), inside or outside?
- Is threshing undertaken on a household basis or a communal basis?

- **By beating:** the crop is placed on the ground and beaten with sticks, mallets, flails or other implements.
- **By lashing:** sheaves are swung against a wall or frame.
- **By sledging:** the crop is spread out on the ground while a sledge, either wooden or metal, set either with stones or with metal disks, is pulled by animals over the crop.
- **By trampling:** animals, sometimes shod with metal plates, or humans tread the crop.

- **By crushing with rollers:** used in a similar fashion to a threshing sledge.

Removal of large straw pieces

After sledging or trampling large straw pieces are removed by raking. After flailing or lashing, the straw usually remains in bunches and can be lifted clear with a fork.

Winnowing

After threshing with a threshing sledge, the lighter fragments of chopped straw and light weed seeds can be removed by winnowing. The threshed mixture is thrown into the air, allowing a breeze to separate the light and heavy components. This procedure can be repeated to ensure full separation.

Coarse-sieving

A large-meshed coarse sieve is used which allows the spikelets to fall through, while retaining straw nodes and weed heads in the sieve.

Medium-coarse sieving

A finer-meshed sieve is used, which retains the spikelets in the sieve but allows loose weed seeds to fall through.

We must emphasize that although the basic sequence of winnowing, coarse-sieving and finer-sieving has been widely recorded in the Near East for free-threshing wheats, few ethnographic records are available for hulled wheats. More data are urgently needed on how the mixtures resulting from threshing are treated. It is likely that variant sequences to that described here exist. Today threshing and cleaning of spikelets may be combined in one action in a threshing machine or combine harvester.

Bulk-storage of spikelets

After cleaning, spikelets are usually placed in storage. If some or all of the spikelets are to be processed to grain, this may be done in bulk, or piecemeal through the year. Germination losses compared with other cereals should be discussed.

Measuring yields

Accurate assessments of yield are particularly difficult to make for the hulled wheats. This is because yield can be measured both as spikelets and as free grain. Measurements may be in local units of weight or volume, and may not correspond to the units used to measure the seed spikelets. We recommend two approaches to this problem. First, farmers may be able to estimate yield by ratio: for example, one spikelet sown yields 20 at harvest. Estimates of this ratio should be collected from as many farmers as possible for as many different cereals as possible. However, as sowing at a lower density will result in higher yields for each plant, this may not be a good guide to yield from a given area (Powell 1985:34-36). Second, actual quantities sown and harvested for a given field or unit area can be obtained. In this case, it is essential to find out whether grain or spikelets are referred to, and to find out what different units of measurement mean. The same caveats apply to information on prices.

In most cases a more productive approach will be to consider yield and yield stability in relation to other crops. Farmers are usually willing to rank crops in relation to different soil conditions, resistance to cold, diseases or pests.

It is important to find out what inputs are associated with different relative yields. How do yields relate to fertilizer, irrigation or soil quality? Have yields changed within living memory? Figures that are not supported by explanations of inputs and on units of measurement can be highly misleading.

Use of different products

For the remaining part of the checklist we have felt it more important to explain the basic questions than to detail points to be recorded. It will be obvious for most of the following actions as to what needs to be recorded.

Straw

The importance of straw products to many small-scale farmers is increasingly recognized. As straw properties may be valuable for plant-breeding purposes, it is important to collect farmers' observations of the quality of straw for different purposes. This information should be obtained for all the cereals grown by a farmer, not just the hulled wheats.

Fodder: chopped straw is generally preferred for fodder rather than whole straw. If crop-processing does not result in adequately chopped straw, it may be placed under a threshing sledge or otherwise broken up. Different classes of straw may be given different names and used for different purposes. Information should be collected on the different classes and their uses.

Potential uses include fodder for different animals, bedding, fuel, temper for mudbrick, plaster or dung-cakes.

Intact straw may be used for thatch, basketry or straw-hats. Other uses for straw include stuffing saddles and mattresses.

Chaff

As with straw, chaff can be a valuable commodity with different classes of material with different names and uses. Uses as for straw.

Whole spikelets

The spikelets can either be used as whole spikelets, or processed further to whole grain (Fig. 2). Uses for intact spikelets include:

Seed: this may be subject to further cleaning, including hand-picking of remaining weed seeds. Spikelets may be further sieved to remove small spikelets. Spikelets may be stored in special cupboards, pits or other well-protected storage locations until sowing time.

Animal feed: Spikelets may be fed intact or be partly ground or pounded prior to feeding. They may be mixed with another feedstuff. The animals to which the spikelets are fed should be recorded, with any special properties of this animal feed.

Human food: The siliceous and barbed nature of hulled wheat chaff makes it unsuitable for human consumption, and in any case whole spikelets would be highly indigestible. However, spikelets are ideal for malting purposes. As in hulled barley, the husk holds the solid parts of the grain together during the malting process. If a malted or fermented drink is prepared from hulled wheats, the recipe should be obtained, and it should be established whether whole spikelets are used.

Dehusking the spikelet

Stripping the husks

As discussed earlier, there are two basic techniques for stripping off the husks (glumes, lemmas and paleas) of hulled wheats: pounding and milling. These are discussed separately.

Pounding: Spikelets are placed in mortar, may be dampened with water, and are pounded with a pestle or mallet. The size, shape and materials (wood, stone) of the tools should be noted, as well as the exact procedures used. If the spikelets have been dampened the resulting mixture of grain and shredded chaff must be dried before the chaff is removed by winnowing. The mortar may be specific to dehusking spikelets or may be multipurpose.

Milling: The spikelets are placed in a rotary quern or between millstones. The millstone is set higher than for flour production. A mixture results of whole grain, fragmented grain and chaff. The chaff can be separated by winnowing, and the different grades of whole and fragmented grain can be separated by sieving. In some cases the grains are ground into flour at this stage, and the husks and bran are then removed by sieving. The mill may be multipurpose, or specially designed for dehusking spikelets.

Cleaning the grain

After winnowing, weed seeds, pieces of chaff and stones that remain mixed with the grain must be removed. Typically whole grain will be sieved first through a coarse sieve, which will retain items such as large spikelet fragments. After this, grain will be sieved with a fine-meshed sieve. This will allow small weed seeds and pieces of chaff to fall through. After this, remaining weed seeds and stones can be picked out by hand. A supplementary process is grain-washing, in which grain is dipped into a stream. Weed seeds such as grains of wild oats, and fungus-infested grains will float off.

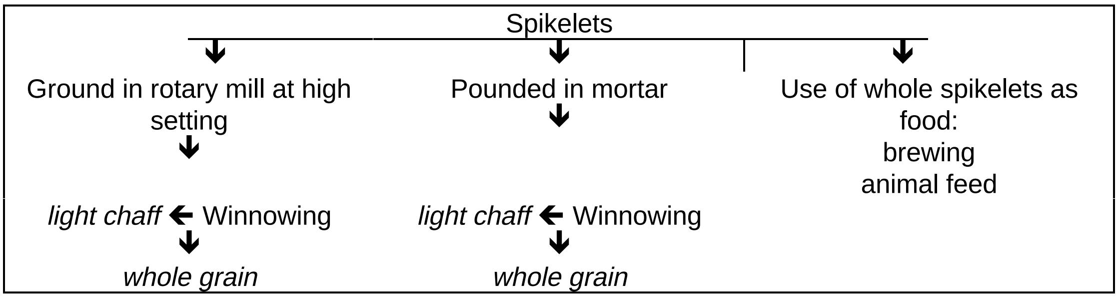


Fig. 2. Processing options for spikelets.

Processing and uses of grain

Storage of grain

A variety of sacks, jars, baskets, silos or pits can be used.

Animal feed

Grain may be fed to animals whole, crushed or ground. It may be fed pure or mixed with other feedstuffs.

Whole and cracked grain products

Untreated grain: whole grain and cracked grain can be used for bulgur and porridge-type dishes. As Hillman (1984:136) points out, emmer is thin-branned compared with *T. durum*, and does not need to be subjected to the full bulgur process described below.

Bulgur: a typical Near Eastern food in which whole grain is boiled in water and sun-dried. The bran is then stripped off by pounding the moistened grain in a mortar or by milling it with a vertical millstone. The bran is then winnowed away and the grain sun-dried. If the grain is to be consumed in cracked form, it will then be pounded in a special mortar. Note that it is therefore possible for hulled wheat to be subjected to pounding on three separate occasions, perhaps in a different type of mortar each time. The potential for confusion in describing these operations is obvious. Only by talking to the processors and physically examining the contents of each mortar can the processing sequence be clarified.

Greencorn: in Germany unripe grain of spelt wheat is harvested and dried over fires, before being sold as whole grain.

Flour products

Bread and other baked foods: hulled wheats have often been used to make bread, but few detailed ethnographic records exist. As bread represents a major potential market for glume wheats, better information is of considerable economic interest. Points that need to be recorded include:

- Was the flour used pure or mixed with other species?
- Was the flour wholemeal or white?
- What are the baking procedures? Is yeast or sourdough added? Could the bread be described as leavened?
- What are the special properties of the bread? Does it taste better? Keep longer?
- Colour of the flour, dough and final product.
- Medicinal properties.

Processing beyond the farm

- How much of the crop is consumed by the farmer's household; how much is shared or sold to others?
- Destination of spikelets or processed products. If necessary, consumers should be visited to record uses and perceptions of hulled wheat products.
- Prices of grain, spikelets or other products, related to a standard market product such as hens or eggs. This information should be recorded for all the cereals being sold.

Acknowledgements

We are grateful to Victor Vallega (Rome) and Concetta Vazzana (Florence) for helpful comments.

References

Hillman, G.C. 1981. Reconstructing crop husbandry practices from charred remains of crops. Pp. 123-162 in Farming Practice in British Prehistory (R. Mercer, ed.). Edinburgh University Press, Edinburgh.

Hillman, G.C. 1984. Traditional husbandry and processing of archaic cereals in modern times: Part I, the glume-wheats. Bull. on Sumerian Agriculture 1:114-152.

Hillman, G.C. 1985. Traditional husbandry and processing of archaic cereals in modern times: Part II, the free-threshing cereals. Bull. on Sumerian Agriculture 2:1-31.

Meurers-Balke, J. and J. Lüning. 1992. Some aspects and experiments concerning the processing of glume wheats. Pp. 341-362 *in* Préhistoire de l'agriculture (P.C. Anderson, ed.). Monographie du Centre de Recherches Archéologiques 6. Éditions du CNRS, Paris.

Powell, M.A. 1985. Salt, seed, and yields in Sumerian agriculture. A critique of the theory of progressive salinization. Z. für Assyriologie und Vorderasiatische Archäologie 75(1):7-38.

Samuel, D.J. 1993. Ancient Egyptian cereal processing: beyond the artistic record. Cambridge Archaeological J. 3(2):276-283.

van der Veen, M. 1989. Charred grain assemblages from Roman-period corn driers in Britain. Archaeological J. 146:302-319.

V. International Cooperation

First meeting of the Hulled Wheat Genetic Resources Network

Il Ciocco Hotel, Castelvecchio Pascoli (Garfagnana), 22 July 1995.

Attendants

Al Ajlouni, Basso, Benedettelli, Boller, Borghi, Bravi, Castagna, Cubadda, D'Antuono, Di Fonzo, Engels, Fortoul, Frison, Jaradat, Hammer, Heller, Kanbertay, Karagöz, Laghetti, Marconi, Mariani, Monti, Nesbitt, Padulosi, Pena Chocarro, Perrino, Piergiovanni, Pignone, Pisante, Porfiri, Quattrucci, Samuel, Stavropoulos, Szabó, Vallega, Vazzana, Waines

Person chairing the meeting

Frison

Person taking the minutes of the meeting

Padulosi

The meeting

The meeting started at 9.00 hrs and ended at 19.00 hrs. The discussion was held with the participation of all attendants, following a guideline document in which were summarized most relevant points to be addressed by the Network. The document had been developed earlier by Padulosi through consultations with participants during the preparatory process of the meeting. Below are summarized the major points agreed upon during the meeting together with highlights of the Workplan of the Hulled Wheat Network. A more detailed account of this meeting will be made available by Padulosi in the following weeks.

Genetic diversity

Two committees were established to look more closely into the taxonomy of hulled wheat species:

1. committee on *Triticum monococcum* (focus on A genome)
   Hammer, Szabó, Castagna
2. committee on *Triticum dicoccum*
   Germplasm Institute, Szabó, Hammer

ACTION: by the **end of August** a common position paper regarding their taxonomy on behalf of the Network will be developed by the groups.

Karl Hammer was elected coordinator of the two committees. These groups will also look at *T. spelta* in order to assess the need for revising its taxonomy.

Conservation

Abdallah Jaradat was elected a focal point for coordinating actions required in the area of conservation, such as compiling the list of hulled wheat material available in genebanks.

ACTION: those genebanks whose information on holdings is not yet available will be contacted shortly.

Documentation

The Network recommended that both the Germplasm Institute and ICARDA act as depository of a Hulled Wheat Species Database to be soon developed by the Network.

ACTION: the Germplasm Institute will contact ICARDA in this regard and develop jointly with them a common format to use for the DB. By the end of September 1995 letters to genebanks to request information will have to be sent out.

Participants unanimously agreed on the need for revising the IPGRI wheat descriptors list. Having in mind, however, the specific objectives of the Network, it was decided that the Network should focus only on those characters relevant for the characterization / evaluation of hulled wheat species. A committee composed of Perrino, Szabó, Hammer, Vallega, Jaradat, Castagna and Pena-Chocarro was established to work on the compilation of a descriptors list for hulled wheats. The IPGRI wheat and barley descriptors lists will be used as a basis for carrying out this work. Pietro Perrino has been elected focal point for this committee.

ACTION: a first draft of the descriptors list will have to be sent to Padulosi **by end of September 1995** for inclusion in the monograph.

In the area of dissemination of information on the Network initiatives, it has been proposed to use one of the following media:
- the International Wheat Newsletter
- an electronic bulletin board (it was suggested to use *Hynaldia* publication developed by Szabó). Members not having email facilities would receive the bulletin by mail through Padulosi / Network chairperson.
- a quarterly report (this option would require much more effort from the Group)
- IPGRI's Europe Newsletter.

ACTION:
1. Borghi will write to the editor of the Wheat Newsletter to investigate the possibility of having a section assigned to the Network
2. Padulosi will identify, together with Network chairperson, the best option to be implemented and together will encourage Network participants to submit their future contributions to this information medium
3. Szabó will investigate the possibilities to develop the electronic bulletin board.

Utilization

The Network decided to give a concrete contribution in promoting the use of hulled wheat species by preparing a paper on how to record different uses of these species to be added to the monograph. A committee composed by Nesbitt, Szabó, D'Antuono, Vazzana and Peña-Cocharro was established to write this contribution. Nesbitt volunteered to coordinate the production of this paper. The collation of cooking recipes on hulled wheats was also considered as an important tool for encouraging the promotion of these crops.

ACTION:
1. Contributions to be sent to Padulosi by **the end of August 1995**.
2. Vazzana will gather information on recipes on hulled wheats assisted by all Network members.

On-farm conservation

ACTION:
1. Padulosi will suggest including hulled wheats in the *in situ* project proposal that is being developed for a multidonor-supported initiative by IPGRI in collaboration with various partners.
2. the Germplasm Institute will follow up on strengthening the collaborations/ interactions with extension work organizations in Italy in order to study the possibility of having trials with hulled wheats with the direct involvement of farmers.
3. Other Network participants have been requested to follow up on this aspect in their respective regions.

Election of Network Chairperson

Pietro Perrino, of the Germplasm Institute of Bari, Italy, has been elected as Chairperson of the Hulled Wheat Genetic Resources Network.

Next meeting: when and where

The Network recommended holding a meeting in about one year from now. The venue and the exact date will be decided later, but a number of suggestions were brought forward on where to hold the meeting:
1. Turkey (June, during the International Wheat Conference to be held there)
2. France, Provence region
3. Greece (June, during the International Conference on Bread and Cereals)
4. Foggia, Italy at the new facilities of the Istituto per la Cerealicoltura
5. Bari, Italy at the Germplasm Institute in conjunction with the first meeting of the partners of the EU Hulled wheat project (in case this is approved).

ACTION: Padulosi to gather more information on the various options and identify in collaboration with Network chairperson the most favourable date and venue.

Current and future activities on hulled wheat species

Following is a list of activities grouped by countries, which have been recently carried out/will be undertaken in the near future in the area of hulled wheats research.

Greece

Greek Gene Bank (Nikolaos Stavropoulos)

Currently the Greek Gene Bank (GGB) maintains only one *T. monococcum* accession (var. 'Kaploutzas'). Seed increase of this variety was undertaken in 1994 by the GGB in collaboration with a group of entrusted amateur growers to which the initial seed was provided by GGB. These groups are interested in ecological farming, on-farm conservation activities and in the re-introduction of old landraces into cultivation. Seeds of this variety of einkorn have been also provided in 1995 to the Archeobotany Dept. of the University of Sheffield, UK to allow some micromorphological and evolutionary comparative investigations with paleolithic seeds discovered in archeological sites near Thessaloniki, Greece. Greece is actively involved in a number of projects aiming at a better conservation and use of hulled wheat species, including the IPGRI project on underutilized Mediterranean species, the newly established initiative of ECP/GR on minor crops, and two proposals (one on hulled wheats and another on European Triticineae) recently submitted to the European Union for funding.

Hungary

University of Western Hungary (Attila Szabó)

The work carried out and that likely to continue on hulled wheats can be summarized as follows. Activities on hulled wheats started from problems related to agrobotany, botanical taxonomy, ethnobotany, genetic resources conservation and crop evolution and have been carried out while Szabó was a member of the Agrobotanical garden of Cluj-Napoca (Romania). A review or the *T. monococcum* cultivation in Eastern Carpathian Mountainous range, including the Transylvanian basin, was produced using these findings. This work took also into account the results of investigations carried out by Al. Borza, A.T. Szabó senior and S. Sakamoto of the Plant Germplasm Institute of Kyoto, Japan. The most important data gathered during the period 1967-87 are those related to the status of genetic erosion of einkorn in Transylvania and Carpathian basin. In 1988 the newly established laboratory of Ecological Genetics and Crop Evolution of Szombathely (Western Hungary) launched a number of collecting expeditions for gathering hulled wheats (including *Agropyron, Elytrigia* and *Haynadia* species). Along with these activities, characterization and evaluation works have been conducted on collected material, including esterase isoenzymes and high molecular weight glutenins analyses (this latter activity carried out in collaboration with J. Sutka, A. Belea of the Agricultural Research Institute of the Hungarian Academy of Science of Mortonvásár and T. Lelley of the Interuniversity Agricultural Research Institute of Tulln, Austria. Major results from these activities are represented by the collection of landraces still under cultivation in the Alp-Carpath-Balkan-Danube area, the compilation of an electronic database regarding the historical and actual chorology and ethnobotany of hulled wheats in Carpathian area and the start of an electronic publication on this subject (HYNALDIA* BIO TÁR Series). On the basis of the conclusions of the first meeting of the Hulled Wheat Genetic Resources Network a hulled wheats descriptors list has been compiled recently. Presently our main interest on hulled wheats is related to theoretical and practical problems of crop evolution and ethnobiodiversity.

Italy

Experimental Institute for Cereal Crops, Rome (Victor Vallega)

He has carried out work on einkorn breeding and quality evaluations, variability studies on *T. dicoccum* and transfer of useful genes to *T. durum*. Presently he is involved in the evaluation of einkorn resistance to soilborne viruses (SBWMV and WSSMV) and development of near-isogenic lines for presence/absence of Glu-Al and GLU-Bl encoded bands, and for presence/absence of awns.

Experimental Institute for Cereal Crops, Foggia (Natale Di Fonzo)

The Station of Foggia is involved in agronomic trials on hulled wheats aiming at evaluating the performance of these species in drylands and environments at low altitudes. Included in these investigations are trials for evaluating the performance of hulled wheats in fields subjected to various level of weed infestations (*Avena* and *Phalarys* species). The trials use *T. durum* as a comparison species. The station is also involved in breeding activities on emmer: 100 lines have been obtained from crosses of this species with durum wheat (cvs. 'Simento', 'Tavoliere', 'Duilio' and 'Ofanto') and will be evaluated in 1995/96 for their agronomic performances.

Experimental Institute for Cereal Crops, S. Angelo Lodigiano (B. Borghi and R. Castagna)

This work is being carried out in collaboration with F. Salamini and M. Heun of the Max Planck Institute, Köln, Germany. The Institute has been actively pursuing since the early 1990s an integrated breeding approach on hulled wheat species. In 1990 some 1393 einkorn accessions were gathered from several international and national germplasm collections and various investigations have been carried out on this material. All accessions have been grown at two locations (Milan, Italy and Cologne, Germany) for two years (1992-93 and 1993-94) and characterized for several morphophysiological traits, viz. days to heading, plant height, lodging resistance, number of spikelets per spike, kernel weight and hairiness of the culm and leaves. Yield and yield-related traits of 21 lines of *T. monococcum* were evaluated in replicated plot trials carried out for 2 years at Cologne, Milan, Ascoli Piceno and Foggia. In order to explore the genetical and environmental variability for qualitative traits and for the rheological properties of einkorn flours (including bread-making aptitude) seeds from the genotypes included in the agronomic trials grown at Milan and Cologne were hulled and milled. The entire collection of einkorn was screened by means of the SDS sedimentation test (Zeleny test) and storage proteins of about 140 accessions were analyzed through electrophoresis technique. To investigate the genetic variability and the relationships between different species of the einkorn group, 55 different accessions of *T. monococcum* subsp. *monococcum*, subsp. *boeoticum*, subsp. *sinskajae* and *T. urartu* were also analyzed by means of RFLPs. Since the need for the einkorn taxonomy revision became evident, the phylogenetical study of einkorn wheats based on DNA techniques was enlarged to 300 accessions, chosen to represent the original area of diversification as well as the extreme regions where einkorn cultivation spread in Europe. We are currently constructing a map of the A genome of einkorn in order to localize quality traits and some of the important agronomic traits (free-threshing, cold resistance as well as yield-related QTLs). To get a first skeleton of the map we are mapping the available DNA clones of the published barley RFLP map on an F_2 progeny of a cross subsp. *boeoticum* x subsp. *sinskaja*. In regard to breeding activities since 1992 we have been crossing several lines presenting positive agronomic traits like short straw, earliness, large kernel, high SDS sedimentation volume. To date 266 different crosses have been produced and the segregating generations are under evaluation.

CERMIS, Tolentino, Macerata (Oriana Porfiri)
CERMIS is largely involved in assisting farmers for a better utilization of hulled wheat species. To this regard the centre has gathered a large germplasm representation (60 accessions) of hulled wheat grown in Italy and has characterized such material for its taxonomic position and major agromorphological traits. The information is made available to farmers who will be thus in the position to choose material most suitable to grow in their land, while at the same time collaborating with CERMIS for the on-farm conservation of these landraces.

Ente Regional Sviluppo Agricolo Molise –ERSAM, Campobasso (Giuseppe Mariani)
Mainly involved in field trials in marginal areas of Molise region. ERSAM's activities on hulled wheats aim at evaluating different landraces of emmer and spelt landraces on their yield performance and at investigating their responses to population density and fertilization factors during cultivation.

Germplasm Institute, Bari (Gaetano Laghetti)
Since 1989 I have been working on exploration, collecting, multiplication, characterization, evaluation and utilization of hulled wheat genetic resources (both wild and cultivated). In particular I have carried out many collecting missions, especially in Italy and Albania, to gather hulled wheat germplasm threatened with genetic erosion and/or useful for wheat breeding programmes. I also have been coordinating a project on hulled wheats (emmer and spelt) aimed at improving these species and their utilization in marginal areas of South Italy. In the framework of this project two new varieties are being patented and registered in the Italian national register of crop varieties. A computerized databank of agronomic and biological traits of hulled wheat collection stored at the Institute has been produced. The Institute also will be carrying out investigations on qualitative characteristics of hulled wheat species in regard to their pasta- and bread-making abilities.

Germplasm Institute, Bari (Angela Rosa Piergiovanni)
In 1994 the Institute started a biochemical and technological evaluation of hulled wheat accessions previously selected on the basis of their agronomic performances. An initial batch of 87 accessions (37 of spelt and 50 of emmer) have been evaluated in regard to their composition (protein, ashes, glutenins, fats and beta-carotene) and for some parameters correlated to their technological properties (SDS test, hydration capacity of the glutenins and ratio glutenins/proteins). The results of this work have pointed out the presence of remarkable differences among and within species in regard to these parameters. Currently, electrophoretic analyses are being conducted on the selected material in regard to gliadin and glutenin contents.

Nutrition Institute, Rome (Elisa Quattrucci)
See University of Molise

University of Basilicata, Potenza (Michele Pisante and Francesco Basso)
The Department of Crop Production of the University started investigating the agronomic performances (plant growth and yield analyses) of hulled wheat populations and comparing results with those obtained in trials using common wheat species. The aim of this work is to explore the actual potentials of re-introduction of hulled wheats in Italy. In these studies significant variations were found in the correspondence of main phenological phases, hulled wheats showing the longest biological cycle. These trials will be continued in the future. As regards

the yield, emmer and spelt were definitively less productive than *T. aestivum* and *T. durum*. Electrophoretic analyses carried out at the University have also indicated the presence of significant differences between SDS profiles of hulled wheats and those from common wheat accessions.

University of Bologna (Filippo D'Antuono)

The University is involved in six major areas of investigation:

1. Comparison of the Italian landraces of *T. dicoccum* and *T. monococcum* at different levels of nitrogen fertilization. This research is being carried out at the experimental farm of Ozzano, near Bologna and aims at evaluating the different nitrogen efficiency between hulled wheats and modern wheat varieties (experiments conducted in 1995 and to be partially repeated in 1996).
2. Participation in collaborative research activities aiming at assessing the yield capacity of hulled wheats (mainly emmer) in different Italian environments (work started in 1995 and likely to continue in 1996).
3. Seed multiplication of rare landraces. Of the 10 landraces of emmer that have been collected over the last few years, some can hardly be found growing. Such multiplication will be carried out in 1996.
4. Surveys and assess the consistency and typology of hulled wheats cultivation in Italy. The work started in 1995 and will continue in 1996. The spreading of the cultivation of hulled wheats outside the traditional areas has caused a lot of confusion over the genetic material being used by farmers. This activity is therefore aimed at individuating the original sources of seed of present cultivations, with special attention to the detection of those areas in which unmixed native landraces are still being used.
5. Analytical work: preliminary analysis of dietary fibre of emmer kernels started in 1995. These investigations, made through the use of prolysis gass-mass techniques provided so far interesting results and they are likely to be continued also in 1996.
6. Monitoring the state of hulled wheats cultivation and utilization. This work is being carried out in close collaboration with producers (both firms and users) and aims at keeping track of crop evolution and its utilization.

University of Molise, Campobasso (R. Cubadda and E. Marconi)

Activities are carried out in close collaboration with the Nutrition Institute of Rome. There are six main areas of investigation:

1. Evaluation of chemical, nutritional and technological potential of *T. dicoccum* and *T. spelta* varieties, selected lines and landraces.
2. Investigation of the relationship between bread quality attributes and several analytical tools already developed aiming at developing sound laboratory tests for bread-making quality in hulled wheat.
3. Determination of the specific role of proteins, rate of damage starch, pentosans and extraction rate on the hydration of dough, its rheological properties and quality of end-products.
4. Investigation of the influence of different bread-making methods on the qualitative characteristics of hulled wheats bread.
5. Evaluation of the potentials of hulled wheats for making pasta and breakfast products and development of appropriate technologies.
6. Investigation of the nutritional and organoleptic characteristics of end-products.

University of Udine (Fabiano Miceli)

The Department of Vegetal Production and Agrarian Technologies has been involved in winter wheat research since 1986 (half a decade after the establishment of the University of Udine in the early 1980s). Wheat crop physiology, nitrogen nutrition and bread-making quality management have been major research topics. In 1992 a close collaboration with the Friulano Botanical Garden of Udine – depository of some 60 accessions of Triticeace – started, aiming at investigating these subjects. In addition to these studies, flag leaf gas exchange measurements were also carried out aiming at comparing the different photosynthetic capability of these wheats and modern wheat varieties. Although this work was interrupted in 1994/95 owing to lack of funds, it is likely that it will resume in the 1995/96 season.

Spain

Leonor Peña-Chocarro

She will continue her ethnographic studies with growers of einkorn, emmer and spelt in Spain in collaboration with the Institute of Archeology, University College London.

Turkey

Aegean Agricultural Institute, Izmir (Mesut Kanbertay)

Activities conducted by the Institute in the period 1994/95 can be summarized as follows:

1. Characterization and evaluation: 310 einkorn lines derived from 31 populations have been characterized for growth habit, days to heading, days to maturity, lodging, plant height, spike length, glume colour, kernel colour, 1000 kernel weight and protein percentage; 26 samples of *T. dicoccoides* have been evaluated to search for useful traits for durum wheat breeding. The laboratory stages of these two activities are still in progress.
2. Collecting of germplasm material from Gaziantep Province, near the Syrian border was carried out in June 1995. During this trip 31 *T. boeticum* and 18 *T. dicoccoides* samples were gathered as a whole from mixed stands and growing in basaltic soils.
3. Rejuvenation was carried out in the 1994/95 season for 15 accessions of *T. monococcum*, 103 of *T. boeticum*, 7 of *T. dicoccum* and 18 of *T. dicoccoides*.

Central Research Institute for Field Crops, Ankara (Alptekin Karagöz)

Turkey is an active member of the IPGRI initiative *In situ* Conservation of Agricultural Biodiveristy. One component of this project is represented by hulled wheat genetic resources. The area that will be covered in Turkey by this work is that presented at the workshop in Castelvecchio Pascoli. The Institute will carry out this work in collaboration with the Izmir Aegean Agricultural Research Institute, the Eskisehir Transitional Zone Agricultural Research Institute, The Aegean University and an NGO. The project is likely to be implemented in 1996.

United Kingdom

Institute of Archaeology, University College London, London (Mark Nesbitt)

Nesbitt will continue working on the publication of charred plant remains from archeological sites in Turkey, focusing on the timing and explanation of the decline of hulled wheats from antiquity to the present day.

McDonald Institute for Archaeological Research, University of Cambridge, Cambridge (Delwen Samuel)

Samuel will continue her work at Cambridge on the ancient food uses of hulled wheats, focusing on the technology of dehusking, milling, baking and brewing in ancient Egypt and the Near East. Special techniques include the use of correlative microscopy, especially high power light and scanning electron microscopy, to study the microstructure of ancient cereal food residues.

VI. List of Participants

Mohamed AL AJLOUNI
University of Science and Technology
Faculty of Agriculture
Irbid, JORDAN
Fax: (+962) 2- 295123

Pierluigi ANGELI
Comunità Montana della Garfagnana
Castelnuovo di Garfagnana
55032 (Lucca), ITALY
Tel: (+39) 583-658990
Fax: (+39) 583-644410

Luigi BACCHI LAZZARI
Assessorato Agricoltura
Regione Emilia Romagna
Servizio Sviluppo Agricolo
V.le Silvani, 6
40122 Bologna, ITALY
Tel: (+39) 51-284667
Fax: (+39) 51-284359

Francesco BASSO
Dean, University of Basilicata
Via Nazario Sauro, 85
85100 Potenza, ITALY
Tel: (+39) 971-57429
Fax: (+39) 971-4742669
email pisante@pzvx85.cineca.it

Stefano BENEDETTELLI
Dip. Agronomia e Produzioni Erbacee
Faculty of Agriculture
University of Firenze
P.le delle Cascine, 18
50144 Firenze, ITALY
Tel: (+39) 55- 352051
Fax: (+39) 55- 332472

Simone BOLLER
Dept. of Plant Breeding
Swiss Federal Research Station for Agronomy
Reckenholzstrasse 191
8046 Zurich-Reckenholz
SWITZERLAND
Tel: (+41) 1-3777364 / 3777111
Fax: (+41) 1-3777201
email hans@efap.dial-switch.ch

Romana BRAVI
Ente Nazionale Sementi Elette
Via della Zecca, 1
Bologna, ITALY
Tel: (+39) 51-220409
Fax: (+39) 51-263069

Prassede BRAVI
55031 Camporgiano
Casciana (Lucca), ITALY

Basilio BORGHI
Istituto Sperimentale per la Cerealicoltura
Via Mulino, 3
20079 S Angelo Lodigiano (MI)
ITALY
Tel: (+39) 371-90269 / 92658
Fax: (+39) 371-934785

Paolo CALARAI
Dip. Agronomia e Coltivazioni Erbacee
Faculty of Agriculture
University of Florence
Piazzale delle Cascine, 18
Firenze, ITALY
Tel: (+39) 55-352051
Fax: (+39) 55-332472

Renato CASTAGNA
Istituto Sperimentale per la Cerealicoltura
Via Mulino, 3
20079 S Angelo Lodigiano (MI)
ITALY
Tel: (+39) 371-90269 / 92658
Fax: (+39) 371-934785

Marina CIARALDI
c/o Dept. of Ancient History and Archeology
Archeological Laboratory
Edgebaston B15 2TT
Birmingham, ENGLAND
Tel: (+44) 121-414 386

Sandrine COLARD
ENSAR
4 Cours de Lisbonne
35200 Rennes, FRANCE

Nicola COLONNA
ENEA C.R.E. Casaccia
Via Anguillarese 301
S. Maria di Galeria
00060 Rome, ITALY
Tel: (+39) 6-30486381
Fax: (+39) 6-30483055

Raimondo CUBADDA
Dip. Scienze e Tecnologie Agroalimentari Ambientali e Microbiologiche
Faculty of Agriculture
University of Campobasso
Via Tiberio, 21
86100 Campobasso, ITALY
Tel: (+39) 874-481357
Fax: (+39) 874-481382

L. Filippo D'ANTUONO
Dept. of Agronomy
Faculty of Agriculture
University of Bologna
Via Filippo Re 6-8
40126 Bologna, ITALY
Tel: (+39) 51-351510
Fax: (+39) 51-351545

Natale DI FONZO
Istituto Sperimentale per la Cerealicoltura
S.S. 16, km 675
71100 Foggia, ITALY
Tel: (+39) 881-742972
Fax: (+39) 881-693150

Louis FORTOUL
Cereles Ventoux
Quartiere les Baumes
Route de St Christol
84390 Sault, FRANCE
Tel: (+33) 923-13147
Fax: (+33) 923-24861

Massimo FIORAMI
Via Ponte Armellini, 28
610120 Trasanni di Urbino (Perugia)
ITALY
Tel: (+39) 722-52886
Fax: (+39) 722-52886

Jan ENGELS
IPGRI
Via delle Sette Chiese, 142
00145, Rome, ITALY
Tel: (+39) 6-51892266
Fax: (+39) 6-5750309
email j.engels@cgnet.com

Emile FRISON
IPGRI
Via delle Sette Chiese, 142
00145, Rome, ITALY
Tel: (+39) 6-51892221
Fax: (+39) 6-5750309
email e.frison@cgnet.com
Present address:
INIBAP
Parc Scientifique Agropolis
34397 Montpellier cedex 5, FRANCE
Tel: (33) 676113-02
Fax: (33) 67610334
email e.frison@cgnet.com

Lisetta GHISELLI
Dip. Agronomia e Coltivazioni Erbacee
Faculty of Agriculture
University of Florence
Piazzale delle Cascine, 18
Firenze, ITALY
Tel: (+39) 55-352051
Fax: (+39) 55-332472

B. GIORGI
ENEA, C.R.E. Casaccia
Via Anguillarese 301
S. Maria di Galeria
00060 Rome, ITALY
Tel: (+39) 6-30483797
Fax: (+39) 6-30486545

Karl HAMMER
Institut für Pfanzengenetik und Kulturpflanzenforschung (IPK)
Correnstrasse 3
06466 Gatersleben, GERMANY
Tel: (+49) 39-4825280
Fax: (+49) 39-4825155

Joachim HELLER
IPGRI
Via delle Sette Chiese, 142
00145 Rome, ITALY
Tel: (+39) 6-51892226
Fax: (+39) 6-5750309
email j.heller@cgnet.com

Abdallah JARADAT
IPGRI
c/o ICARDA
PO Box 5466
Aleppo, SYRIA
Tel: (+963) 21-247485
Fax: (+963) 21-225105/ 213490
email a.jaradat@cgnet.com

Alptekin KARAGÖZ
Central Research Institute for Field Crops
PK 226
06042 Ankara, TURKEY
Tel: (+90) 312-287 3334
Fax: (+90) 312-287 8958

Mesut KANBERTAY
Cereal Department
Aegean Agricultural Research Institute
PO Box 9, Menemen
Izmir 35661, TURKEY
Tel: (+90) 232 -8461331
Fax: (+90) 232 -8461107

Bertalan KOKENY
Istituto Sperimentale per le Colture Industriali
Via di Corticella, 139
40129 Bologna, ITALY
Tel: (+39) 51-353598
Fax: (+39) 51-374857

Gaetano LAGHETTI
Istituto del Germoplasma
National Research Council
Via Amendola 165/A
70126 Bari, ITALY
Tel: (+39) 80-5583400
Fax: (+39) 80-5587566
email ricerca@vm.csata.it

Emanuele MARCONI
Dip. Scienze e Tecnologie Agroalimentari Ambientali e Microbiologiche
Faculty of Agriculture
University of Molise
Via Tiberio, 21
86100 Campobasso, ITALY
Tel: (+39) 874-481357
Fax: (+39) 874-481382

Giuseppe MARIANI
Rome, ITALY
Fax: (+39) 6-334398

Fabiano MICELI
Dip. Produzione Vegetale e Tecnologie Agrarie
Via delle Scienze, 208
33100 Udine, ITALY
Fax: (+39) 432-558603

Luigi M. MONTI
Chair of Plant Genetics
Faculty of Agriculture
University of Naples
Via Università 100
80055 Portici (NA), ITALY
Tel: (+39) 81-7752056
Fax: (+39) 81-7753579
email cnrmonti@inacriai.it

Mark NESBITT
Institute of Archeology
University College London
31-34 Gordon Square
London, WCI HOPY, ENGLAND
Tel: (+44) 171-3807777 (# 4763)
Fax: (+44) 171-3832572
email tcfa270@ucl.ac.uk

Stefano PADULOSI
IPGRI
Via delle Sette Chiese, 142
00145 Rome, ITALY
Tel: (+39) 6-51892266
Fax: (+39) 6-5750309
email s.padulosi@cgnet.com

Cristina PAPA
University of Perugia
Istituto di Etnologia e Antropologia Culturale
Via Aquilonia, 7
06122 Perugia, ITALY
Tel: (+39) 75-5853830
Fax: (+39) 75-5853831

Roberto PAPA
Dip. Biotecnologia Agraria ed Ambientale
Via Brecce bianche
60131 Ancona, ITALY
Tel: (+39) 71- 2204934
Fax: (+39) 71- 2204858

Leonor PEÑA-CHOCARRO
Institute of Archeology
University College London
31-34 Gordon Square
London, WCI HOPY, ENGLAND
Tel: (+44) 171-3807777 (# 4763)
Fax: (+44) 171-3832572

Pietro PERRINO
Istituto del Germoplasma
National Research Council
Via Amendola 165,A
70126 Bari, ITALY
Tel: (+39) 80-5583400
Fax: (+39) 80-5587566
email ricerca@vm.csata.it

A.R. PIERGIOVANNI
Istituto del Germoplasma
National Research Council
Via Amendola 165,A
70126 Bari, ITALY
Tel: (+39) 80-5583400
Fax: (+39) 80-5587566
email ricerca@vm.csata.it

Sandro PIERONI
Presidente
Consorzio “Garfagnana Produce”
Loc. Pianaccia
Castelnuovo Garfagnana
55032 (Lucca), ITALY
Tel: (+39) 583-65169
Fax: (+39) 583-65169

Domenico PIGNONE
Istituto del Germoplasma
National Research Council
Via Amendola 165/A
70126 Bari, ITALY
Tel: (+39) 80- 5583400
Fax: (+39) 80- 5587566
email germdp02@area.ba.cnr.it

Oriana PORFIRI
CERMIS
c/o Fondazione Giustiniano-Bandini
Abbadia di Fiastra, 3
62029 Tolentino (MC), ITALY
Tel: (+39) 733-203437
Fax: (+39) 733-203437

Michele PISANTE
Dip. Produzione Vegetale
University of Basilicata
Via Nazario Sauro, 85
85100 Potenza, ITALY
Tel: (+39) 971-57429
Fax: (+39) 971-4742669
email pisante@pzvx85.cineca.it

Enrica QUATTRUCCI
Istituto Nazionale della Nutrizione
Via Ardeatina 546
00178 Rome, ITALY
Tel: (+39) 6-5032412
Fax: (+39) 6-5031592

Edoardo ROMOLI
University of Florence
Firenze, ITALY
Tel: (-39) 55-2755456

Adanella ROSSI
Dip. Ecomonia dell' Agricoltura Agraria
University of Pisa
Via del Borghetto, 80
56124 Pisa, ITALY
Tel: (+39) 50-571553
Fax: (+39) 50-571344

Massimo ROVAI
Dip. Ecomonia dell' Agricoltura Agraria
Univeristy of Pisa
Via del Borghetto, 80
56124 Pisa, ITALY
Tel: (+39) 50-571553
Fax: (+39) 50-571344

Delwen SAMUEL
The Mc Donald Institute for Archeological Research
Downing Street
Cambridge CB2 3ER, ENGLAND
Tel: (+44) 1223-333538 / 339338
Fax: (+44) 1223-333536
email ds123@hermes.cam.ac.uk

Mario SATTI
Assessorato Agricoltura
Comunità Montana della Garfagnana
Castelnuovo di Garfagnana
55032 (Lucca), ITALY
Tel: (+39) 583-658990
Fax: (+39) 583-644410

Nikolaos STAVROPOULOS
National Agricultural Research Foundation
Agricultural Research Center of Makedonia and Thraki, Greek Gene Bank
57100 Thermi-Thessaloniki, GREECE
Tel: (+30) 31-471544 / 471439
Fax: (+30) 31-471209

Agostino STEFANI
Scuola Superiore e di Perfezionamento S. Anna
Via G. Carducci, 40
56100 Pisa, ITALY
Tel: (+39) 50-883292
Fax: (+39) 80-883210-215

Giovanni SUFFRADINI
Castiglione di Garfagnana
(Lucca), ITALY
Tel: (+39) 583-68035

Attila T. SZABÓ
Head, Botany Department
BDTF, UWH
PO Box 1700
9700 Szombathely, HUNGARY
Tel: (+36) 94-312248
Fax: (+36) 94-313892
email szta@fs2.bdtf.hu

Remigio TALLARICO
Dip. Agronomia e Coltivazioni Erbacee
Faculty of Agriculture
University of Florence
Piazzale delle Cascine, 18
Firenze, ITALY
Tel: (+39) 55-352051
Fax: (+39) 55-332472

Victor VALLEGA
Istituto Sperimentale per la Cerealicoltura
Via Cassia, 176
00191 Rome, ITALY
Tel: (+39) 6-3295705
Fax: (+39) 6-36306022

Concetta VAZZANA
Dip. Agronomia e Produzioni Erbacee
Faculty of Agriculture
University of Firenze
P.le delle Cascine, 18
50144 Firenze, ITALY
Tel: (+39) 55-352051
Fax: (+39) 55-332472

Nicola VOLPE
Istituto del Germoplasma
National Research Council
Via Amendola 165 / A
70126 Bari, ITALY
Tel: (+39) 80-5583400
Fax: (+39) 80-5587566
email ricerca@vm.csata.it

J. Giles WAINES
Dept. of Botany and Plant Science
University of California
Riverside, CA 92521, USA
Tel: (+1) 909-7874437
Fax: (+1) 909-7874437
email bpscjm@ucrac1.ucr.edu

Unable to attend

Giulio ANGIONI
Istituto di Discipline
Socioantropologiche
Facoltà di Magistero
Università degli Studi di Cagliari
Piazza d'Armi
Cagliari, ITALY
Fax: (+39) 70-2002304

Franceso BONCIARELLI
President
Comitato Scienze Agrarie
Consiglio Nazionale delle Ricerche
P.zzale Aldo Moro, 7
00185 Rome, ITALY

R. COCCIA
President
Comunità Montana della Valnerina
Norcia (PG), ITALY
Fax: (+39) 743-817566

Francesco D'AMATO
Institute of Genetics
Faculty of Agriculture
University of Pisa
Via Matteotti
Pisa, ITALY

Luciano GIACCHE
"Centro Bazzucchi"
S. Sisto, Perugia, ITALY

Manfred HEUN
Dept. of Biotechnological Sciences
POB 5040
1432, Ås NLH, NORWAY
Tel: (+47) 64-947691
Fax: (+39) 64-947679

Ivan KREFT
Centre for Plant Biotechnology and Breeding
Dept. of Agronomy
Biotechnical Faculty
University of Ljubljana
Jamnikarjeva 101
Ljubljana, SLOVENIA
Tel: (+386) 61-263376
Fax: (+386) 61-1231088

G. LUNATICI
Comunità Montana della Garfagnana
Castelnuovo di Garfagnana
55032 (Lucca), ITALY
Tel: (+39) 583-658990
Fax: (+39) 583-644410

Davide MARINO
EUROPROGETTO
Via Dessiè, 4
Rome, ITALY
Tel: (+39) 6-8610164
Fax: (+39) 6-8607854

Giannetta MURRU
Istituto di Discipline Socioantropologiche
Facoltà di Magistero
Università degli Studi Di Cagliari
Piazza d'Armi
Cagliari, ITALY
Fax: (+39) 70-2002304

Enrico PORCEDDU
Faculty of Agriculture
University of Tuscia
Via S. Giovanni Decollato
01100 Viterbo, ITALY

Selso SAVOLI
President
Comunità Montana della Garfagnana
Castelnuovo di Garfagnana
55032 (Lucca), ITALY
Tel: (+39) 583-658990
Fax: (+39) 583-644410

G.T. SCARASCIA MUGNOZZA
Rector
University of Tuscia
Via San Giovanni decollato
01100 Viterbo, ITALY
Tel: (+39) 761-324687
Fax: (+39) 761-325785

Fabio VERONESI
Dip. Biotecnologia Agraria ed
Ambientale
University of Ancona
Via Brecce bianche 60131
Ancona, ITALY