Chapter 11

Archaeobotanical Significance of Growing Near Eastern Progenitors of Domestic Plants at Jalès, France

George H. Willcox

Author's note

This chapter, as published in 1992, described the results of experimental cultivation of cereals at Jalès between 1985 and 1988; the results were presented at the round table held at Jalès in 1988. This was a trial period leading up to experiments on selection rates in wild cereals. Now, over a decade later, important new archaeobotanical results from a number of key sites combined with theoretical results from continued experiments at Jalès have radically changed our understanding of the origins of cereal and pulse agriculture in Southwest Asia. The publications by Kislev on the difficulties of distinguishing wild and domestic emmer wheats (1989b:148), Hillman and Davies' (1990) publication on rates of domestication, and Baruch and Bottema's (1991) and Helmer et al. (1998) work on climatic change, which might be a contributing factor in the emergence of cereal cultivation (Cauvin et al. 1998), have begun to fill in the gaps in our knowledge. In addition, DNA studies on modern cereals (Heun et al. 1997) and a number of collective works such as Harris (1996) and Damania et al. (1999) have contributed to a far more complete understanding of early agriculture. Two recent conferences on the origins of agriculture in South west Asia, one at ICARDA (International Center for Agricultural Research in Dry Areas; Aleppo 1997: Damania and Valkoun 1997, Damania et al. 1999) and another at the University of Groningen (1998), produced a consensus of opinion among researchers who agreed that agricultural emergence was a very slow and gradual process (Pringle 1998, Willcox 1997).

Archaeobotanical data from a number of new early agriculture sites are helping our understanding of the process of domestication: for example, Cafer Höyük (de Moulins 1997), Abu Hureyra (Hillman et al. 1989, Roitel and Willcox in press), Cayönü (van Zeist and de Roller 1994), and Ashikli (van Zeist 1995) have recently been published, and others such as Jerf al Ahmar, Djade, Halula (Willcox 1996, Willcox and Fornite in press), Nevali Cori (Pasternak 1995), Qermez Dere, M'lefaat, Hallan Cemi, Nemrik (Nesbitt 1995), and Göbekli Tepe are now being analyzed. In addition new evidence has come to light concerning the present-day distributions of wild cereals, particularly in Syria (Valkoun 1992, 1997), but also their ancient distribution (Hillman 1996). These new results have added concrete evidence that we can compare with experimental data.

Following the roundtable meeting, and between 1988 and 1993, agricultural experiments at Jalès using wild einkorn (*Triticum boeoticum*) concentrated on an attempt to test the rapidity of the domestication process. A number of researchers had suggested that the selective pressure, under cultivation, for solid rachis cereals would have been high and that domestication would have proceeded so rapidly that the predomestic phase would not show up in the archaeobotanical record. To test this hypothesis in the field we used the model developed by Hillman and Davies (1990) in order to examine a range of possible cultivation techniques. Preliminary results have been published (Willcox 1990, but see also Willcox 1997, N.D.).

Experimental cultivation at Jalès of wild einkorn showed that spontaneous sowing was inevitable and may represent as much as 25% of the crop. Spontaneous seed corn in a harvest results in diminished selection rates (coefficients) for semisolid rachis mutants of inbreeding populations of wild cereals under cultivation. This implies that the lapse in time

Table 11.1 Temperature and rainfall statistics from two weather stations in Jalès region

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SALINDRES (altitude: 195 M), 1956–1985												
Avg. monthly max. temp. (overall mean = 18.1 C)	9.2	10.7	13.06	17.1	20.9	25.0	28.7	27.5	24.1	18.6	12.8	9.5
Abs. max. temp.	18.8	23.0	25.0	28.2	31.2	35.6	39.5	39.8	36.0	28.2	24.2	20.0
Abs. min. temp.	-13.6	-14.5	-9.0	-1.9-	0.2	4.4	4.8	7.8	2.0	-0.5	-7.9	-13.0
Avg. monthly rainfall: mm (1042 total)	82.0	67.3	94.4	78.7	89.0	68.5	39.8	62.7	18.9	142	109.5	99.2
COURBESSAC (altitude: 57 M) 1946–1987												
Avg. monthly max. temp. (overall mean = 19.3 C)	10.1	11.7	14.8	18.1	21.9	26.4	29.8	28.8	25.4	19.9	14.2	10.8
Abs. max. temp.	20.9	23.4	25.5	30.6	33.2	37.4	38.6	40.6	35.0	28.7	26.1	20.6
Abs. min. temp.	-12.	-14.	-6.4	-1.1	-1.1	5.4	10.0	9.3	5.4	0.8	-3.3	-9.7
Avg. monthly rainfall: mm (739 total)	58	63	67	51	66	41	25	49	71	109	71	68

between the beginnings of cultivation and morphological domestication (predomestic agriculture) may be longer than suspected. These results are inevitably hypothetical. However the archaeobotanical record, now better understood, does to some extent endorse the hypothesis. First, we are beginning to identify predomestic agriculture several centuries before the appearance of domestication at a number of sites from the associated weed taxa (Willcox 1996, Colledge 1997). Second, wild types persist for long periods after morphological domestication, for example at Aswad, Cayönü, and Halula. This indicates that it was not possible to keep the two populations apart well after domestication. The wild types could have been gathered in the wild, or been part of the field harvest as weeds or as part of the crop. In all cases the wild types because of their similar (almost identical) morphology would be difficult to keep separated from their domestic counterparts. In the initial stages of domestication, this would lower selection rates.

New evidence also suggests that there were multiple domestication events,for example, Hillman's evidence for rye domestication and Willcox's assessment of cereal assemblage variation which were both presented in papers at the Groningen conference in 1998. In addition, a number of sites indicate that wild types were replaced progressively by their domestic counterparts. Finally, in order to try to understand these new results experiments now under way at Jalès are testing different cereals such *T. urartu*, wild emmer, and wild barley.

THIS CHAPTER DESCRIBES SOME OF THE RESULTS obtained from growing wild progenitors at the Institut de Préhistoire Orientale at Jalès in southern France. The project, under the name of "Cultures Préhistoriques Expérimentales," was established in 1985 by Patricia Anderson, a member of the "Équipe de Recherche Archéologique 17," under the directorship of Jacques Cauvin, of the Centre National de Recherche Scientifique.

The domestication of plants was a consequence of their cultivation. The first signs of cultivation appear in the Middle East at the end of the Epipaleolithic and the beginning of the Neolithic, some 10,000 years ago (van Zeist and Bakker-Heeres 1984). This can be variously described as proto-agriculture or, preferably, pre-domestic cultivation, because at the beginning the plants under cultivation were morphologically wild and not yet domesticated.

This period of prehistory is still poorly understood, yet the transition from hunter-gatherers to farmers was fundamental to the history of mankind. The transition may have been gradual, yet the actual domestication appears to have been rapid (see chapter 10). Carbonized plant remains which morphologically resemble wild progenitors have been recovered from a number of sites, but it is difficult to determine whether they were cultivated or gathered from the wild (Hillman et al. 1989; van Zeist and Casparie 1968; van Zeist and Bakker-Heeres 1984). Our aim at Jalès is to elucidate the economy of this period by a process of simulation and experiment, through the cultivation of the very same plants, that is, the wild progenitors of the Old World domestic plants. On the one hand, we can set up experiments, and on the other hand, the act of growing these plants under primitive conditions is an apprenticeship which leads to increased knowledge of how Neolithic man might have cultivated these plants, which have not been cultivated on a large scale since the Neolithic. This project was inspired by Gordon Hillman, who started similar experiments in Wales but was thwarted by unfavorable climatic conditions (see chapter 10).

The wild ancestors of domestic plants have not been cultivated on a large scale since the early Neolithic because they could not compete with domestic crops which have evolved from them. The wild progenitors retained three basic characteristics which are disadvantageous to the prospective farmer, but essential for survival in the wild:

- Dormancy
- Uneven ripening
- Natural dispersal at maturity

These three features constitute the most important difference between wild and domestic Old World cultivars. According to a number of authorities (Harlan 1975; chapter 10; Zohary and Hopf 1988) these features were eliminated soon after the beginning of agriculture, or, more precisely, the beginning of cultivation.

Climate of the Region as Compared with That Occurring in the Natural Habitat

Both wild diploid wheats and wild barley show great climatic tolerance in terms of their natural distribution. Their habitats vary greatly in both latitude and altitude. Einkorn, for example, is found growing from 0 to 2000 m altitude and from Macedonia through eastern Turkey to Iran and Iraq; the most dense stands occur today in southeast Turkey, at altitudes between 900 and 1500 m. Wild emmer is found at 100 m below sea level in the Jordan valley and at 1500 m on the slopes of Mount Hermon (Zohary 1969). According to Zohary, the three Near Eastern wild cereals are important constituents of the sub-Mediterranean oak-park forest vegetation belt, which receives between 400 and 1000 mm of rainfall annually, falling mainly in the winter. In reality the different climatic zones are occupied by different ecotypes adapted to those particular conditions. Thus, it is not simply a question of comparing the different climates but more of finding ecotypes most suitable to the environment at Jalès.

The broad botanical and climatic similarity of the two regions tends to rule out the possibility of bias in our experiments at Jalès. The southern Ardèche, eastern Mediterranean, southeast Anatolia, and Zagros mountain region are in the same general climatic and vegetation belt. The climate of the southern Ardèche is classic Mediterranean. Jalès is situated at 130 m but there is a modifying continental influence of the Massif Central to the west and of the Alps to the east. Table 11.1 gives some statistics from two local weather stations in the region.

Vegetation in the Area of Jalès

The natural climax vegetation of the surrounding hills includes the following species: *Quercus ilex, J. communis, Q. pubescens, Pyrus pyraster, Buxus sempervirens, Celtis orientalis, Juniperus oxycedrus,* and *Phylliria media.* Olive groves are also frequent. On the plain of Beaulieu where Jalès is situated, the original flora has been totally replaced by agriculture. The cultivated fields at Jalès are situated on what was meadow grassland, cut for hay, which accounts for such species as *Medicago sativa, Onobrychis viciafolia* and a number of grasses (see section on weeds below). Inevitably the assemblage of plants making up the meadow determined some of the weeds present in the fields.

The Crops

During the first year we planted a large variety of different progenitors and crop plants, in order to build up a reference collection and gain experience in the behavior of a wide selection of plants. At the time of writing we have built up a grain stock for replanting which allows us to cultivate plots large enough to evaluate our experiments. These consist largely of wild progenitors of Old World cultivated plants, but in addition we are growing four other crops of cultivated wheats: *Triticum aestivo-compactum* #13, *T. dicoccum* #82; *T. spelta* #9, and *T. monococcum* #12.

More importantly, we have five populations of wild diploid wheats composed of *Triticum boeoticum* var. *aegilopoïdes* #55 Plant Breeding Institute; *T. b. aegilopoïdes* #77 Asia minor; *T. b. urartu* #59 Armenia; *T. b. thaoudar* #38 Crimea; and *T. b. thaoudar* #122 Eastern Anatolia. Of these five, our main population, grown on a larger scale than the others, is #122. This population was collected in 1986 in eastern Anatolia near Karaçadag (#7 collection M.-C. Falkowitz and D. Vaughan) between Diyarbakir and Siverek at an altitude of approximately 800 m and in a region where there is an annual rainfall of approximately 600 mm. The winter mean average temperatures are lower than at Jalès, while the summer means are more comparable. This population appears to be well adapted to the climate at Jalès and shows all the signs of being a truly wild species, which is not the case with certain other populations we have acquired from plant breeders.

In 1987 I collected the following wild progenitors in southern Syria: *Triticum dicoccoides* #124; *Hordeum spontaneum* #123; *Pisum humile* #127; *Lens orientalis* #130; *Vicia ervilia* # 131. These plants were gathered from localities in the Jebel Druze, an igneous volcanic massif predominantly of basalt, in contrast to the calcareous substratum at Jalès. The wild cereals were collected at an altitude of 300 to 400 m while the legumes came from a considerably higher altitude, between 900 and 1000 m.

These plants were sown at Jalès in the autumn of the same year, with very poor results, both in germination and in development. The reasons for these failures are no doubt multiple—for example, the absence of the specific *Rhizobium,* the nitrogen-fixing bacteria, in the case of the pulses—but the overriding reason is poor adaptability to the soil and climate of Jalès. We intend to continue planting these populations in the hope of selecting traits that would render them more adapted to this environment. However, it is possible that we could collect other ecotypes of the same species which would be suitable for this region from areas with more similar soil and climate. While wild emmer and barley may occur in or near cultivated areas, they do not to my knowledge show the intermediate morphology that can be seen in einkorn.

Landrace populations

In traditional farming communities the crops are highly variable, being made up of many different lines or genotypes. These are called landrace populations (Harlan 1975), and this built-in variability is an advantage to the farmer in that the various lines are resistant to different hazards in nature. It is only within the last century that landraces have been replaced by uniform true-breeding crops of controlled parentage. The populations we have gathered in the natural habitat show variability even to the extent of having some wild emmer and *Aegilops speltoides* mixed in, these having been accidentally harvested at the same time, which could, at the limit, be considered part of the same gene pool. The populations we obtained from plant breeders, in contrast, are single-line, true-breeding populations and are therefore less representative of early farming practices, despite the fact that they are wild progenitors.

Self-fertilization and its implications for crop plants

The Old World crops are all predominantly self-fertilizing. The rate of selfing may vary depending on a variety of factors. Boyeldieu (1980) reports that in wheat grown under hot conditions in north Africa, the spikelets open prematurely, raising the rate of cross-fertilization to ten or fifteen percent. However, the fact that these plants are predominantly self-fertilizing means that as a population they are made up of numerous true-breeding lines which makes selection of mutants (recessive or not) a straightforward process. For a detailed discussion on how this affects the rates of domestication, see chapter 10.

Time of Planting

Summer sowing

In their natural habitat the wild cereals sow themselves immediately after ripening. Thus the time of sowing is dependent on the altitude and latitude of the particular ecotype. Natural dispersion will therefore vary from May to August, following the relative ripening times in different geographical areas. It is possible that the first farmers copied the course of nature not just because it seemed the most obvious but to eliminate the problems of storage which could lead rapidly to total loss of viability.

During the first year our stocks were attacked by moths whose larvae consume grain; if the stock had not been quickly treated with insecticide we would almost certainly have lost our crop. The spikelets are adapted to survive the hazards encountered when dispersed naturally, that is, as soon as the plants are ripe. The only major danger we have experienced in the fields is from rodents.

There is another important advantage in planting early, though this remains to be proven, and that is to eliminate as much as possible the effects of dormancy. Finally, early planting may considerably increase tillering, a distinct advantage in that yield in terms of grain sown to grain harvested can be increased in this way.

The advantages of early planting are: no loss of viability through storage, increased tillering, and reduction of the effects of dormancy.

Planting dates for Jalès

The planting dates for the crops sown at Jalès are the following:

1985	15 to 20 October
1986	10 to 15 November
1987	25 to 27 November
1988	July to August and November

Until 1988 we planted according to the traditional times, variation from year to year resulting from varying climatic conditions and availability of labor. Spring planting always produced a diminished crop. Our domestic emmer crop produced twice as much from winter sowing when compared with the spring sowing for a given area. We are now in the process of experimenting with summer sowing techniques, that is, in July and August. Hillman observed Turkish farmers planting in early September.

Spontaneous sowing

Following the 1987 harvest the spikelets that were lost by natural shattering (those that fell to the ground), were left to geminate. Many germinated after the first rains during the second week in July and subsequently developed nominally; not a single plant flowered until the following year due presumably to lack of vernalization. The stand produced in 1988 was as extensive as the planted crop of 1987 which appeared to reproduce itself despite cropping. In 1988 we would have liked to continue harvesting this spontaneous crop, but unfortunately we arrived too late, the majority of the crop having already fallen; at the time of writing much of the crop has been lost to rodents, which reached epidemic proportions this year, apparently because of two successive mild winters.

Spontaneous sowing under cultivated conditions

During the Neolithic it is possible that a method of spontaneous sowing was used under conditions of cultivation: that is, the crop was harvested at a time when a proportion of the crop had already fallen. This method would not select for a solid rachis and is a major argument against rapid selection (for more detailed discussion, see chapter 10).

Spring planting and vernalization

Apart from the problems of storage, vernalization is the major factor controlling the season for planting, whether spring or winter. All Old World cereals can be planted in the winter but only those lacking the vernalization factor may be planted in the spring. We have not as yet tested all our crops for vernalization. *T. boeoticum aegilopoïdes* was both spring and winter-sown in 1987/8 and exhibited poor tillering for the spring-sown crop. In general, the wild wheats exhibit varying degrees of vernalization requirement and this almost certainly depends on the geographical distribution of different ecotypes. This kind of study is beyond the scope of this project but those interested should refer to Mathon (1985) who found a need for vernalization in all the wild einkorns he tested. It would appear that in the case of wild einkorn the vernalization factor would have made spring planting improbable for Neolithic farmers.

Both modern and primitive farmers today traditionally plant winter wheat crops because they give a much higher yield; only when the winter crop fails or they lack the right weather conditions for planting are they forced to plant in spring. In semiarid regions the lack of precipitation in spring results in an even greater difference between yields of winter and spring crops. On the other hand, some crops are frost sensitive or have a very short life cycle, as in the case of *Panicum miliaceum* and certain modern barleys and pulses, and so may be planted in the spring.

Table 11.2 Germination tests for 7 to 21 October 1987

SPECIES	REF.	NAKED GRAIN	HULLED	DOUBLE	COMMENTS
	#	%	%	%	
T. monoccoum	12	92	80	0	
T. dicoccoides	18	56	17.5	0	Only 40 spikelets
T. thaoudar	122	82	80	0	Green
T. thaoudar	122	62	42	0	Half green(moldy)
T. thaoudar	122	92	90	0	Ripe
T. thaoudar	77	94	94	0	Green
T. thaoudar	77	98	96	18	Half green
T. thaoudar	77	92	84	46	Ripe
T. thaoudar	38	92	98	16	Green
T. thaoudar	38	100	95	10	Half green
T. thaoudar	38	100	100	20	Ripe
T. urartu	59	82	94	6	Ripe
T. compactum	13	90	-	-	Free threshing
H. spontaneum	33	97.5	58	-	Ripe
	52	54	-	-	Green

Methods of Planting

Sowing naked or hulled

Germination tests show that when wild einkorn is sown naked the effect of germination inhibition is removed. It would therefore be logical to sow naked grains; however, the problem is that during removal of the glumes the grain is frequently damaged. For this reason, we sow hulled grains.

Sowing with or without awns

While it is not possible to throw the spikelets of awned cereals in the same way as one can broadcast naked grains it is perfectly possible to sprinkle the awned spikelets evenly over the soil. At first we removed the awns, but now this does not seem necessary. Contrary to what one might expect, the spikelets do not enter the cultivated soil more easily with the awns, whose function seems to be to help the spikelets penetrate a mat of vegetation and cracks in the ground in the wild situation, which they do very effectively. The awns serve an important purpose during separation of the straw and the spikelets because they burrow under the straw.

Depth of planting

Modem varieties of wheat are planted at a depth of between 2 and 5 cm. Wild wheats on the other hand have a much smaller grain and therefore need to be planted at a more shallow depth. The reason for poor germination in the field in 1986 was probably in part owing to the fact that the grains were sown too deeply.

Density of sowing

The optimum density given for modem wheats is 250 to 300 plants per square meter. However this is within the context of giving maximum yield per acre, as opposed to the return from a given amount of grain sown. It is the latter method of measuring the success of a given crop which would have been of interest to Neolithic farmers. Sowing at a low density may have been to his advantage because of increased tillering per plant. Having said this we have noted several important advantages when sowing wild wheats as densely as possible, which are:

- Elimination of weeds through increased competition
- More uniform ripening
- Ease of harvesting
- Elimination of sterile tillers
- Less tilling required

In fact, dense sowing produces a population which is much easier to harvest, and competion may cause it to ripen more uniformly. For this reason dense sowing is seen as a possible advantage to a farmer of wild cereals. It would also increase the chances of cross-pollination in what are basically selfers.

Broadcast as opposed to furrow sowing

Both techniques have certain advantages. Broadcast sowing undoubtedly requires more grain, although in our case the figures may be exaggerated through lack of experience. Agricultural manuals give the following figures for the number of kilos of wheat to be planted per hectare: 150 to 225 for broadcast by hand and 150 to 200 for furrow using seed drill. Our main crop of wild einkorn gave the following figures: 200 to 250 for broadcast by hand and 60 to 100 for furrow using seed drill. In terms of the number of stems per square meter we have the following figures for *Triticum boeoticum thaoudar* 122b: 402 broadcast and 436 furrow. Thus there is little doubt which is the most efficient in terms of yield. However, on a subjective level the ease of broadcast sowing and its efficiency makes it preferable. The gesture of throwing the seed, allowing it to slide out of the palm of the hand creating an even spread over a wide surface, seems the most natural of actions. Sowing in furrows is best suited to mechanical farming. We intend to continue using the two methods. In future, it will be important to record the number of spikelets per square meter and the number of plants.

Fallow system

The fields at Jalès have not been under cultivation long enough to determine whether or not we will adopt a fallow system. In terms of simulating the domestication process, there is little doubt that a fallow system would favor the domestic trait of the solid rachis, because there would be no chance of spontaneous sowing of the crop. Thus 100% of sown seed would have been harvested with no germination of fallen grain from the previous harvest (see also chapter 10).

In the Middle East the open nature of the landscape lends itself to the fallow system. For example, in southern Syria before the introduction of fertilizers, fields were only cultivated once every four years (Delbiet 1856). Hillman reports that in eastern Turkey the fallow system increased relative to the distance of fields from the village (Hillman 1973c). A further extension of the fallow system is to open new land every year. This would be useful in keeping agricultural weeds at bay and also avoid depletion of soil nutrients (for further discussion, see chapter 10).

Preparation of the soil

The soil before planting was prepared by ploughing with a tractor and then by passing a rotavator in the conventional way. This aggressive tillage does not resemble the possible methods of tilling available to Neolithic man and will in the long term affect the weed species present in our fields. On the other hand it should not greatly affect the behavior of the wild progenitors.

Germination

Germination in the laboratory

This is carried out systematically every year by the local agricultural college at Aubenas on samples of our seed grain, in order to compare germination in the field with that in the laboratory; test the levels of dormancy exhibited by our crops; and test the viability of wild cereals harvested before maturity. Table 11.2 gives the results of germination tests for October 7 through 21 in 1987. Four important conclusions can be tentatively drawn from these results: in the case of wild einkorn, a crop harvested before maturity gives viable seed for planting the following autumn; the glumes in the twinned-grained einkorns tend to inhibit the germination of the "second grain;" no twinned germination occurred in # 122; wild emmer and wild barley gave poor results, perhaps because of strong germination inhibitors; and #77 appears to lack the dormancy factor when harvested ripe. This population, which appears to be a single line (true-breeding), also tends to a more solid rachis. These results should be treated with caution until further tests have been carried out to confirm them. The

Table 11.3 Optimal harvest period

#	1986	1987	1988
122	1–5 July	1–5 July	1–5 July
55	5–10 July	10–15 July	10–15 July
59	25–30 June	5–10 July	10–15 July
77	5–10 July	5–10 July	10–15 July
38	5–10 July	5–10 July	10–15 July
124	–	*20–25 May*	15–20 June
123	–	*15–20 May*	10–15 June

Italic type is used to indicate collection in natural habitat.

choice of heads at different stages of ripeness is not based on the development of the grain but on the following features:

green	=	all glumes green, unshattered
half green	=	top-most glumes dry, unshattered
ripe	=	glumes dry, top of ear shattered

The reason for this method rather than the more conventional method as used by agronomists, who use a scale based on the hardness or softness of the grain, is that in the wild cereals, the spikelets on any one ear will not all be at the same stage of development.

To further test the effects of regulation of germination, that is to test the dormancy factor in hulled wheats, we will be carrying out tests over longer periods. Until now we have only been testing for 14-day periods.

Germination in the field

Germination in the field has proved to be far more difficult to assess, for two reasons: 1) when planting spikelets one is not always sure how many grains are present, and 2) our methods of planting are such that it is not always easy to compare the number of plants with the number of grains sown. In addition, germination in the field is a function of many different factors, including:

- Depth
- Relative humidity
- Temperature
- Time of planting

In many cases germination in the field was extremely variable from area to area, but the reasons for this are difficult to determine. Depth of planting and waterlogging are the most probable reasons. From the archaeological point of view it is obvious that it is the field germination which is relative to the evolution of crop plants and the eventual loss of dormancy. For this reason we will be including a program of field experiments in the future: for example, to test whether summer sowing decreases the effects of dormancy.

The fact that our population of single-grain wild einkorn, *Triticum boeoticum aegilopoïdes*, does not exhibit dormancy suggests it is perhaps more predisposed to domestication. The majority of domestic einkorns are of course single-

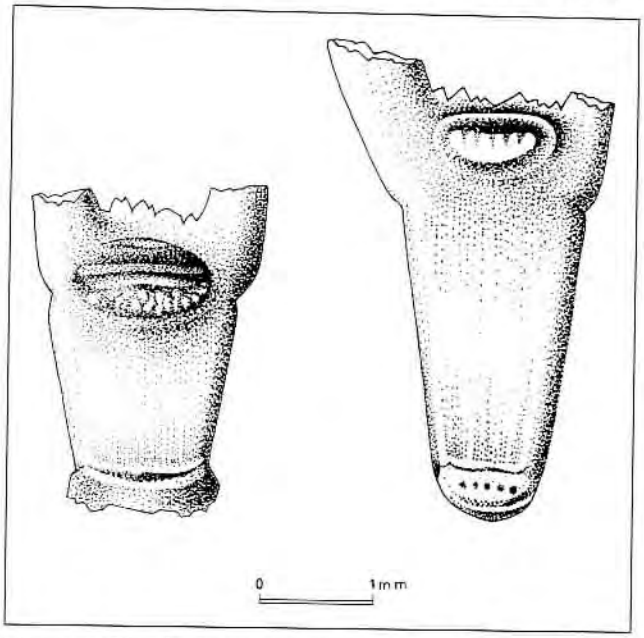

Figure 11.1 The abscission scars on the internodes of modern domestic and wild einkorn. While the morphological difference is clear in modern material 10,000 year after domestication, this is not always the case with archaeobotanical material.

grained. However it could be misleading to make conclusions from a single population.

Dormancy in the field

At present we have no accurate data on dormancy in the field, except to say that in a number of cases the emergence of the seedlings in wild cereals is later than in their domestic counterparts. Emergence under field conditions will be determined primarily by the weather conditions in any one year. Preliminary results show that in two-grained wild einkorn, grains do not remain dormant in the soil for more than the winter season.

Relative Ripening Times

One of the features of annuals in their natural habitat is that there is no uniform ripening of seeds from one plant to another or within the inflorescence. This is true for the wild cereals and pulses. It is also true for some of the more primitive domestic cereals such as einkorn, emmer, and spelt. For this reason it not always easy to estimate the time of ripening. In table 11.3 I have estimated the relative optimal five-day period during which a harvest was carried out with minimum loss through shattering and yet with a minimum number of immature heads.

These figures represent crops sown in the winter: those sown in the spring mature five to ten days later. The same population in different plots may vary up to five days, apparently depending on soil conditions; poor soil conditions retard the development of the plants by a period of approximately five to ten days. In 1986 we sowed #38 and #77 very densely on rich soil. There was good germination and the plots developed in a thick stand which appeared to force them into maturing more uniformly. These two samples both come from the Cambridge Plant Breeding Institute and have a rachis which behaves as an intermediate between wild and domestic plants.

Once the crop plants retain their seeds, irregular ripening becomes a harmless trait, and indeed remained with many crop plants. However, from our experience irregular ripening is disadvantageous when cultivating nondomestic cereals, this being an argument for rapid selection of a semisolid rachis once cultivation began.

Natural Dispersal Mechanism in Predomestic Crops

Abscission layer and disarticulation of rachis

Before discussing the details of our observations it should be noted that four different morphological types can be distinguished as far as the rachis is concerned:

1) Wild einkorn, fragile rachis
2) Segetal einkorn, and many populations from plant breeders, intermediate between 1 and 3
3) Domestic einkorn, emmer, and spelt with semibrittle/ solid rachis
4) Hard and soft free-threshing wheats with a solid rachis

In wild cereals the ear matures progressively with the uppermost spikelets ripening first. As they dry out, the abscission layer, which is already formed, separates on drying and the segments fall. That the abscission layer in wild barley is formed early in the development of the plant can be shown by cutting an ear at an early stage, for example when it is in flower, then allowing it to dry in the sun; eventually the ear will break up just as it does at maturity, though not having formed grain. Thus the danger of confusing the remains of a green harvest of a wild cereal with that of a solid or semirachis population under the conditions of carbonization (pseudo-solid rachis) would be extremely unlikely, since any crop harvested green would be immediately dried, an almost unavoidable process in a Mediterranean climate. In the case of wild einkorn the same experiment was conducted for #122 with the same results.

Weather conditions, or more specifically relative humidity, greatly affect the shattering of the rachis. Thus if a wild crop is ripe, it is an advantage to harvest early in the morning, while the dew is still on the plant, to avoid shattering.

According to Zohary the evolution of the semisolid rachis involves only one gene (see chapter 6); he suggests that theoretically the shift from brittle to nonbrittle rachis should have been fast, and if the planted populations were large enough it could have been accomplished in a matter of a few generations (Zohary 1969, 60). The presence of intermediate types indicates the possibility of other genes being involved. However these intermediate types have not been identified in archaeological sites.

Hillman and Davis (chapter 10) have measured selection coefficients and on this basis have estimated the time between the beginning of cultivation and the appearance of a semisolid rachised population. In 1984, Hillman suggested that we should attempt a simulation of the domestication process in order to test the theory at Jalès. This experiment has already been set in motion as part of the project. However there remains, in the experimental situation, the problem of population size, which in the Neolithic was ample enough (see chapter 10). Green harvesting, if this was indeed an ancient harvesting technique, would be less selective in terms of a population with a semisolid rachis population and may tend to select for late ripening (see Willcox and Anderson, "The effect of different harvesting techniques on mutant frequency," 1991).

Possible intermediate types

Two populations of wild einkorn, #77 and #38, retain their spikelets more readily than the other populations, yet not as efficiently as the true domesticates. These populations were sent to us from the PBI in Cambridge, England, and their history since they were collected has not been established at the time of writing. Indeed this phenomenon could be explained if the plants were collected from weed populations where intermediate forms had evolved. For weedy ecotypes this intermediate stage appears to be an advantage because part of the population remains with the crop and part falls to the ground (Harlan 1975). All the populations which were obtained from plant breeders are true-breeding single-line populations and two of these populations must have originated from an intermediate type of parentage or from a cross between wild and domestic forms which occurred during breeding.

Rachis fracture in wild and domestic einkorn

The difference at the point of the break between wild and domestic einkorns after shattering can be clearly distinguished (figure 11.1). Our conclusion is that the internodes from a green harvest will break up after drying, but that intermediate varieties such as we have seen in populations obtained from plant breeders could complicate the issue. Whether these types existed in antiquity has not been demonstrated.

Selection for the semisolid rachis

Because the Old World cereals and the pulses are all "selfers" the selection rates for nonshattering heads would have been relatively quick, unlike cross-pollinators where recessive traits would not be manifest so frequently. Domestic plants which are cross-pollinating are often vegetatively propagated; thus as with "selfers" advantageous mutants are not lost through segregation and introgression, According to Harlan (1975) tribes in Africa do consciously select seed from sorghums and broomcorn millet. It is doubtful that this was an important factor in the development of Near Eastern cereals. However, once the semisolid rachis genotype became obvious, then it is possible that Neolithic man could have consciously kept back grain which to him seemed most suitable for cultivation. For the evolution rates of the domestication of wild einkorn in respect to the semisolid rachis, see chapter 10.

Methods of Harvesting

For a detailed discussion on the implications of different harvesting techniques see chapter 12. The following observations were found to be significant for interpreting the archaeobotanical record:

- A harvester will attempt to avoid weeds, particularly spiny plants such as thistles;
- Shaking ripe heads into a container was unsuitable for wild einkorn in our densely sown plots. However it may be more suitable in the wild situation, especially in the case of panicled grasses;
- Uprooting contaminates grain stock with soil and so may be more suitable for fodder crops such as hulled barley and bitter vetch;
- A green or premature harvest provides a viable crop with less seed loss than a ripe harvest.

Threshing

Fragile rachis

At present we can only report on our experiments in separating the spikelets from the straw, which is the first stage of threshing (Hillman 1984a), and one that would be eliminated if the harvest was carried out by shaking. For wild einkorn the crop must be left to dry, which starts the process of shattering the ears. Beating, trampling or flailing are all effective methods (many others exist, Hillman 1984a). The most efficient method is to beat small sheaths against a wall in order to break up any ears which are not completely shattered. Any straw that falls or becomes mixed with the spikelets is automatically separated because the arrow-shaped spikelets with their barbed awns always burrow down so that the straw simply has to be raked off the surface from time to time.

Semifragile rachis (as seen in T. monococcum and T. dicoccum)

These crops have a semifragile rachis. The process of separating the spikelets from the straw is exactly the same as for wild einkorn. For this reason it would appear that the semifragile rachis is indeed an advantage when threshing hulled wheats, and this no doubt is why it was retained in the hulled wheats since the Neolithic.

Table 11.4 Weed species found among crops

Salicaceae	*Populus alba* (suckers)
Polygonaceae	*Polygonum aviculare*
	P. persicaria
	Fumex crispis
	Bilderdykia convolvulus
Chenopodiaceae	*Chenopodium alba*
	Atriplex patula
Amaranthaceae	*Amaranthus retroflexus*
Caryophilaceae	*Stellaria media*
	S. sp.
	Silene alba
Ranunculaceae	*Ranunculus bulbosus*
	Nigella damascena
Papveraceae	*Papaver rhosas*
	P. somnifera
	Fumaria officinalis
Crucifereae	*Sisymbrium officiale*
	Capsella bursa-pastoris
Resedaceae	*Reseda phyteuma*
Rosaceae	*Potentillia reptans*
	Agrimonia euphatoria
	Sanguisorba minor
	Fragaria vesca
Leguminoseae	*Medicago arabica*
	M. sativa
	M. lupulina
	Ononis spinosa
	Melilotus altissima
	M. officinalis
	M. alba
	Trifolium pretense
	T. dubium
	Vicia sativa
	V. benghalensis
	V. hirsuta
	Lotus corniculatus
	L. tenuis
	Onobrychis viciifolia
	Lathyrus hirsutus
	L. sp.
Geraniaceae	*Geranium robenianum*
Euphorbiaceae	*Mercurialis annua*
	Euphorbia sp.
Polygalaceae	*Polygala vulgaris*
Malvaceae	*Malva sylvestris*
	Althaea cannabina
Umbilliferae	*Daucus carota*
	Eryngium campestra
Rubiaceae	*Galium verum*
	G. aparine
Convolvulaceae	*Convolvulus arvensis*
Boragonaceae	*Heliotropium europaeum*
Verbenaceae	*Verbena officinalis*
Labiatae	*Galeopsis segetum*
	Calamintha nepeta
	Prunella vulgaris
	Salvia sclarea
Solanaceae	*Solanum nigrum*
Scophulariaceae	*Linaria* sp.
	Kickseia sp.
Plantaginaceae	*Plantago major*
	P. lancelata
	P. media
Campanulaceae	*Legousia speculum veneris*
Compositae	*Cirsium arvense*
	C. vulgaris
	Sonchus arvensis
	S. oleraceus
	Senecio vulgaris
	Helianthus annuas
	Carthamus lanatus
	Lactuca serriola
	L. verminea
	Picris echioides
	P. hieracoides
	Taraxacum vulgare
	Tragopogon porifolium
	T. pratensis
	Achillea millefolium
	Centaurea nigrum
	Chrysanthemum leucanthemum
	Cichorium intybus
Liliaceae	*Muscaria* sp.
Gramineae	*Lolium rigidum*
	Bromus tectorum
	B. erectus
	B. sterilis
	Festuca pratensis
	Cynodon dactylon
	Setaria viridis
	Gramineae spp

Solid rachis

This morphological feature occurs only with free-threshing wheats where the chaff and the straw are separated from the naked grains in the same operation. Why this labor-saving characteristic was not adopted on a wide scale since solid rachis forms were present during the Neolithic, is a mystery.

Weed Species

Not all the species found growing among our crops are true weed species; some come from the meadow flora which had existed before we ploughed. Over the first three years we have already seen some of these species diminish and the ruderals increase, but it is difficult to draw any conclusions over such a short period. In the first year the most dominant weeds were *Bromus tectorum* and *Cirsium arvensis*. The second year was similar, but in the third year there is a predominance of *Lolium rigidum, Daucus carota* and *Melilotus officinalis*. Table 11.4 is a list of the plants that have occurred in the fields to date and have been noted during the time of the harvests of 1986, 1987, and 1988. As can be seen

Table 11.5 Threshing floor residues

	SEEDS	TYPE
122B H1 1988 COURTYARD JALÈS		
Ononis spinosa	28	W
Onobrychis vicilfolia	1	W
Trifolium dubium	31	W
Lolium sp.	5	W
Mercurialis annua	3	W
Bromus sp.	10	W
T. boeoticum	5	C
Tilia cordata	3	ct
122B H7 1988 BARN		
Vicia sativa	5	W
V. bythynica	3	W
Melilotus sp.	16	W
Galium aperine	25	W
Rumex crispis	17	W
Bromus sp.	4	W
Lolium sp.	5	W
Aegilops speltoides	2	W cont.Turk
T. boeoticum naked grains	3	C
T. boeoticum internode frags	2	C
T. aestivo-durum	3	ct
Stem base	2	C
Mouse droppings	3	ct
Vitis vinifera	1	ct
Helianthus annuus	6	ct
Fragments of wood	1	ct

W = weed; W cont. Turk = weed from collecting area; C = part of crop; ct = contamination at the threshing floor

Table 11.6 Dimensions and index values for crops at Jalès, 1988

		L	B	T	L/B	T/B
122	Max	8.9	1.8	3.0	778	227
	Min	5.6	9	1.2	444	100
	Avg	7.3	1.3	1.8	558	141
122	Max	8.8	1.9	2.5	714	220
	Min	5.0	7	1.3	381	100
	Avg	6.7	1.3	1.8	513	137
55	Max	8.8	1.9	2.5	714	300
	Min	5.0	7	1.3	381	125
	Avg	6.7	1.	1.8	513	208
77	Max	8.0	1.8	2.5	681	211
	Min	5.1	0.9	1.3	387	100
	Avg	6.6	1.3	1.8	487	132
Percival		6-7.5	1-1.5	2.1-2.6	-	-
Mureybet	Max	6.5	1.7	1.7	570	155
carb.	Min	3.4	0.8	0.9	232	68
	Avg	4.6	1.2	1.3	394	107
Lens					1987	1988
orientalis		Diam.	Thickness		Diam.	Diam.
1987	Max	3.5	1.7	*Pisum*	5.8	5.0
	Min	2.2	0.8	*humile*	3.5	2.6
	Avg	2.9	1.5		4.6	4.0
		L	B			
Vicia	Max	3.4	3.2			
ervilia	Min	2.5	2.3			
1987	Avg	2.9	2.7			

from the list there are at least ten perennials present despite our aggressive tilling methods. Thus the presence of perennials associated with a crop is not indicative of gathering, especially when one considers that during the early Neolithic the tilling was almost certainly very shallow.

Table 11.4 includes many species that reflect the surrounding vegetation rather than a field cultivated under primitive conditions. For example, the sunflowers were brought in by birds from surrounding fields. *Setaria viridis* is typical of the irrigated fields around Jalès, as is amaranth which is found on the more sandy soils in the region. How much of a problem weeds were to the farmer of primitive crops can not be determined from our experiments, because the type of tilling would greatly affect the weed population.

Described in the section below are the weeds present in the residues from threshing areas sampled during harvesting. So far our experience shows that by sowing early and densely, the weed problem can be greatly reduced. Some of the weeds in the fields are of course edible and it is possible that primitive humans may have encouraged certain field weeds.

Threshing Areas

Self-seeding

The presence of self-seeded cereals occurring in and around threshing areas at Jalès is common, and no doubt this almost unavoidable phenomenon also occurred during the Epipalaeolithic at the gathering stage. Could this natural process have heightened man's awareness of plant potentiality? In other words, when he inadvertently displaced wild einkorn, it may have introduced him to the idea of cultivation.

Analysis of threshing floor residues

Archaeobotanical finds from early Neolithic sites frequently contain a large number of weeds (see Hillman et al. 1989, 1984a, 1985, and van Zeist and Bakker-Heeres 1984). The exact origin of these carbonized seeds is not always clear. We have analyzed residues after threshing in order to determine what weeds are contaminating our harvests, in the hope of aiding the archaeobotanical interpretation. Table 11.5 includes two lists of seeds from a sickle harvest, from two separate threshing areas, excluding spikelets of the main crop.

When compared with the results from archaeological sites this assemblage of weeds appears rather poor in number of species. This may be more apparent than real, since in the archaeological context there is a much richer concentration of residue, representing possible buildup over many years of harvesting. Hillman reports that on modern Turkish threshing floors he has recorded up to seventy species (Hillman 1984a).

The most common weeds are represented by species which are medium to tall, the weeds of less than 20 cm being less represented. During the harvest the harvester tried to avoid

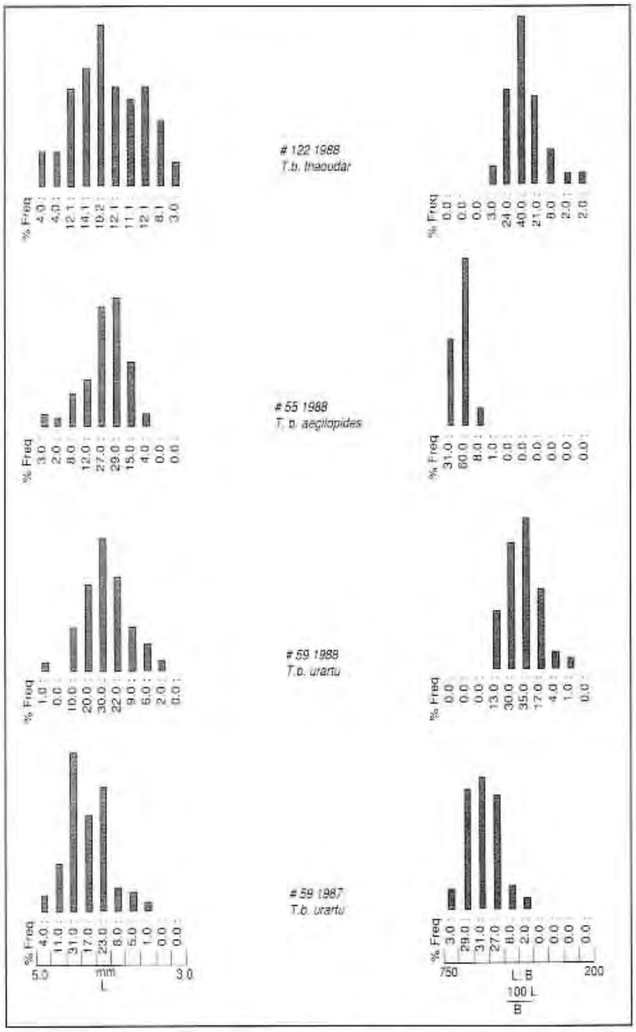

Figure 11.2 Histograms giving length and length/breadth index for four wild einkorns cultivated at Jalès

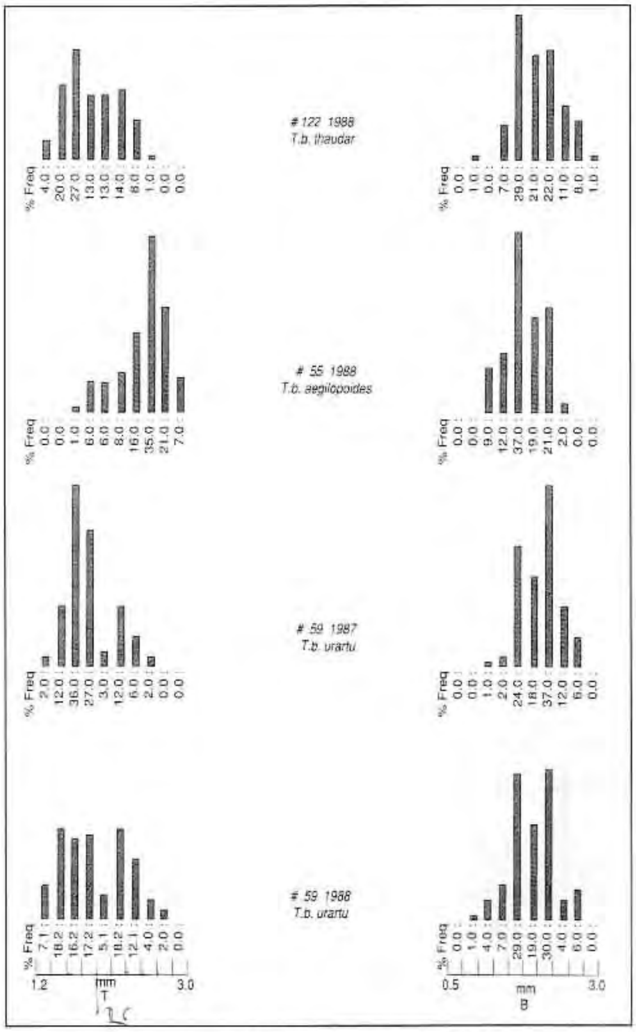

Figure 11.3 Histograms of thickness and breadth dimensions from four cultivated wild einkorns. Note double peak for the twin-grained varieties.

the weeds by cutting round them or making a high cut above them; despite this there are always a few which become tangled with the harvest. As can be seen from table 11.5 there are also a number of species that come not from the field but from the threshing floor itself. The list represents what was discarded. In the prehistoric context it would have been this part that was more likely to end up in the fire and subsequently carbonized rather than the crop itself. It is thus not surprising that frequently on archaeological sites the weeds may outnumber the crop plants. It is also for this reason that medicinal plants and other plants of special value are so rarely represented.

Biometrical Analysis

Grain size

Measurements of grain size and relative shape are frequently used to aid in the identification of cereal remains from archaeological sites (Renfrew 1973; van Zeist and Bakker-Heeres 1984; Helbaek 1963; Percival 1921). Between very similar subspecies, environmental variation may be as great or greater than variability at the genetic level. While this is almost always the case with stem height, it does not appear to be true of grain size. Within a crop a wide variation in the genotypes is also possible, as seen in variability in the population, in a number of landrace lines (see above). In addition to the variables already mentioned in the archaeobotanical material there is the process of carbonization, which distorts the grain (Renfrew 1973; Helbaek 1963).

It should be pointed out that measurements of grain size are only one way to describe populations recovered from archaeological sites. Others include embryo shape, hilum form, testa histology, and chemical indicators. However, here we are especially concerned with grain size. The most convenient method to describe grain size/shape is by scatter diagrams and histograms. Measurements of the crops we have grown at Jalès were taken from 100 grains. These are given below for reference to archaeological material. For the twinned einkorns we opened the necessary number of

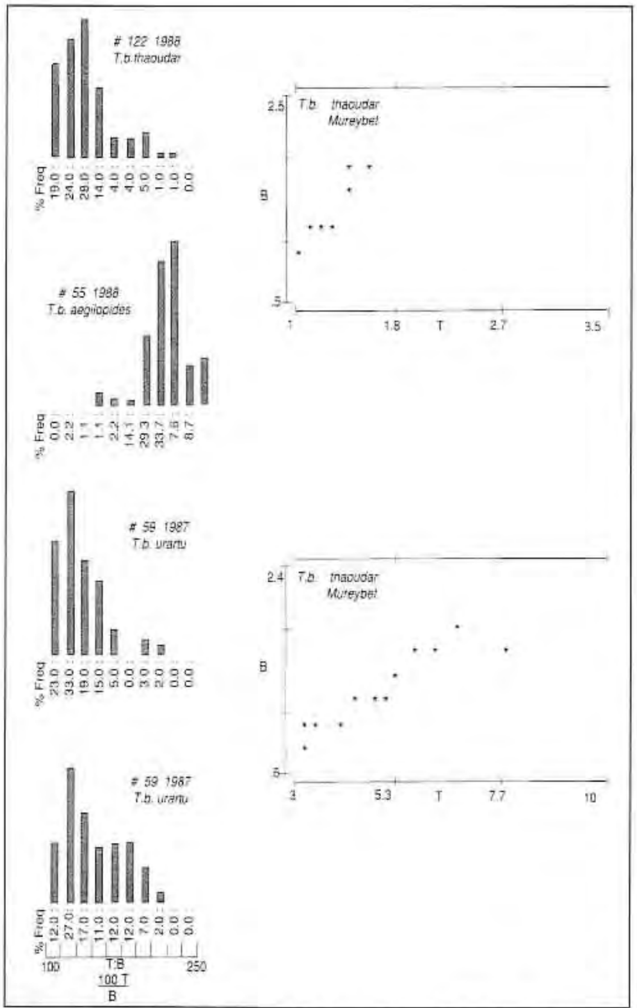

Figure 11.4 Histograms giving thickness/breadth index. Note difference in the single-grained variety #55. Scatter diagrams of carbonized grains from Mureybet taken from van Zeist (1984).

Table 11.7 Aubenas measurements

#	WT SAMPLE	WT GRAIN	WT CHAFF	% GRAIN	% CHAFF	WT 100 GRAINS
122	4.40	1.91	2.49	43.4	56.6	1.27
55	0.82	0.27	0.55	32.9	67.1	1.66
77	0.98	0.51	0.47	52.0	48.0	3.50
59	2.57	1.26	1.31	49.0	51.0	1.54
38	4.07	1.88	2.19	46.2	53.8	1.40
12	1.82	1.30	0.52	71.4	28.6	2.50
82	2.48	1.55	0.93	62.5	37.5	3.35
9	11.06	7.33	3.73	66.3	33.7	4.08

Table 11.8 Weights and surface areas for Jalès crops

#	SOWN 1986	M^2	HARVEST 1987	SOWN 1987	M^2	HARVEST 1988
122	0.75	130	6.5	6.5	501	17.4
77	0.130	14	2.5	2.0	61	3.8
59	0.08	15	2.5	2.0	58	2.1
55	1.36	180	10.0	5.5	150	5.5
38	0.18	35	6.0	2.5	96	7.0
123	-	-	-	0.65	115	0.9
12	0.46	70	11.0	6.0	146	10.1
13	1.09	66	14.0	13.5	576	22.0
82	1.4	100	12.0	7.0	150	11.07

spikelets in order to arrive at 100 grains; some spikelets only contained one grain. The proportions are:

			DOUBLE	SINGLE
T. thaoudar	122	1988	84	16
T. thaoudar	122	1988	88	12
T. urartu	59	1988	66	33
T. urartu	59	1987	90	10
T. aegilopoïdes	55	1988	0	100

Notice the strikingly different figures for #59 from one year to the next. In 1988 the crop did very poorly and, significantly, produced far fewer twinned-grain spikelets.

Table 11.6 gives the dimensions and index values for the crops at Jalès for 1988. The measurements obtained from wild einkorn grown at Jalès are greater than those of the modern grains reported by van Zeist and Casparie (1968) and considerably larger than the carbonized grains reported from the archaeological site of Tell Mureybet in northern Syria. The process of carbonization may account for these differences. On the other hand, these measurements are not so different from those given by Renfrew (1973).

In figures 11.2, 11.3, 11.4, 11.5, and 11.6, the morphology of the grains are described in the form of scatter diagrams and histograms, in order to determine the possibility of distinguishing the three races of wild einkorn on the basis of grain size. Measurements for #77 are given for 1987 and 1988 in order to see whether environmental differences would show up, since in 1987 this crop was very successful, having been grown on rich soil in the garden area. The following year, 1988, it was grown on poor soil. While certain differences can be seen, they are not as great as those between *T. aegilopoïdes* and *T. thaoudar,* which show up clearly in thickness and the TB and LB index as well as in the scatter diagrams. On the other hand, the distinction between the two twin-grained races, *T. urartu* and *T. thaoudar,* is not apparent. These two types can only be securely separated on the basis of their glumes.

Ear Lengths

The height of the ear in the diploid wheats is a feature that distinguishes truly wild forms from their domestic counterparts. This reduction in ear height may be related to the less fragile rachis seen in domestic wheats and is caused by the compactness of the spikelets rather than a reduction in the number of spikelets per ear. This compactness may also influence the relative ripening of the ear. As the height of the ear may be a determining factor for domestication, we measured relative heights and these are given below. Although the length of the internodes is of more use for comparison with the archaeological material, the length of the ear gives a relative measure and in the future we will be giving exact dimensions for the internodes.

The length of ears before shattering, mean average from

100 heads, is as follows:

Triticum boeoticum thaoudar	122b	8.65 cm
Triticum boeoticum thaoudar	122b	9.12 cm
Triticum boeoticum aegilopoïdes	55c	8.38 cm
Triticum boeoticum aegilopoïdes	77c	7.43 cm
Triticum boeoticum urartu	59c	7.05 cm
Triticum monococcum	12c	6.14 cm

The above measurements show that the domestic population has the shortest ear. Also, the populations that are thought to be intermediate are shorter than the population of #122.

Other biometrical data concerning the ear

The results in table 11.7 are based on measurements made by the agricultural college at Aubenas. As shown, *T. boeoticum aegilopoïdes* #77 gives a very high figure for the weight of grain, although this sample, supplied from plant breeders, should be treated with caution. The table also shows that for the wild einkorns the weight of grain is less than the weight of the chaff. This is relevant in terms of the possibility of long-distance transport of cereals because there would be a distinct weight advantage in transporting threshed grains. In terms of bulk the removal of the envelope would also make a great difference (van Zeist 1984; Hillman et al. 1989).

Yield

The relevance of crop yield in the modern sense is of limited interest to the archaeobotany of the early Neolithic in the Middle East. The primitive farmer would have been less interested in how many tons he obtained per hectare than in the return from a given amount of grain, regardless of the surface area. He would also favor a constant return, despite natural environmental fluctuations. Even in Europe, up to the turn of the century farmers still measured their harvests in this way (see chapter 28). In drier areas, as in the Middle East where the ground naturally has very little vegetation cover and is easily tilled, there is far more tillable land compared with northern Europe. It is for this reason that in many areas of the Middle East there is an extensive fallow system (Delbet 1856).

Table 11.8 gives the various weights in kilos and surface areas in square meters for some of the major crops at Jalès.

Interpretation of the yield

The difference between 1987 and 1988 is very marked. This difference can be accounted for by the following variables:

- Differing weather conditions
- Spring planting in the case of #82 and #55 in 1988
- For #59 and #77 the tillering was very poor: this may have resulted from an exceptionally mild winter which did not provide the necessary vernalization
- Plants were generally grown on poorer soil in 1988
- Harvesting techniques for the 1988 season were less efficient, and in some cases there was unnecessary loss
- In 1988 the fields became infested with harvest mice and other rodents which in some cases, particularly the wild barley crop, led to large losses
- In the case of # 122 and #55 we did not harvest early enough so many of the ears had already begun to shatter and had therefore lost their upper spikelets

The results from 1987 show that it is possible to produce a viable harvest from wild einkorn. Yet the results from 1988 alone would not be encouraging. By experience we hope to learn how to increase the yield of these wild plants.

Storage

While early planting may ease the problem of storage, there is still a need for storage, not just for consumption but also as an insurance against years with catastrophic harvests. At present we are not at the stage where we can experiment with copies of so-called storage structures found on early Neolithic sites, but it is our intention to investigate the possibilities of storing wild progenitors in future experiments. It might also be useful to compare hulled and naked wheats.

Conclusion

After three seasons of growing the wild progenitors of domestic plants it is clear that there is a great deal to learn about pre-domestication cultivation and the beginning of agriculture, which occurred at the interface of the Epipaleolithic and the Neolithic. The results are beginning to give us a more complete view of the problems faced by the first farmers, and the observations and data we are collecting are proving useful in interpreting the archaeological and archaeobotanical record.

The most important archaeological question is to determine the duration of this period, in order to accurately distinguish between the gathering stage and the cultivation stage, when the plants were morphologically identical. Hillman has provided extremely convincing data which indicate that under certain conditions selection for domestic characteristics would have been very rapid. By establishing the probable agricultural techniques wild plants require, we hope to be able to show how they might affect the rates of selection of domestic traits occurring as natural mutations in a given population. The rates of evolutionary domestication based on measurements of selection coefficients generated by primitive forms of harvesting are discussed in chapter 10. One outcome of growing these plants is that we find ourselves attempting to discover ways of eliminating the problems posed by their undomestic behavior. The first farmers faced the same problems and would have sought to overcome them too. We are not yet at a stage where we can demonstrate that

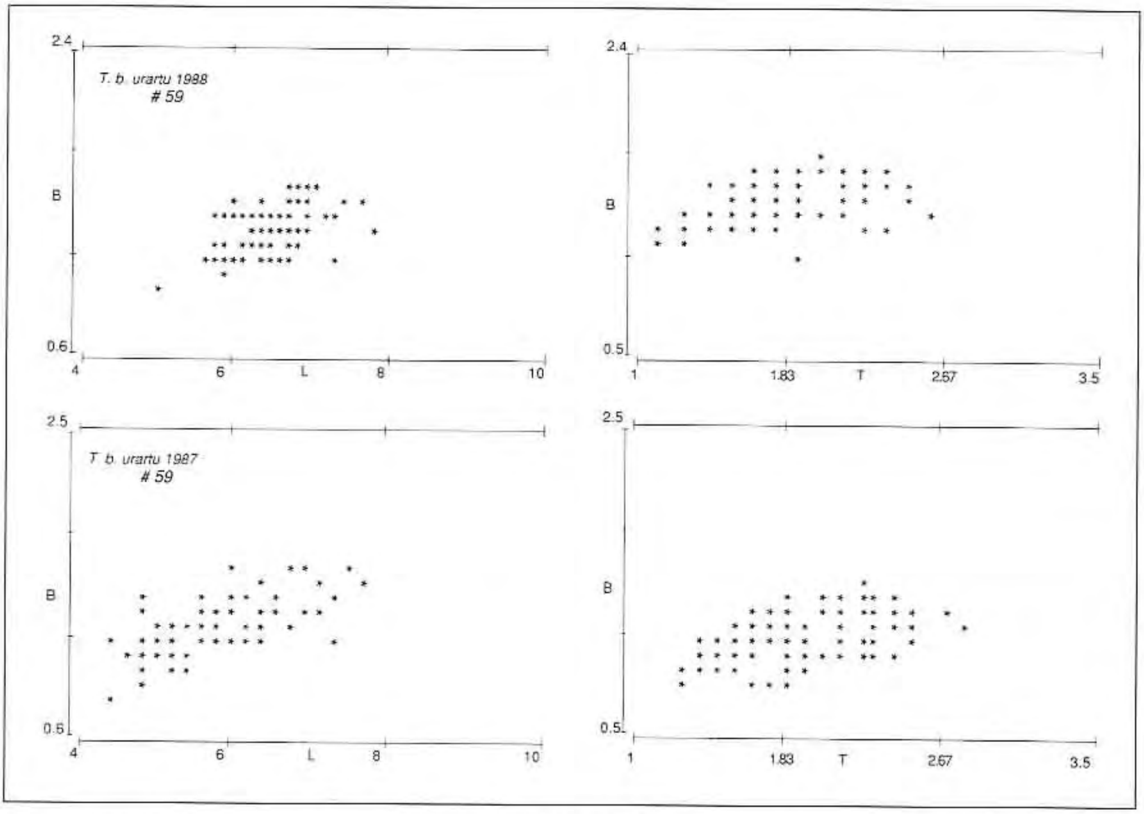

Figure 11.5 Scatter diagrams plotting length against breadth and thickness against breadth for different populations of einkorn

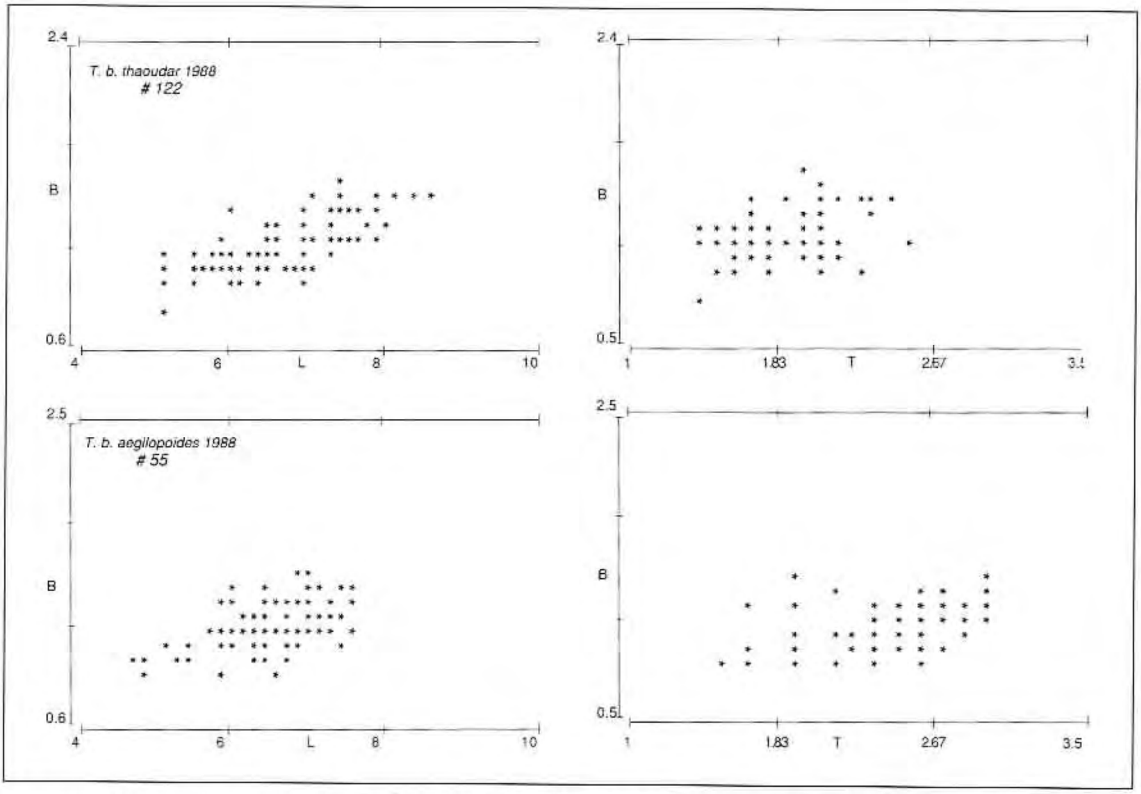

Figure 11.6 Scatter diagrams plotting length against breadth and thickness against breadth for different populations of einkorn

by using certain techniques the wild characteristics which are disadvantageous to agriculture can be overcome, but we can suggest possible methods; regulation of germination—summer planting; cultivation of one-grained einkorn; uneven ripening—dense sowing; and dispersal of grain—harvest before maturity. If these techniques prove successful in overcoming the difficulties of cultivating wild crops, we could then envisage reduced selective pressure for domestic mutants. This would imply a prolonged stage of predomestic cultivation. However our initial and inexperienced attempts at simulating the plant husbandry of the neolithic farmers suggest, on the contrary, that selection pressures were very high. The question is, can we adapt to these plants before they adapt to our manipulation?

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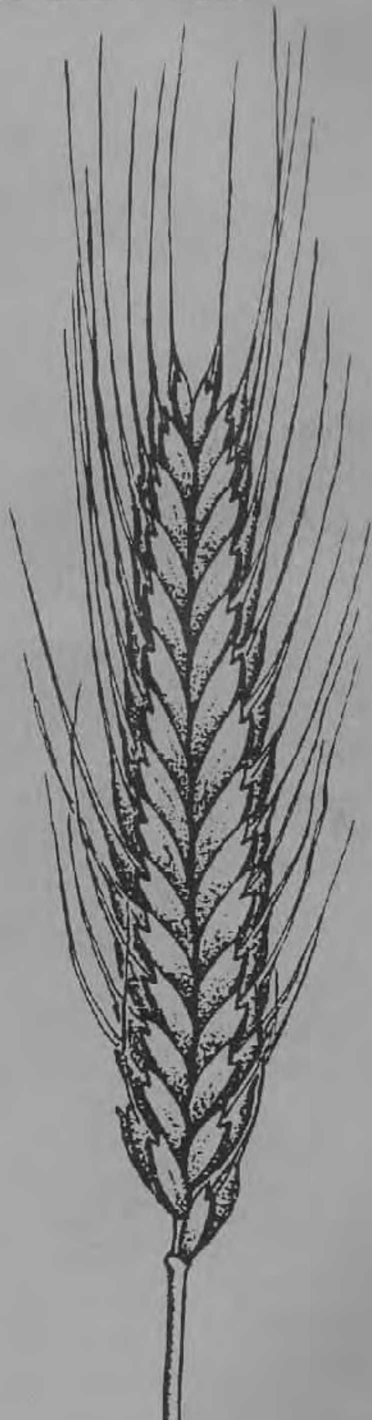

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