CROP YIELDS OF THE PREHISTORIC CEREAL TYPES EMMER AND SPELT: THE WORST OPTION

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The Butser Ancient Farm Project was set up in 1972 as a unique open air laboratory dedicated to exploring empirically the archaeological evidence for the agricultural and domestic economy of the latter part of the 1st millennium BC In effect, the component elements of an Iron Age farm were built as experimental constructs with time utilised as a crucial validating factor. The overall programme includes investigations into buildings, earthworks, livestock and crop husbandry. The latter clearly involves field management and fencing as well as grassland maintenance (Reynolds, 1979).

At present (1997), Butser Ancient Farm manages three specific locations, the main site of the laboratory itself at Bascomb Copse near to the village of Chalton (N.G. 719166), an experimental earthworks site in the Science Museum grounds at Wroughton, near Swindon and a further earthworks site in the grounds of Fishbourne Roman Palace near Chichester. In addition, it has international co-operative research programmes at L'Esquerda near Vic in Osona, Catalonia, Spain (Reynolds, 1998) and at Szazhalombatta, near Budapest in Hungary (Reynolds, forthcoming). At both of these sites, a major research programme includes studies of the yield potential of prehistoric cereal types. The original locations of the Ancient Farm at Little Butser and later at Hillhampton Down were given up in 1990 when the lease was withdrawn by Hampshire County Council (Reynolds, 1995). The withdrawal of the lease coincided with a need to terminate the 'worst option' (q.v. below) and move to a different and improved bio-climatic zone more typical of the landscape exploited in the Iron Age which in due course will provide a balance to the data published in this paper.

The first location, exploited from 1972 to 1989 and the one specifically pertinent to this report, is on a spur called Little Butser which juts northwards from Butser Hill, the highest of the chalk downs in Hampshire in southern England (Ordnance Survey Sheet 197. ref. 719208). The history of the spur at 174 metres above sea level indicates the hostility of its location. It has only been used as rough pasture within living memory, the grassland remaining unimproved and, therefore, relatively species rich (Tansley, 1939). Archaeologically there are several field monuments on the spur. The most recent is a pillow mound, an artificial rabbit warren, probably dating to the 18th or 19th century (Crawford & Keiller, 1928). In addition, there is a circular dished depression which was probably an Iron Age house platform and a length of unfinished ditch and bank also of Iron Age date. A number of trackways dating from the Neolithic to the mediaeval period traverse the site. Archaeological investigation has revealed indications of fairly intensive occupation of the spur from the late Bronze Age through the Iron Age. There is no evidence of Roman occupation. It would seem that the spur supported a small prehistoric farmstead, the fields of which were probably on the eastern slopes of the spur and in the valley to the north. Excavation has shown that the site area itself was not cultivated in prehistory. The abandonment of the spur probably occurred during the first century BC. Apart from rough grazing, the wooded slopes of the spur which support hazel *(Corylus avellana)* and ash *(Fraxinus excelsior)* were clearly used as coppice within the recent past.

The soil cover on Little Butser is a puffy black friable rendzina averaging just 100 mm in depth directly onto middle chalk, the hardest of the three types of chalk of the downlands in Southern Britain. In effect, the location is extremely hostile. The spur is oriented to the north being totally exposed to the harsh climatic winter conditions from the northwest round to the east yet shielded from the best summer conditions by the bulk of Butser Hill to the south and south-west. The soil is shallow and relatively poor with an average pH of 8.0. The middle chalk rock allows least transpiration of moisture into the topsoil. These conditions clearly explain why the spur has never been used for arable agriculture in the past, the only benefit being that the site has escaped exploitation by modern agro-chemicals. It is without doubt a worst option in the sense that there are extremely narrow margins between success and failure. Any slight variable is likely to be magnified far beyond a more favourable location.

Thus the trials carried out on this site have greater significance in terms of success and failure and that failure is more likely to be total while success does not necessarily reflect a true potential. Notwithstanding, the site was exploited in the Iron Age and, therefore, although there is no evidence for prehistoric cultivation, it provides a valuable experimental area. The core research programmes of Butser Ancient Farm comprising constructs, earthworks, animal and crop husbandry, which began in 1972, have been subsequently enhanced by parallel programmes in less harsh locations which have allowed valuable comparisons to be drawn. This paper, however, deals specifically with two elements of the core cropping programme on Little Butser and the results are offered as the product of a worst option.

In order to establish a series of constants within the trials, the archaeological evidence for agriculture was examined in some depth. The plough or ard types recovered from waterlogged deposits in Britain (Piggot, 1953) and Denmark indicate the presence of three specific implements, the sod buster for initial breaking up of virgin or fallow ground, the tilth maker and, significantly, a seed drill ard (Glob, 1951; Reynolds, 1981). This last implement is perhaps the most important of all since it indicates, more than any other implement, the practice of crop management. The greatest enemies of farmers in any area through time are arable weeds evidenced both by carbonised seed deposits recovered from excavations and, indeed, from subsequent Roman writers, notably Virgil who refers to the unremitting struggle against weeds. The clear implication is that cereals were planted in rows, allowing hoeing to take place between the rows and thus combat the inevitable weed infestation. Thus an arbitrary decision was made to plant the cereals in the cropping trials in rows set 300 mm apart.

The weeding programme comprises a similar constant in that the cereals are thoroughly hoed on three specific occasions during April, May and June. The hoeing concentrates upon the spaces between the seed rows with only the larger competitors like docks *(Rumex spp.)* and sow thistle *(Sonchus arvensis)* being carefully pulled out from the rows by hand. A simple proportional analysis is made for each treatment determining the ratio of cereal plants to arable weeds usually in July.

There is no evidence available, either in the writings of the Greek and Roman agriculturalists or from the archaeological evidence, for the rate of seed sown with exception of Columella who describes sowing rates for *Triticum aestivum* and *Triticum dicoccum*. However, although the method of sowing is not specifically clear, it is most probably broadcasting. It is also interesting to note that the rate of sowing Emmer wheat in the spikelet is nearly twice that of ordinary bread wheat as naked seed. The former is extremely difficult to reduce to the naked state while the latter is a free-threshing species. This practice clearly presages a recognition of seed weight in relation to seed frequency in the sowing process. However, this has little relevance to European practice in prehistory especially if the hypothesis of the seed drill is accepted. Consequently a second arbitrary decision was made to sow the seed at a rate of 63 kilos per hectare (56 lbs. per acre). The decision was based upon halving the modern rate of seed sowing as in 1972 which then averaged 125 kilos per hectare (one cwt per acre) in Britain. Subsequently this modern rate has increased considerably.

These two constants obtain through all the trials carried out at the Ancient Farm and reported here. Beyond sowing rate and seed rows and their disposition, treatment variables were considered to be extremely important. There is a body of evidence suggesting that manuring fields was practised from as early as the Bronze Age and certainly in the Iron Age. Roman writers refer regularly to the importance and value of manuring. In simple terms, the evidence for manuring in northern Europe in the prehistoric period stems from the habit of maintaining livestock indoors during the winter with the consequent build-up of midden material. This is enhanced by the recovery of abraded pottery sherds from prehistoric field systems argued to be the result of their transport with the midden material from the settlement to the fields and subsequently worn smooth by their movement in the soil structure.

The trials reported here, however, do not include the variable of manuring. In parallel trials which examine the effect of manuring, an arbitrary constant was adopted of 50 tonnes per hectare (20 tons per acre). This figure was calculated upon the potential manure yield from an average of six cows of commensurate size to the Celtic Shorthorn per settlement with an average daily output of c. 25 kilos (56 lbs.) per animal. There is abundant evidence that cattle were used as the traction power for the prehistoric ploughs and to maintain a working pair a minimum of six beasts was regarded as essential.

In this way, the constants for the trials were established, embracing sowing rate, seed rows and crop management. The cereals used for the trials were obtained by the Plant Breeding Institute, Cambridge from Turkey. Effectively, the Emmer wheat comprises a mix of just two landraces which have proved by chance to be suited to this climate. The Spelt wheat comprises three types, the bearded black and grey spelt and the beardless grey spelt. Separate trials with these three types have shown virtually no difference in results to the general mix used in the trials.

It is necessary to underline that, because it is impossible to determine exactly which landraces of emmer or spelt were used in Britain from the surviving evidence from excavations of Iron Age sites, the trials are essentially dealing with probability factors. The problems of genetic variations and performance and the extreme difficulty of recognition are explored by Miller (1987).

Given the above constants, the trials reported below were designed to explore two fundamental questions. The first question sets out to explore the practicability of crop rotation under a spring sowing regime with Emmer wheat *(Tr. dicoccum)* following Celtic bean *(Vicia faba minor)*. The second question examines the performance and comparative qualities of Emmer *(Tr. dicoccum)* and Spelt *(Tr. spelta)* under an autumn sown regime.

The abundant presence of Celtic beans amongst the carbonised seed recovered from excavations of Iron Age settlement sites suggests that they were a staple and important crop. It is not unreasonable to suppose that the traditional benefits of exploiting a nitrogen fixing crop followed by a nitrogen using crop had been realised by this stage of agricultural development. It may also be hypothesised that the value of other vetches, notably the tufted vetch *(Vicia cracca)* and the narrow leaved vetch *(Vicia angustifolia)* had been realised, not only for the food value (Renfrew, 1973) as a wild harvest but also for their symbiotic value within a cereal crop. The hypothesis explored in these trials is the simple probability that crop rotation was practised. Because the Celtic bean is susceptible to harsh weather conditions, it is not grown north of the midland region of Britain for this reason, a spring sowing regime was adopted for both the pulse and cereal crops.

The area of little Butser exploited for the field trials allows three distinct micro-climatic zones to be examined. The natural curve of the spur from east to west gives a zone facing the east, a central zone facing north and a third zone facing west. Consequently, although the field is treated as a single managed unit, the data are collected from the three zones of the field thus giving three distinct sets of results. The zones are indicated on the tables and figures as Field I East, Central and West respectively. The weather pattern on the spur is monitored by a standard meteorological station situated immediately against the central zone of the field area. The station is read daily at 09.00 hrs GMT. Attempts to monitor precisely the three individual micro-climates had to be abandoned because of equipment costs and time. Nonetheless, the results themselves are sufficiently different to underline the micro-climatic variations. In general terms, the most favourable zone is the east, the most unfavourable the west.

In the trials, the field area is divided in such a way that after the first year, 1973, when the whole field was originally set up, every succeeding year Emmer wheat follows a bean crop. The data are devoted to the wheat crop only. The yield factor is achieved by taking five randomised one metre squares from each zone, weighing the naked seed weight, averaging the result and converting into tonnes per hectare, hundredweights per acre and expressing the yield as a ratio to the seed sown. The results from 1973 to 1987 can be seen in Table I and expressed as histograms in figures 1-3.

The eastern zone averages 2.48 tonnes per hectare over the fifteen year period, the central zone 2.03 and the western zone 1.73. The figures are remarkably consistent through time with few exceptions. The most notable variation is in 1976 when drought conditions prevailed in southern England and all crop yields, both ancient and modern were dramatically reduced. The other variation

	East			Central			West		
Year	T/H	C/A	Ratio	T/H	C/A	Ratio	T/H	C/A	Ratio
1973	2.90	23.1	1:46	2.40	19.2	1:38	2.00	16.0	1:32
1974	3.70	29.4	1:58	3.00	23.8	1:48	2.40	19.2	1:38
1975	2.49	19.2	1:40	2.00	16.0	1:32	1.27	10.1	1:20
1976	0.78	6.2	1:12	0.82	6.5	1:13	0.73	5.9	1:12
1977	2.58	20.6	1:41	1.59	19.9	1:40	1.37	10.9	1:21
1978	2.68	21.4	1:42	1.79	14.3	1:28	1.31	10.5	1:21
1979	2.46	19.6	1:39	1.31	10.5	1:21	0.80	6.4	1:13
1980	2.90	23.1	1:46	2.46	19.6	1:39	2.42	19.3	1:38
1981	2.02	16.1	1:32	1.83	14.6	1:30	1.27	10.1	1:20
1982	1.87	14.9	1:30	1.90	15.2	1:30	1.82	14.5	1:29
1983	4.40	35.1	1:70	2.83	22.6	1:45	2.10	16.8	1:33
1984	2.11	16.8	1:33	2.47	10.0	1:40	1.61	13.0	1:26
1985	2.12	17.0	1:34	1.93	15.4	1:31	1.96	15.6	1:32
1986	2.22	17.6	1:35	1.89	15.0	1:30	2.02	16.0	1:34
1987	1.90	15.2	1:30	2.22	17.6	1:35	2.80	22.2	1:40

Table 1 : Field I – Break crop rotation – Wheat (*Tr. Dicoccum*) with Beans (*Vicia faba minor*)
Spring sown.
T/H : tonnes per hectare : C/A : hundredweights per acre : Ratio : seed sown to seed yield

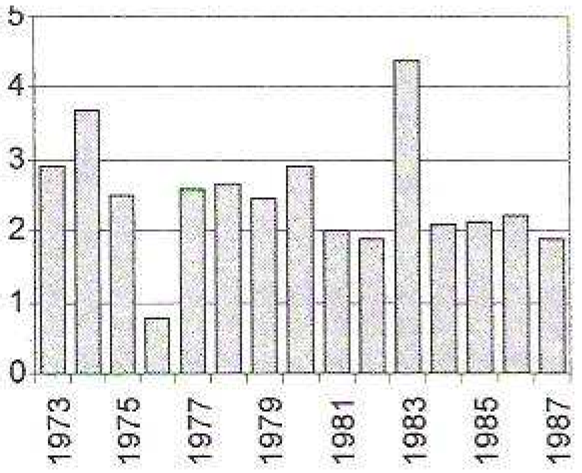

Fig. 1 : Butser Ancient Farm crop yields – Emmer. Field I East. Crop rotation with Beans. Spring. Tonnes/ha

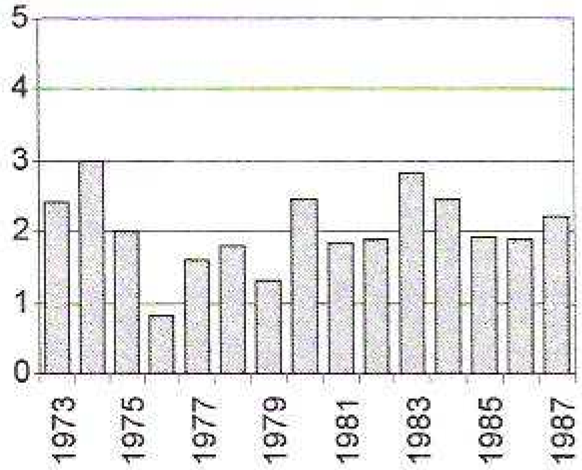

Fig. 2 : Butser Ancient Farm crop yields – Emmer. Field I Central. Crop rotation with Beans. Spring. Tonnes/ha

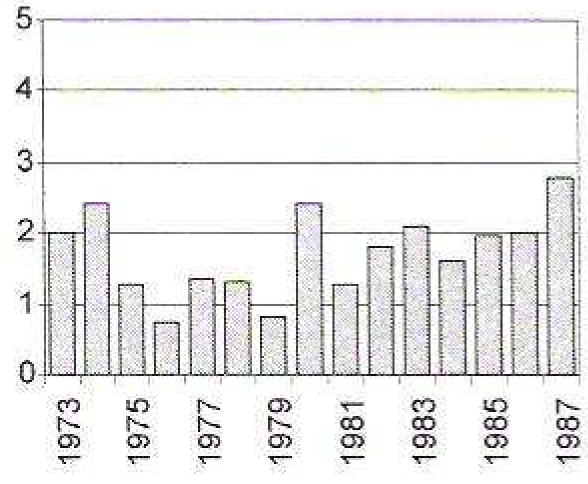

Fig. 3 : Butser Ancient Farm crop yields – Emmer. Field I West. Crop rotation with Beans. Spring. Tonnes/ha.

occurred in 1983, when an exceptional yield was recorded for the eastern sector of 4.4 tonnes per hectare. In this year, frosts in late April/early May initially arrested growth but subsequent massive tillering gave rise to a heavy crop but with much smaller spikes than normal, averaging c. 24 seeds per spike against the normal 36 seeds, with as many as eleven to fourteen tillers per plant against the normal three to seven. Normally, the western zone is the least successful, with the exception of 1987, when the normal pattern across the field was reversed. The particular reason for this reversal is difficult to isolate, beyond unusual wind and temperature damage from the east that occurred immediately after germination and following on from the extreme frost damage which destroyed the autumn sown cereals in the adjacent field (see table 3). The natural contour of the field, in fact, protected the western element of the field.

Year	Tonnes/ha
1973	2.43
1974	3.03
1975	1.92
1976	0.78
1977	1.85
1978	1.93
1979	1.52
1980	2.59
1981	1.71
1982	1.86
1983	3.11
1984	2.06
1985	2.00
1986	2.04
1987	2.31

Table 2: Field I – Break Crop Rotation Spring sown. Average annual yield across all micro-climatic zones. Average yield over 15 seasons = 2.08 tonnes/ha

There are two main observations to be made from this particular long term trial. The first is the overall consistency of the results, and where inconsistencies do arise the vagaries of the weather can be held directly responsible.

Although it is usually impossible to measure and quantify available nitrogen for plant take-up in the soil, the rotation does seem to have brought about this general state of stability. The second observation is the overall high yield return on what is a poor soil in a hostile location. Although the data are divided into three climatic zones of the field, were they to be averaged across the zones the yields are still adequate and exceed general expectation (table 2). The overall average for all zones for fifteen consecutive seasons is a creditable 2.08 tonnes per hectare

The second trial is designed to examine the performance and comparative qualities of Emmer *(Tr. dicoccum)* and Spelt *(Tr. spelta)* under an autumn sown regime without any manurial input whatsoever. The arguments for setting up this trial, apart from providing comparative figures to the above crop rotation trials and spring sown trials not reported here, are relatively straightforward. The most obvious reason is that observations of the natural growth pattern of the cereals after harvest in the wild state show that, after a short period of dormancy, germination occurs in late September and early October. Given no abnormal conditions maturation follows in the next summer. Spring sowing therefore would seem to express a deliberate human choice to change the natural order of events. The generally accepted view of prehistoric practice, however, is that spring sowing was the norm especially for Emmer wheat. The fact is that there are many landraces of Emmer wheat with a wide range of characteristics and some landraces undoubtedly performed better when sown in the spring. Seed morphology, however, does not allow identification of such characteristics, the more so when the seeds in question are carbonised. Yet there is a long held, but completely unsubstantiated, belief that Spelt wheat was introduced into Britain because it was an autumn sown cereal in contrast to Emmer (Applebaum. 1954). In fact, the introduction of Spelt was regarded as the commencement of a new agricultural age! Therefore, although only two landraces of Emmer and three types of Spelt were used in the trials to date, the random selection of these lends weight to the programme in that the same

Year	East			Central			West		
	T/H	C/A	Ratio	T/H	C/A	Ratio	T/H	C/A	Ratio
1973	2.40	19.0	1:38	1.90	15.2	1:30	1.70	13.6	1:27
1974	2.30	18.3	1:37	2.10	16.8	1:34	2.30	18.3	1:36
1975	1.70	13.7	1:28	1.36	10.9	1:21	1.62	12.9	1:26
1976	0.80	7.2	1:14	0.93	7.4	1:15	0.41	3.2	1:7
1977	2.30	18.4	1:37	1.87	14.9	1:30	1.72	13.7	1:27
1978	2.16	17.2	1:34	1.72	13.7	1:27	1.31	10.4	1: 21
1979	0.70	6.2	1:12	0.59	4.7	1:10	0.72	5.8	1:12
1980	1.43	11.4	1: 23	0.80	6.3	1:13	1.07	8.5	1:18
1981	1.95	15.6	1:31	1.80	14.4	1:29	1.62	12.9	1:26
1982	1.12	9.0	1:18	1.36	10.9	1:21	0.90	7.2	1:14
1983	1.98	15.8	1:31	0.94	7.5	1:15	1.14	9.1	1:18
1984	1.17	9.3	1:18	0.81	6.4	1:13	0.68	5.4	1:11
1985	2.75	21.8	1:43	2.45	19.5	1:39	2.49	19.8	1:39
1986	2.79	22.2	1:44	2.50	19.9	1:40	2.54	20.2	1:40
1987	Destroyed by frost			Destroyed by frost			Destroyed by frost		

Table 3 : Field II. Continuous cropping non-manuring regime. Autumn sown. Spelt wheat.
T/H : tonnes per hectare ; C/A : hundredweights per acre ; Ratio : seed sown to seed yield.

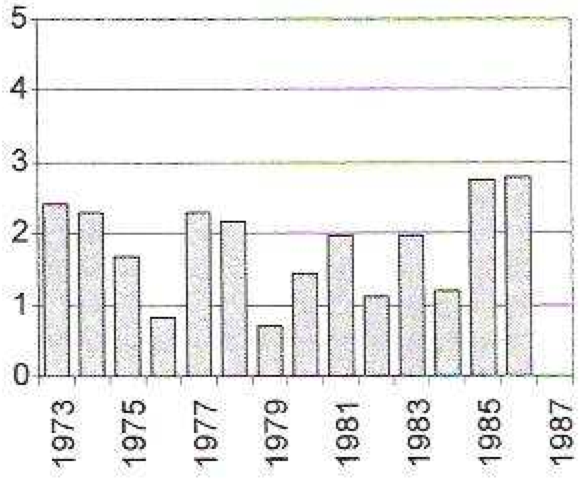

Fig. 4 : Butser Ancient Farm crop yields – Spelt. Field II East. Continuous cropping non-manuring regime. Autumn.

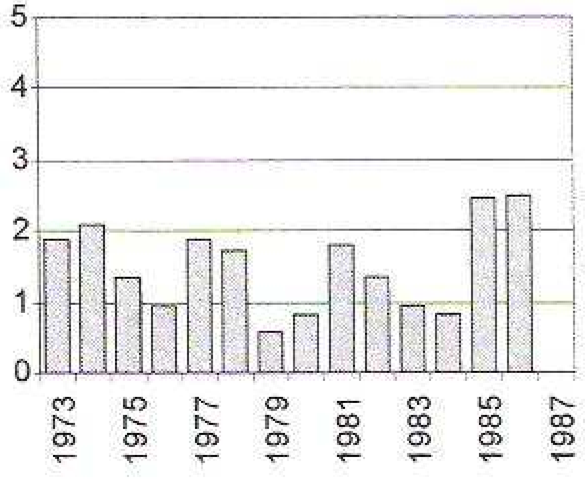

Fig. 5 : Butser Ancient Farm crop yields – Spelt. Field II Central.Continuous cropping non-manuring regime. Autumn.

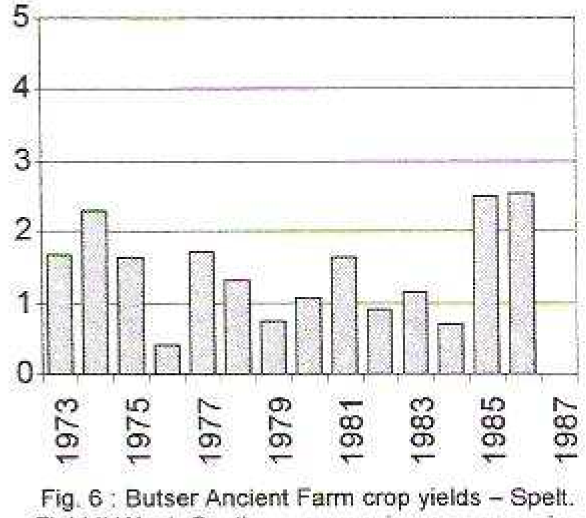

Fig. 6 : Butser Ancient Farm crop yields – Spelt. Field II West. Continuous cropping non-manuring regime. Autumn.

seed stock is used for all trials whether spring or autumn sown. Given the supposed superiority of Spelt as an autumn sown cereal, a clear result should emerge. The third reason, which has emerged during the trials but can equally be used as a primary cause for them, is the behaviour pattern of a particular arable weed, Common Cleavers (*Galium aperine*). The presence of Common Cleavers in carbonised seed assemblages from Iron Age sites is relatively well attested.

The plant effectively has two germination periods, a minor one in October, a major one the following March/April. Cultivation during the critical period of germination tends to disrupt germination totally. Consequently, in an autumn sown field, Common Cleavers tend to be a major pest, while in a spring sown field, it is normally absent. Practical observations over two fields on Little Butser separated by a two metre strip of grassland show that the autumn sown field is regularly pervaded by Cleavers while the spring sown field is innocent of the weed. Given the presence of carbonised seeds of Cleavers in assemblages of seeds which include cereals, the hypothesis that such assemblages came from a harvest of autumn sown cereals is not unreasonable. There is a *caveat*, however, because should the spring sowing be accomplished by the third week in March, the normal spring germination of Cleavers proceeds unabated and there is little difference in infestation levels. This was tested by a small control programme over the past three years at the Ancient Farm. For the autumn sown trials, the field area designated Field II, has exactly the same characteristics of three different micro-climatic zones as Field I and is treated in exactly the same way. The planting programme requires the field to be cultivated in September and early October with the seed being sown in the second week of October. The field is divided into two halves across the zones, one half devoted to Emmer, the other to Spelt.

The basic results from the cropping trials can be seen in tables 4 and 5 for Spelt and Emmer respectively. These results are also expressed in Histogram format in figures 4 – 9. The results broadly relate to the crop rotation data from Field I, in that the major anomalies are directly attributable to the weather. Especially is this the case for 1976, when drought conditions severely affected the crops. The other anomalies, also brought about by weather conditions, refer specifically to the late autumn and winter. The greatest effect occurred during the early part of 1987 when, for the first time, the whole autumn sown cereal crop was totally destroyed by intense and unrelieved frost without any protective snow cover for a period of some fourteen days (Reynolds and Wyman, 1988). This complete failure is calculated within the overall yield factor results. The 1979 season was characterised by low temperatures but more particularly by low rainfall in the period immediately after sowing which led directly to poor germination and a thin crop. The low figures for 1982 were similarly attributable to poor rainfall and extensive periods of dry but cold weather in the early part of the spring. These anomalies apart, the results are quite consistent and remarkably high bearing in mind the hostility of the location.

There is a correlation between these trials and the ones carried out at Broad Balk at the Rothamsted Experimental Station in Harpenden, Hertfordshire (Reports 1969 and 1982). There continuous cropping trials have been carried out on the same land area for over 100 years with viable yields being maintained throughout, with major variations in yield being occasioned by extreme weather conditions. In the case of little Butser, it was initially expected that yield figures would steadily deteriorate to a nil return, primarily because of the poor soil. This has obviously not occurred, but the variations in crop yield are seemingly directly proportional to the rainfall and ground temperature. The continued fertility of the soil lies in the high organic levels. Initially, when the field area was created from the turf cover, the organic levels were c. 24 %. Currently, after fifteen years, the level is broadly maintained at 18 %. Thus, given adequate rainfall in spring the biodegradation of the fibrous material releases nitrogen and trace elements for plant take-up. Low rainfall leads to less

Year	East			Central			West		
	T/H	C/A	Ratio	T/H	C/A	Ratio	T/H	C/A	Ratio
1973	2.80	22.8	1:46	2.15	17.2	1:34	1.96	15.6	1:31
1974	3.70	29.8	1:60	2.90	23.4	1:46	2.50	20.3	1:40
1975	1.80	14.1	1:28	2.32	18.5	1:37	2.15	17.0	1:34
1976	0.70	6.4	1: 13	1.01	8.1	1:16	0.83	6.6	1:13
1977	2.16	17.2	1:34	1.29	10.3	1: 21	1.01	8.1	1:16
1978	2.79	22.3	1:45	1.97	15.7	1:31	1.75	13.6	1:27
1979	0.42	3.4	1:7	0.25	1.9	1:4	0.40	3.2	1:6
1980	1.63	13.0	1:26	1.10	8.8	1:17	0.66	5.3	1:11
1981	2.11	16.8	1:33	1.87	14.9	1:30	2.45	19.6	1:39
1982	0.90	7.2	1:14	1.02	8.1	1:16	0.71	5.7	1:12
1983	3.32	16.5	1:53	2.32	18.5	1:37	2.84	22.7	1:45
1984	1.23	9.8	1:20	1.05	8.4	1:17	0.56	4.5	1:9
1985	2.44	19.4	1:38	2.35	18.6	1: 37	2.00	15.9	1:32
1986	2.55	20.3	1:40	2.37	18.9	1:38	2.14	17.0	1:34
1987	Destroyed by frost			Destroyed by frost			Destroyed by frost		

Table 4 : Field II. Continuous cropping non-manured regime. Autumn sown. Emmer Wheat
T/H = tonnes per hectare; C/A = hundredweights per acre; Ratio = seed sown to seed yield

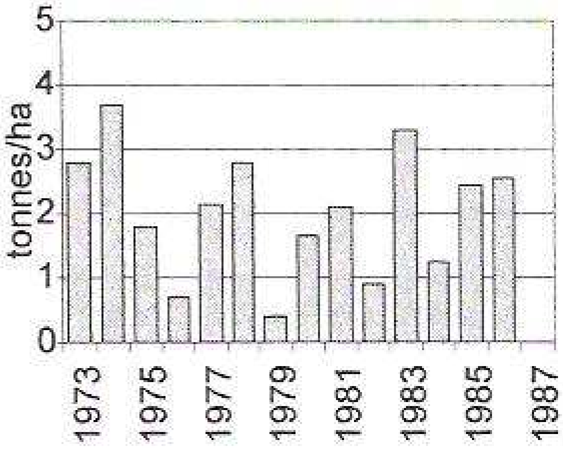

Fig. 7 : Butser Ancient Farm crop yields – Emmer. Field II East. Continuous cropping non-manured regime. Autumn. Tonnes/ha.

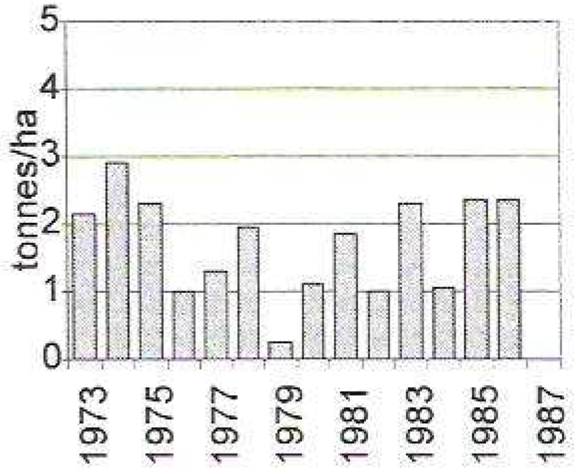

Fig. 8 : Butser Ancient Farm crop yields – Emmer. Field II Central. Continuous cropping non-manured regime. Autumn. Tonnes/ha.

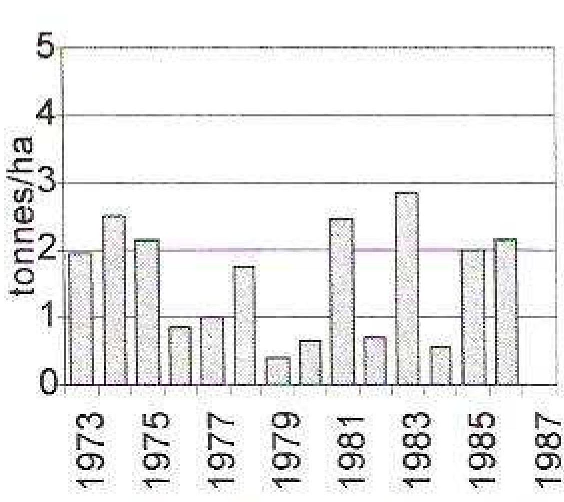

Fig. 9 : Butser Ancient Farm crop yields – Emmer. Field II West. Continuous cropping non-manured regime. Autumn. Tonnes/ha.

degradation and available nitrogen. The fibre content of the soil is further enhanced by the simple management of inter-row hoeing of the arable weeds which are left in situ. This also has the added effect of inhibiting evaporation of the moisture from the soil.

The data are presented in tonnes per hectare and hundredweights per acre, and the yields are also expressed as a ratio of the seed sown to the seed yield (tables 3 and 4). These ratios are significantly higher than any expectation allowed but are nonetheless real. The weights are of the processed, and therefore, naked seed weight. Even from the Roman writers, yield figures are extremely rare. These range from Varro's estimates of ten to fifteen fold for Italy, Columella four fold, Cicero eight to ten fold. Other figures recorded for Babylon suggest one hundred fold under good management and fifty fold under poor management (Theophrastus).

The crux of the matter would seem to lie with the soil, the climate and good management. However, there is great probability that technology plays a most important role in understanding the huge difference in these documented yields and also emphasises the hypothesis regarding the seed drill ard referred to above. From Babylon, there is a seal of the 2nd millennium BC depicting an ard with a seed drill attachment. This is a cup set on a tube fixed to the stilt or handle of the ard through which seed could be dribbled directly into the furrow (Singer, Holmyard et al, 1965). Such seed drill attachments have survived into the recent historical record in countries like Iran and it is tempting to see these implements as direct descendants of the Babylonian version bearing in mind that the Persians under Cyrus The Great annexed this area in 538 B. C. The theory of technical persistence is well enough attested to allow this to occur. Critically, by delivering the seed into the ard made furrow at perhaps a depth of 150-200 mm it is in the ideal position to germinate in this climatic zone. In Europe, on the other hand, this would be too deep. The Hvorslev seed drill ard, in contrast, draws a shallow furrow approximately 50 -60 mm deep (Reynolds, 1981) which is ideal for the more humid conditions of Northwest Europe. The practice evidenced in the countries on the northern shore of the Mediterranean is rather the broadcast method. This leaves much to be desired in terms of good husbandry, despite the fact that it became the normal practise throughout almost the whole of western Europe until the introduction of the seed drill in the eighteenth/ nineteenth centuries. Folklore is full of the inefficiency of broadcasting seed from the biblical parable of the sower to doggerel like 'One (seed) for God and one for the crow, One to die and one to grow'(Anon), suggesting, in the latter case, a 75 % seed loss! Extending this into a yield factor ratio, the simple mathematics are instantly error loaded unless quite fundamental adjustments are made.

The research results in the following Tables should not really be surprising, given the nature of the plant with its average of thirty six grains per spike. The yield records expressed as ratios from the historic periods in Britain which refer to returns of seven to ten fold require considerable explanation and presently deserve scepticism if they refer to the actual harvest itself.

To return to the reason for this series of trials, the objective was to examine if Spelt wheat was significantly superior to Emmer wheat as an autumn sown cereal. It can be seen that, on an annual basis, within specific micro-climatic zones (tables 3 and 4), Emmer normally outperforms Spelt in most particulars. Indeed, the western aspect which is the most hostile of the micro-climatic zones is the one area in which, if Spelt is a superior autumn sown cereal, the results should demonstrate the case. In fact, the results are closer for this zone than any other and are uniformly less than the others, but still Spelt is generally outperformed by Emmer. In order to use the data base, these figures provide the average yields and have been calculated for each zone for each cereal (table 5). Given the sample size, the results are entirely persuasive that Emmer significantly outperforms Spelt as an autumn sown cereal. Similarly, if the different micro-climatic zones, significant though they are, are ignored and the field is treated as a single entity again, the overall averages argue that Emmer is the superior autumn sown cereal (table 6). It has been pointed out that there were more than two landraces of Emmer used in the trials. Ideally, with a mix of landraces with differing characteristics, even the anomalous result would probably be lessened in their impact (Miller, pers. comm.). Certainly, these results demonstrate that Spelt has no particular characteristics indicating its qualities as an autumn sown cereal, and the hypothesis, that it was deliberately introduced for this purpose, is now in quite serious doubt if not completely invalidated

Average yield factors for each micro-climatic zone over fifteen seasons

	East	Central	West
Emmer	1.90	1.60	1.46
Spelt	1.70	1.41	1.35

Average yield factor for all micro-climatic zones over fifteen seasons

Emmer	1.65
Spelt	1.49

	Emmer	Spelt
1987	zero	Zero
1986	2.35	2.61
1985	2.26	2.56
1984	0.95	0.89
1983	2.83	1.35
1982	0.88	1.13
1981	2.14	1.79
1980	1.13	1.10
1979	0.36	0.67
1978	2.17	1.73
1977	1.49	1.96
1976	0.84	0.71
1975	2.09	1.56
1974	3.03	2.23
1973	2.30	2.00

Table 6 : Average annual yield across all micro-climatic zones over fifteen seasons.
All figures in tonnes per hectare.

To conclude, the overall objective of these and other cropping trials carried out at the Butser Ancient Farm is to explore the agricultural economy of the latter part of the Iron Age period as it may have obtained on this soil type in this bioclimatic zone. The data, as they are presented above, are the direct result of empirical trials carried out over a fifteen year period, which means that the averages calculated are significant but only within the confines of the trials. In effect, they are representative only of a probability statement given the constants and variables within the design of the trials. Their value as probability statements lies in the rigour by which they were obtained and the overall time span of the trials. Because they are real results and not estimates, they can be used more confidently in building a working hypothesis for the agricultural economy, but at no time must they be regarded as more than a probability and be converted into a prehistoric fact. As a final *caveat*, these results were obtained from a worst option scenario. Any transfer into a better soil, in a more favourable bioclimatic zone, would require significant enhancement. The long term objective of supplying validated data that could be employed in computer simulations of agricultural productivity is presently being achieved. In this paper, the data achieved from two specific treatments could be utilised, with the necessary restrictions, for three different distinct landscape orientations, or combinations thereof, relating to specific sites and their immediate exploitable land resources. With the future publication of the remaining elements of the cropping programmes at the Ancient Farm, these data will be considerably enhanced, including different soil types and bioclimatic zones and different treatments (Reynolds forthcoming).

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