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CARBONISED SEED, CROP YIELD, WEED INFESTATION AND HARVESTING TECHNIQUES OF THE IRON AGE

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There is no doubt that the basic economy of the prehistoric period from the Neolithic onwards was agriculture. Indeed an alternative view of prehistory, rather than determining specific periods by the basic material employed for the manufacture of artefacts, would be to regard it as a straight development of agriculture. The increasing abundance of evidence from archaeological investigations and aerial surveys in the United Kingdom fully support the developmental principle so much so that by the latter part of the Iron Age, broadly the centuries immediately preceding the Roman invasion of England in 43 A.D., the agricultural landscape as we know it today was firmly established. In fact, there is every reason to believe that even larger areas of arable were in cultivation in that hundreds of hectares of prehistoric field systems evidenced by lynchets and trackways have been and still are under a pastoral régime. In this particular case the land is generally of a marginal nature and was once thought to have been exploited by the prehistoric farmer because they lacked the technological ability to deal with the heavier valley soils. Aerial photography and excavation (Everton and Fowler in Bowen and Fowler 1978, Gillam, Harrison and Newman 1973) has now disproved this contention in terms of field evidence and empirical examination of the available technology has shown it to be sufficiently advanced to cope with all subsoils including the most intractable clays (Reynolds 1980). Indeed the present hypothesis of land use in the prehistoric period and particularly the Iron Age is that those areas of marginal land where prehistoric field systems still survive represent the exploitation of marginal land at that time. Their survival today is directly attributable to a change of basic economy from arable to pastoral in the third and fourth centuries A.D. which has been sustained throughout the millenia. It is only in the last decade that many of these areas are being brought back into arable cultivation with the subsequent loss of archaeological evidence. The implication is clearly one of enormous pressure in available land for arable purposes on the one hand, on the other an extremely successful and stable agricultural economy.

The classical documentary evidence for this buoyant economy is quite unequivocal. For example, Caesar *(De Bello Gallico IV)* refers to the export of grain and leather from Britain to the continent. In the same text he describes the densely occupied landscape *(creberrima aedificia)* and further hints at the reason why agriculture was so much more successful here than on the continent when he describes the climate as having less severe frosts *(remissioribus frigoribus)*. The Atlantic climate of this country is, indeed, dramatically different to that of the continent and to it can be attributed in part the consistently more advanced agricultural economy throughout the prehistoric and historic periods. This is especially clear in the sixteenth and nineteenth centuries A.D. (Whyte 1979, Fussell 1959). In any agricultural economy the avoidance of extremes of climate bears directly upon its consistent development and success. It is, of course, the major variable in any consideration of crop husbandry.

The major archaeological sources of evidence for agriculture in the Iron Age comprise the field evidence (e.g. Bowen 1961, Bowen and Fowler 1978) as represented by lynchets and soil marks, plough marks (e.g. Fowler and Evans 1967, Hartridge 1978, Reynolds 1980), carbonised seed and seed impressions fired into pottery. The pollen evidence, which is of some value, has little relevance to large tracts of the countryside because of minimal preservation and more importantly unless actual pollen grain indentification is definitely assured confusion with other *gramineae* species may distort the overall picture.

It is against this background of the basic data that one of the major research programmes at the Butser Ancient Farm Project Trust (Reynolds 1978, Reynolds 1979) is designed to assess potential yield factors of prehistoric cereal types under different treatments and cultivation techniques. As commented above the major variable in any attempt to simulate the husbandry of the Iron Age is the climate. In this respect it is argued that the climate of the last three centuries of the first millennium B.C. and the first two centuries A.D. directly comparable to the present day climate (H. Lamb pers. comm and in *The Environment of Man. The Iron Age and the Anglo Saxon Period* — publication forthcoming 1981). Naturally this includes the minor variations and occasional extremes, for example, the drought of 1976 experienced within the modern weather pattern. Thus this variable can be seen as a constant to any empirical study of cereal production. The second variable is the soil itself. In this case the principal land area of the Ancient Farm is particularly suitable. It comprises a spur of middle chalk covered with a thin layer (c. 10 centimetres) of friable redzina, the typical soil covering the chalk lands of southern England. In addition the land area of the farm has not been cultivated for the past two hundred years and it is doubtful whether it has ever sustained an arable crop of any kind. Certainly there are no archaeological traces of agriculture. There is, however, a prehistoric settlement of Bronze Age/Iron Age date located on the spur and abundant evidence in the immediate vicinity of prehistoric field systems and trackways suggesting that the settlement was, in fact, a farmstead. Thus the soil type with a consistent pH value of 7.2, is accurate and has been uncontaminated by modern farming techniques. Since the Ancient Farm began in 1972 every care has been taken to avoid any subsequent contamination from modern agrochemicals. The secondary land area of the Ancient Farm comprises the typical hillwash soil of present dry valleys in the chalklands known to have been exploited in the Iron Age. It is composed of a mixture of clay with flints, degraded chalk and redzina with a neutral pH value. For the past hundred years it has been under rough grass cover and is thus unimproved in the modern sense. It was taken under control in 1976 and the last application of nitrogen to improve the grazing was dated to 1974. Consequently the effects were neutralised by the time of its cultivation.

The varieties of cereals cultivated in the Iron Age are well attested by the analysis of carbonised seed and seed impressions recovered from a large number of excavations of Iron Age sites (Helbaek 1952). As excavation techniques have improved especially with the introduction of fine mesh wet sieving and flotation systems so the bulk of carbonised seed evidence has increased proportionally. There is still, however, too little evidence of find location within sites except in exceptional circumstances, like pits, to determine processes or functions or even crop dominance with any certainty. As discussed below it is preferable at this time simply to regard the evidence of carbonised seed only as statements of presence or absence. Any apparent significance suggested by an abundance of one plant species over another may be an effect of a subsequent process within the settlement and in response to a specific requirement and not reflect the husbandry practice at all. Similarly the very fact that the seed is carbonised at all suggests an unusual event or accident and, therefore, renders it as an atypical element within the artefact assemblage.

Nonetheless the dominant wheat cereals of the Iron Age and Romano-British periods were undoubtedly Emmer wheat *(Tr. dicoccum)* and Spelt wheat *(Tr. spelta)*. Consequently although other cereal types are the subject of cropping trials at the Ancient Farm, Emmer and Spelt wheats are the principal varieties. For this study seed was provided by the Plant Breeding Institute at Cambridge from Asia Minor where it is still cultivated in the remote regions. Careful analysis of the seed proved it to be morphologically the same as the prehistoric seed and while it can never be proved, it is not unreasonable to believe that its protein characteristics are equally exactly similar. Certainly its characteristics as a stable as opposed to a hybrid plant are beyond question. The development of these cereals is discussed elsewhere (Reynolds 1977).

The cropping trials at the Ancient Farm are both varied and complex. The constant within the trials, the weather pattern and soil structure are subject to continuous recording and analysis with in the case of the former a standard meteorological station set on each site. In addition certain fields are monitored for their microclimate. The treatment under which the crops are grown are as far as possible evidenced by either the archaeology or documentary references. The preparation of the fields and the rendering of a tilth are always carried out by ard (Reynolds 1981) or by spade and mattock hoe cultivation. Seed is always hand sown in seed drills (Reynolds 1967 and 1981) and at a constant rate of 63 kilos per hectare (56 lbs per acre). Concomitant arable weed growth is subjected to handweeding and hoeing. In certain trials, because large numbers of arable weed commonly evidenced in the carbonised seed record are virtually extinct in the British countryside, arable weeds are deliberately introduced to provide specific and accurate competition. In association with the cropping trials, an extensive and complex research programme is devoted to the propagation, germinability and fruiting characteristics and conservation of a large number of arable weed species. Primary focus has been the calcicole species with a secondary focus in the last two years upon the calcifuge species. Throughout the trials the competitive weed flora is monitored and analysed with special reference to potential function indicators (see below). Similarly the crop in the field is monitored as to stand height and tillering and subsequent to harvest is further analysed for spikelet length and weight, fruiting capacity and seed : chaff ratio.

The following tables present the results of a selection of the field trials carried out at the Ancient Farm since 1972. The yield data are obtained by sampling the crop in the standard manner of selecting by random metre square avoiding a metre wide perimeter band around the crop where the "edge effect" can distort results. The figures provided represent gross weight and are presented in kilos per hectare, cwts per acre and seed : yield ratio. This last is the traditional historic system and allows direct comparison with yield figures from the records of the sixteenth century onwards.

Field II Location : Ancient Farm Research Site, Little Butser.
Soil Types : Friable redzina av. 10 cm thick directly overlying middle chalk.
pH : 7,2
Sowing rate : 63 kilos per hectare (56 lbs per acre) — Autumn.
Cereal varieties : Emmer *(Tr. dicoccum)* and Spelt *(Tr. spelta).*
Cultivation : Hand digging and mattock hoes.

The objective of this trial is to assess the yield characteristics of the prehistoric type cereals on a typical unimproved soil of a type available in the Iron Age. The crops are grown without any periods of fallow and without any form of added nutrient of any kind. In effect the purpose is to assess the long held and cherished theory of land exhaustion and the need to rotate arable areas. The intention is to continue cropping this field until a non-viable yield is recorded. Non-viability is determined to be a 1 : 1 or worse seed : yield ratio. The following table gives the data yield sector east of this particular field.

TABLE I : *Crop yields : field II sector east Butser Ancient Farm*

Cereal Types	*Triticum spelta*			*Triticum dicoccum*		
Winter sown	*Tonnes/ hectare*	*Cwts/Acre*	*Seed/Yield*	*Tonnes/ hectare*	*Cwts/Acre*	*Seed/Yield*
Year						
1973	2,4	19,0	1 : 38	2,8	22,8	1 : 46
1974	2,3	18,3	1 : 37	3,7	29,8	1 : 59
1975	1,7	13,7	1 : 28	1,8	14,1	1 : 28
1976	0,8	7,2	1 : 14	0,7	6,4	1 : 13
1977	2,3	18,4	1 : 37	1,2	10,0	1 : 20
1978	2,5	20,1	1 : 40	2,6	20,8	1 : 41
1979	0,7	6,2	1 : 12	0,4	3,3	1 : 7
1980	1,4	11,4	1 : 23	1,6	13,0	1 : 26

DISCUSSION

The relatively large fluctuations can be readily observed over the eight years within the table above but all these fluctuations are directly attributable to the weather patterns rather than any other single factor. For example, the exceptionally low figures for 1979 were caused by continuous heavy frosts on bare ground for six weeks when the ground surface temperature did not exceed 1° C. Similarly the drought of' 76 took an exceedingly heavy toll. What is most significant is the yield when expressed as seed : yield ratio has never fallen below 1 : 7. Bearing in mind that there are no nutrient additives to this field area at all and the cultivation practice is minimal in modern terms this figure is the more remarkable. Given the validity of the experiments there is an urgent need to determine why, with all the above restraints, this figure should be so much in excess of historical records where seed : yield ratios are significantly lower except in England and the Low Countries (average 10 : 1 increasing to 20 : 1). To further point the anomaly the following table gives the soil analysis results showing a minimal change in structure and trace element levels over a period of nine consecutive seasons.

TABLE II : *Soil analysis : field II Butser Ancient Farm*

	organic matter	Potassium p.p.m.	Potassium Index	Phosphorus p.p.m.	Phosphorus Index	Dopper p.p.m.
1972	24,3	234	2	16,2	3	4,14
1979	20,3	140	2	21,0	4	3,84

p.p.m. = parts per million

The levels of organic matter are high and are regarded as indicative of a long period under grass without cultivation. The normal figures for modern arable land is 2 to 5 per cent of organic matter. All other levels are regarded as adequate but on the low side. In effect this system of cultivation is not reducing significantly the organic matter in the soil and the cereal varieties in direct contrast to modern hybrids do not require the same high levels of nitrogen input. The further point that must be stressed is the nature of the cereal itself. The spike is naturally significantly larger than that of the typical wheats of the historical period like Rivet wheat and indeed larger than the modern hybrids. There is no real indication, therefore, of soil exhaustion nor yet of deterioration of yield. The last season of 1980 clearly shows that the yield for both Emmer and Spelt has recovered from the disastrously low levels, in terms of the expectation engendered by previous years, of 1979. Similarly although Spelt has been claimed to be a better winter variety than Emmer (Applebaum 1954), with the exception of one season it is outperformed by the latter. Inevitably within the confines of a short paper it is quite impossible to present the total crop yield data achieved within the Ancient Farm research programmes. However, in order to provide a direct contrast to the above table the following results are drawn from Field VI where the treatment of a hill wash soil described above is subjected to an application of manure at a rate of twenty tonnes per hectare, approximately half the recommended weight distribution of the recent past, once every three years. The first application took place in the winter of 1977 prior to spring sowing of Emmer wheat, in association with other varieties, in 1978.

TABLE III : *Crop yield : field VI : Butser Ancient Farm demonstration area*

Year	Cereal Type Spring Sown	Tonnes per hectare	Cwts per acre	Seed/Yield ratio	Treatment
1978	Emmer *(Tr. dicoccum)*	4,65	37,2	1 : 74	Manured + 1
1980	Emmer *(Tr. dicoccum)*	3,19	25,5	1 : 51	Manured + 3

That manuring took place in the Iron Age has been ably demonstrated by Bowen (1961). In this particular field where manuring is applied in simulation of an availability of dung adequate to the area once every three years it can be seen that the reduction in yield is quite significant but that in gross terms the returns are significantly better than those of Field II above. All the results quoted above are statements of the mean and standard deviations are not supplied nor the gross maxima and minima. In simple terms it allows the figures to bear comparison with results from other periods of history provided similarity of conditions *inter alia* is observed. If nothing else these figures support the contention that given the cereal species of the Iron Age the potential for surplus production existed to an extent well capable of sustaining the export industry reported by Caesar.

In conclusion of this first section devoted to crop yields of prehistoric cereals one particular species of the arable weed infestation of the crops emerged as a potential indicator of agricultural practice. The species, Cleavers *(Galium aparine)*, has successfully and quite naturally pervaded the field (II) sown in the autumn while the spring sown field (IV) separated by only a metre wide strip of turf is completely innocent of this plant. The following table gives the results of the last two seasons survey of this particular species showing the figures from three randomly selected m2 per sector in both fields.

TABLE IV : *Arable weed flora survey : Galium aparine*

			Sector East	*Sector Central*	*Sector West*
1979	Field II	Autumn sown	136	179	85
	Field IV	Spring sown	0	0	0
1980	Field II	Autumn sown	84	109	63
		Spring sown	0'	0	0

The germination characteristics of this plant show a major peak at the end of March/beginning of April with a minor peak in late October. Normally the spring sown field is cultivated at this time prior to planting early in April and consequently should any plants be about to grow they are eradicated by the cultivation. By contrast the autumn sown field is planted in early October and thus the plant can experience and benefit from both peaks of germination allowing considerable numbers to escape the hoe and hand weeding which is carried out in late April and May. Its total absence from the spring sown field, further surveys substantiated the close search of the randomly selected m2, is the most significant factor. Its presence in the carbonised seed record (Helbaek 1952) may well, therefore, be considered as an indicator of autumn or winter planting of cereal crops.

Precise information of harvesting techniques as employed by the Iron Age people as opposed to the Roman systems (White 1970) is difficult to isolate. We do have the comments by Strabo and Diodoros Siculus that the Celtic practice was to reap the ears or spikes of the crops. Support of these statements can be found in the ubiquitous artists impressions of prehistoric harvesting where the so-called sickle is to be seen neatly cutting off cereal heads. Practice, however, has little in common with imaginative representation. From the observation of some eleven seasons of growing the prehistoric type cereals of Emmer and Spelt wheats, belief in the determination of the typical small "sickle" has radically waned to the point of offering an alternative function. This being the splitting of hazel gads to make into thatching spars for which the tool is admirably suited. This is not to say that they cannot be used for cutting wheat ears but rather that they are grossly inefficient and far too slow. The problem lies in the nature of the crop itself. Accepting the classical sources as being a reasonable description of the actual harvesting practice, both at Avoncroft Museum and at the Ancient Farm all the crops have been harvested in this way. Each year replica sickles are provided for the purpose, each year they are unanimously rejected by the reapers. The answer is simply that it is much easier to reap the ears by hand picking.

It was realised from the very first season that the prehistoric cereals have two characteristics which are not ordinarily to be found in modern hybrid wheats. The first major difference lies in the disparity of stand heights achieved by the tillers of the same plant. In the case of both Emmer and Spelt wheats this disparity can be as much as a metre from the shortest to the tallest spike, while in a modern hybrid it rarely exceeds 0,40 m. The importance of this characteristic will be developed below. The second characteristic is the "necking" of the prehistoric types. As the ears ripen so they droop gracefully downwards from the main stalk in the fashion of modern barley. The effect of this not only inhibits water retention within the spike and consequent lodging potential, this being truer of Emmer than Spelt where lodging can be a problem, but also exposes the stalk top to the elements of wind and sun. Once ripe this section of the stalk becomes extremely brittle and is very easy indeed to break off. If allowed to reach maturity the natural result is for the spike to break away from the stalk, and seed itself. The skill of farming is, of course, to pre-empt this point by as short a time as possible.

Observations of this disparity of stand height have led to the direct recording of each successive crop. Annually a thousand measurements of each crop variety and treatment are made across random transects with sample points 0,30 m apart. The results of just one year are provided to substantiate the

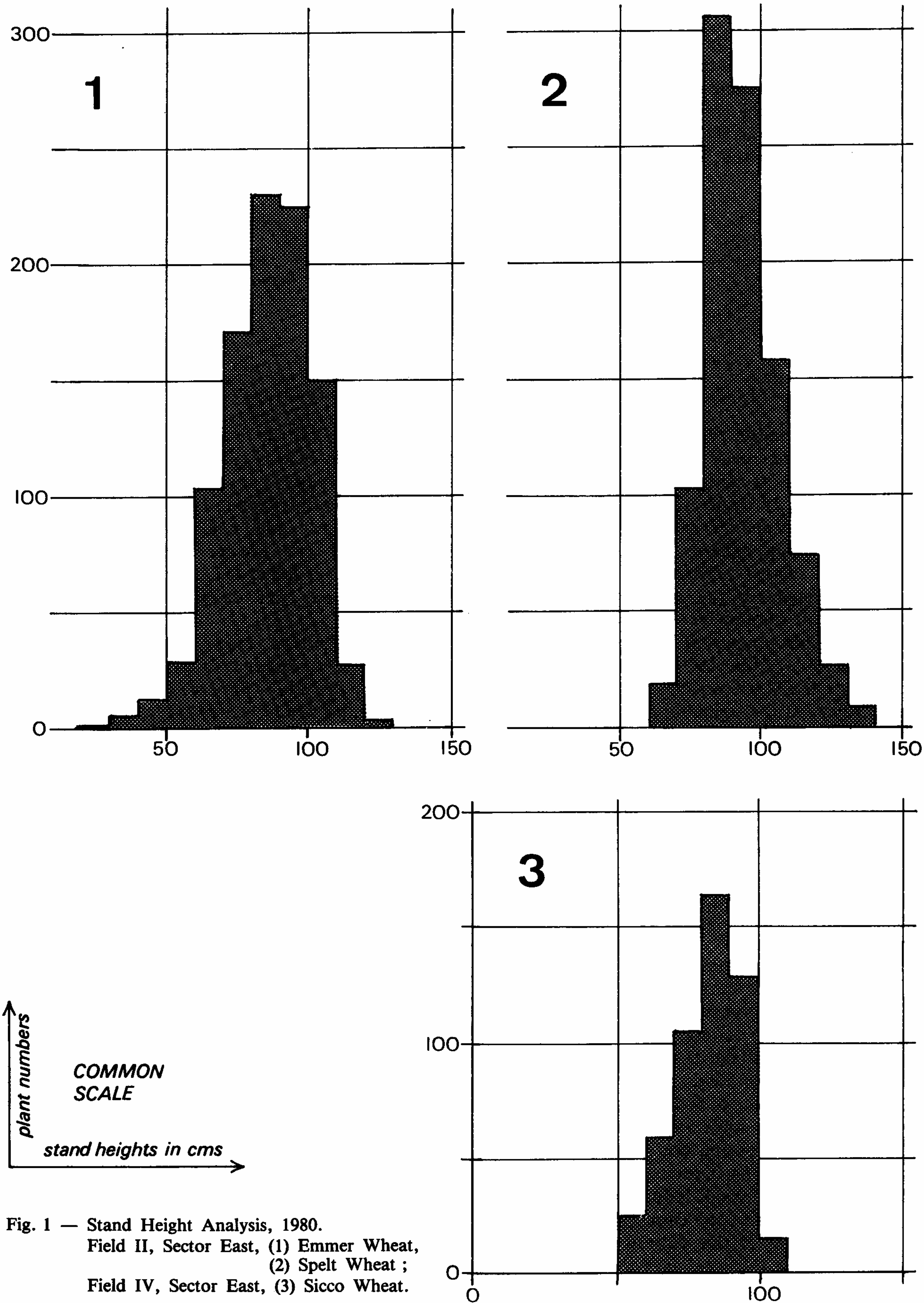

Fig. 1 — Stand Height Analysis, 1980.
Field II, Sector East, (1) Emmer Wheat,
(2) Spelt Wheat ;
Field IV, Sector East, (3) Sicco Wheat.

present argument. These can be seen represented in histogram form in figures 1 and 2. To provide a direct comparison figure 3 shows the results from a modern cereal crop grown under exactly the same conditions. The selection of examples is further deliberately pointed in that they are drawn from a field which has been continuously cropped for the past eight years without any added nutrient whatsoever. The farm is, of course, free from all modern herbicides, pesticides and fertilizers.

The prime data comprise an admixture of cereal and arable weed seeds. Throughout the cropping programme the competitive weed flora has been most carefully monitored. In eleven seasons all the harvests have been effectively pure with but two contaminants. By way of explanation the harvest is taken to be the spikes that are collected from the crop. The contaminants, in turn, are arable weeds which can be found within the gathered spikes. The harvesting process consistantly follows the classical description. However, the crop itself is regularly infested with an abundant weed flora and during the months of June and July particularly is a riot of colour. The primary enemy of farmers of all periods prior to the introduction of herbicides is Charlock *(Sinapis arvensis)*. It is vitally necessary during the early part of the season in April and May to hoe the crop carefully in order to keep at bay this most pernicious competitor. In this century it was not uncommon to hear of crops being ploughed back into the soil because of Charlock infestation. Farming by definition is the provision of a preferred habitat for a specific plant. However, once the plant is established and can outgrow its competitors, there is no advantage in further hoeing and indeed there can be direct disadvantages in that too much soil disturbance in the secondary stages of crop development can damage the spreading roots of the crop itself. Consequently at harvest time there is an abundance of other plants amongst the cereal crops. Careful note has been made of those competitors which reach the reaping height. That is, those plants which head out amongst the majority of spikes and which are likely to be collected by accident during the harvesting process. Such plants are effectively few in number and virtually all of them are sufficiently different in nature and form for avoidance to be a matter of course. The most typical on calcareous soils are the Thistle family *(Cirsia)*, Fat Hen *(Chenopodium album)*, Poppies *(Papaveraceae)*, Charlock *(Sinapis arvensis)* and Hedge Mustard *(Sisymbrium officinale)*. On acid soils as well as most of the above Red Shank *(Polygonum persicaria)* and Pale Persicaria *(Polygonum lapathifolium)* are the most common. The two contaminants referred to above are Black Bindweed *(Polygonum convolvulus)* and Sowthistle *(Sonchus arvensis)*. The former simply entwines itself up the straw stalks and wraps itself inextricably about the spike. The reaper recognises its presence but can do little about it. It hardly detracts from the crop in so far as it is not a poisonous species. The latter is relatively uncommon as a contaminant and only occurs as such since its seed is wind dispersed and occasionally a seed is trapped amongst the awns of the prehistoric type cereals. It too is unlikely to cause any problems in subsequent utilisation of the harvest. It is rare amongst the carbonised seed record as is only to be expected from its nature but it has recently been identified from an Iron Age site along the course of the M3 motorway (pers. comm. P.J.Fasham). Even though its presence within the harvested spikes is occasional this is not to suggest it is rare amongst the crop. In fact, because of its normal height at fruiting being regularly in excess of one metre it appears as a dominant weed. The presence of but one seed in the carbonised record would suggest that it was similarly a dominant weed in prehistoric crops.

The purity of the harvest is the direct result of the reaping system. Since the abundant weed flora occupies the bases of the crop and while it does not necessarily detract from its overall performance, it does mask from the view of the reapers those spikes which are in the lowest stand height range. It would be counter-productive to hunt about amongst the base of the crop to recover what amounts to less than one per cent of the total yield. Ironically there is regularly no difference in the overall seed size of these omitted spikes to those of the reaped harvest. Consequently they cannot be identified as being distinct in any specific analysis programme. Similarly the observation needs to be made that carbonisation itself does not affect seeds uniformly and thus predictive assessments of original seed size are impossible.

Throughout the development of the Ancient Farm every effort has been made to supply as accurate a competitive weed flora as possible. In many cases this had led to supplementary research programmes involving individual species which are either threatened or actually extinct from the United Kingdom. In the latter category, for example, Thorow-wax *(Bupleurum rotundifolium)* can only be observed in the fields and propagation plots at the Ancient Farm. The objectives of these supplementary programmes are to study the germinability, fruiting characteristics, stand heights in competitive milieux of these threatened species and to keep a reserve seed bank in the normal sense as well as the maintenance of living populations. To underline the nature of the competitive arable flora which occupies the base of the crop two typical species, regularly recorded in carbonised seed samples, are selected as particular examples. The first of these, Corn Cockle *(Agrostemma githago)* is sufficiently frequent to have been considered as a potential food supply and its protein levels have been analysed (Renfrew 1973) although, in fact, it is poisonous (Forsyth 1954, Renfrew 1973) and spoils bread made from flour which contains it. Similarly it retains its poisonous characteristics even after drying and storage. In Figure 4 its stand heights are recorded in competitive and non-competitive conditions. Similarly the results of the performance of Corn Flower *(Centaurea cyanus)*, another threatened species although non-poisonous, are shown in Figure 5. In both cases it can be readily seen that given the harvesting system they are well below the reaping height and are to be found locked within the mass of other arable weeds.

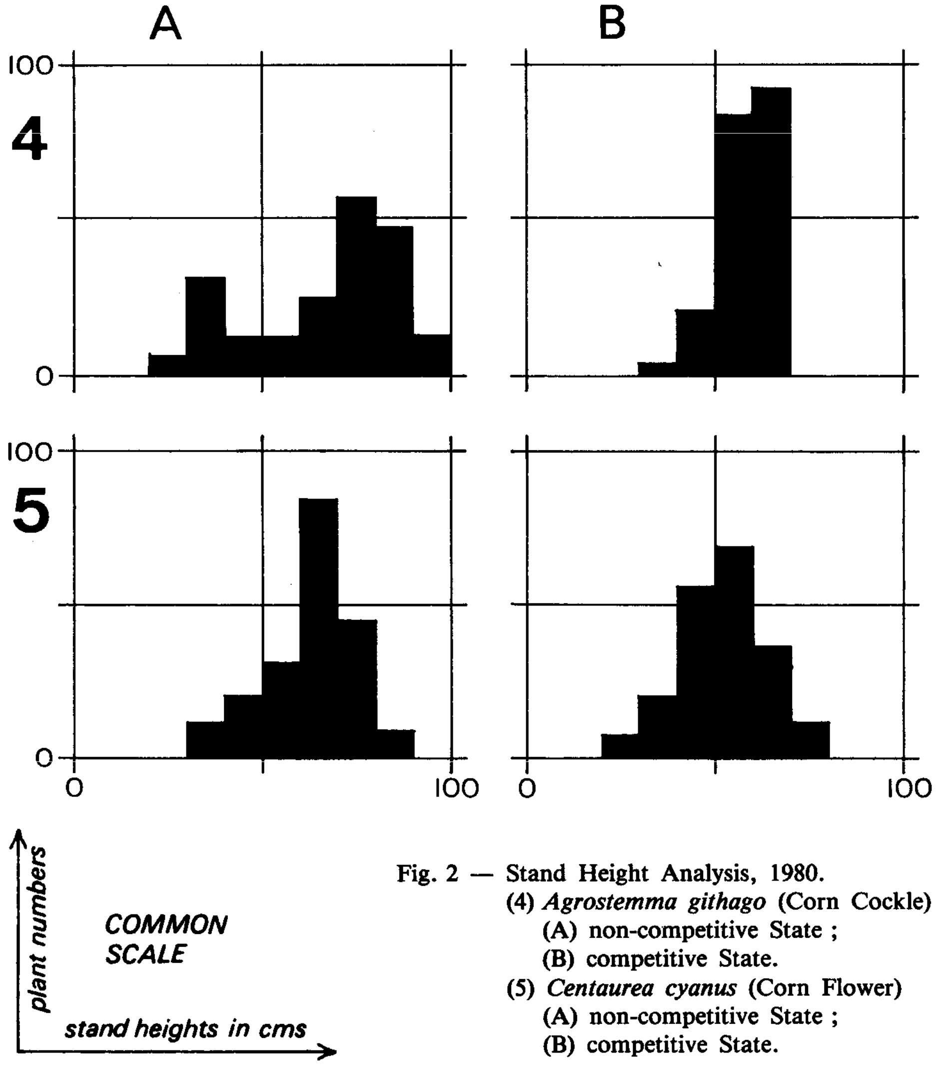

Fig. 2 — Stand Height Analysis, 1980.
(4) *Agrostemma githago* (Corn Cockle)
(A) non-competitive State ;
(B) competitive State.
(5) *Centaurea cyanus* (Corn Flower)
(A) non-competitive State ;
(B) competitive State.

The argument, therefore, is now confused in that to all intents and purposes the norm would have been a pure harvest and yet the carbonised seed samples are anything but pure. Returning to the field situation once the spikes have been harvested there remains still a second and extremely valuable product to be collected, namely the straw. Because of its relatively low gloss factor the straw from the prehistoric cereals is quite palatable to livestock. Similarly it had great value as thatching material, a fact substantiated by the stand heights alone and it would have been required as bedding material for livestock and not improbably for humans. There is always the alternative that then as now the straw could have been burned *in situ* but this does not deny the need for straw within the agricultural economy and it is not unreasonable to assume that it was cut, put into sheaves and carted back into the settlement. In any event the field area would have had to be cleared prior to its recultivation. The straw inevitably contained the mass of weed flora within its bulk. In this way, entirely apart from the harvested cereal the arable weeds could have found their way into the settlement. In order to quantify this exercise, each year several of the straw sheaves from the farm are analysed for the seeds they contain after a winter storage within a stack. The results from just one example are given in Table 5. Even this analysis does not give a true reflection of the field state in that the seed release mechanisms of the different species of arable weeds are widely diverse. For example, the thistle population since its seeds are wind dispersed is rarely represented. Similarly the seeds of Charlock *(Sinapis arvensis)*, are exploded from a pod at the slightest touch of the trigger element. In fact, just prior to harvest one can actually hear the pods exploding as the wind blown stalks of wheat brush against the seed pods. Some simple measurements carried out at the Farm have shown that Charlock can deliver its seed up to three metres from the parent plant. Both Thistles and particularly Charlock are dominant weeds of the research crops, a fact which analysis would fail to substantiate. As has been suggested above in reference to Sowthistle *(Sonchus arvensis)* attention needs to be focussed upon the characteristics of individual plant species and any analysis needs to take account of these characteristics. An aggressive weed in the field need not necessarily appear in quantity as impressions on carbonised material.

SHEAF 15 *Tr. dicoccum* (emmer wheat)

Number of straws	1 833	Sheaf gross weight	3,6 kg
Complete spikes	14		
Rachis ends	602		
Seed yield	97		

TABLE V : *Sheaf analysis. Field II, Harvest 1979, Remanent seeds*

Weed species	Seed numbers
Achilles millefolium	900
Anagallis arvensis	73
Centaurea cyanus	1
Chenopodium album	30,000
Cirsium vulgare	60
Convolvulus arvensis	40
Crepis spp.	1 330
Fraxinus excelsior	2
Leontodon autumnalis	55
Odontites verna	260
Papaver rhoeas	22
Sinapis arvensis	12
Sisymbrium officinale	911
Sonchus arvensis	403
Stellaria media	105
Veronica persica	30
V. chamaedrys	75

However, there is yet the problem of carbonisation for which some account should be made. For carbonisation to occur a fire with a primarily anaerobic atmosphere is required. Undoubtedly some are the product of accidental fires but the following hypothesis seeks to offer a positive alternative to accident. That houses were thatched in the Iron Age is attested by the classical writers and one presumes that straw among other materials was used for this purpose. While it is readily recognised that river reed *(Phragmites)*, heather *(Calluna vulgaris)* and even bracken *(Pteridium aquilinum)* could well have been used, the last being a potential explanation of bracken spores identified on calcareous sites, straw undoubtedly was a readily available material product of the agricultural process. The preparation of straw for thatching requires one most critical operation, it must be cleaned of all other materials including its own leaves, any pithy plant stems, all seeds and especially cereal seeds. The reasons are straightforward. Pithy material rots and by so doing would decrease the bulk and cause the ties to loosen. Any seed material attracts the attention of rodents who in turn may well eat the bundle ties in order to reach the food supplies. Traditionally straw cleaning and the preparation of bundles of yealms which form the thatch require the wetting down of the straw to facilitate the drawing of the straw stalks. The possible implications of the process for the disposition of post-holes is discussed elsewhere (Reynolds 1979). The end product of this cleaning process is a pile of damp waste material comprising arable weeds, stems and seeds and waste cereal heads. It is but a small step to hypothesise the disposal of this damp rubbish with a slow burning bonfire. Such a bonfire inevitably has within it an anaerobic atmosphere which will allow carbonisation to take place.

The two factors which form the objective of this aspect of cereal investigation are, in effect, the result of two distinct approaches, each one relying upon the documentary and archaeological evidence available to us. The first is the pure harvest, the direct result of actually growing prehistoric type cereals in Celtic sized fields and processing them accordingly. The second, the commonly found admixture of carbonised seeds is questioned as being non-representative of a harvest and an alternative hypothesis is raised. If the first, the pure harvest, is a valid hypothesis then the second cannot be representative of that harvest. Throughout it must be emphasised that one is dealing with possibilities and at best probabilities and it would be foolish to deny other hypotheses provided that they can be similarly validated. In effect both the above hypotheses are in a sense offshoots of the main research purpose, that being to establish probable parameters of yield for the prehistoric cereal types given different soil types, treatments and bio-climatic zones.

In this paper I have sought to present not only the broad scale of the archaeological data of the Iron Age period in Britain and to point to potential anomalies within those data as they are currently understood, but also to provide a selection of the results achieved by direct experimentation techniques for crop yields at the Butser Ancient Farm. It is necessary to draw attention to a major *caveat*. The results quoted here which are statistically valid and achieved under the most rigorous conditions, are relevant to the bio-climatic and geological zone within which they were gained. Specifically they relate to the chalk downs and valleys of Southern England. Given the suitability of the present climate for such simulation trials both in Britain and on the continent, it is important and urgent that similar research programmes should be mounted in different zones. Of particular value would be a location in northern France, again on the chalk lands, but where, in the Iron Age, agriculture had reached a significantly high level of success in that an increasing number of "storage pits" are being recovered (Alain Villes — pers. comm.). The potential of this archaeological feature for agriculture and its role within the agricultural cycle has already been explored (Reynolds 1974, also unpublished thesis Leicester University 1978).

In conclusion, the results as demonstrated are exceptional not only because they are unexpectedly high but because they are not effectively improved upon agriculturally until after the last World War. The primary reason for this high performance lies specifically in the nature of the cereal plants themselves and the physical scale of the spikes. Similarly these results further dispel the theory that the Iron Age period was sustained by a subsistence economy and give support to the documentary references such as are available. Finally the recovery of increasing numbers of Iron Age settlement sites and field systems, particularly on low lying land, for example, in eastern England and in the river valleys, further substantiate the hypothesis of a dense population with concomitant complex social and commercial structure.

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