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On the Origin of Carbonised Cereal Grain in Prehistoric Settlement Sites: an Alternative Interpretation

In the analysis of samples of carbonised seeds from prehistoric sites the regular presumption is that these are the product of cereal or food processing. This paper presents the results of an extended series of trials which explore an alternative source of this type of evidence. Given that the natural focus of excavation is upon settlements, seed assemblages are primarily recovered from features and layers within the zone of the domestic economy as opposed to the agricultural economy. Frequently the find location has no specific identifed function which can explain satisfactorily the presence of carbonised seed as the result cooking or processing error. An exception to this general observation is carbonised seeds which have been recovered from a pit interpreted as a storage pit. In this case the seed could well have been carbonised as the side effect of pit cleaning and preparation for further storage. However, the agricultural economy itself provides a potential interpretation of a source of carbonised grain with the usual admixture of other plant seed which is more persuasive both of the nature of seed assemblages and their carbonlsation. This hypothesis is capable of no more proof than any other since it relies upon assumed activities and processes but it does have the advantage that such activities and processes must have taken place in one form or another for the economy to have existed at all. This hypothesis has been derived from the long term cropping trials of Emmer and Spelt wheats carried out at the Butler Ancient Farm since 1972. It suggests that a logical source of carbonised seed found within the settlement zone is the waste product of house thatching. Bonfires simulating the disposal of waste straw with a known input of seed have been burned on a large number of occasions. The remains have been analysed for the survival of carbonised seed with quite remarkable results. The average survival is in excess of sixty percent with a very low standard deviation.

A basic tenet of any experiment is that the hypothesis it seeks to test arises from the known data. In this particular instance it was the data which became apparent during another experiment which gave rise to an hypothesis. A primary objective has been to ascertain the yield factors of the prehistoric type cereals Emmer (*Triticum dicoccum*) and Spelt (*Tr. spelta*) wheats under different treatments against recorded climatic and soil conditions. This series of trials has necessarily been long term with a minimum of ten years being regarded as adequate for obtaining reliable and statistically valid results. The information garnered from these trials includes not only the end product of yield figures but also a large body of data from the growing and standing crop (Reynolds, 1981). Of all these observations, the stage immediately before harvesting has proved particularly fascinating. The crop is always infested with arable weeds which, while in normal circumstances are outgrown by the cereal, nonetheless compete for available light and in consequence certain species achieve a considerable height within the crop. It has been the normal practice in these cropping trials to measure the stand heights of the cereal along random transects immediately prior to harvesting. Initially a thousand measurements were made for each treatment but this was reduced to five hundred since the same distribution was obtained. Typically the range of stand heights varied from as low as 20cms to as high as 180cms. Naturally the bulk of stand heights were between these extremes. A typical range can be seen in Figure 1 where the results are presented in histogram form (Reynolds, 1990). The reason for this seemingly large disparity which is not observed in modern cereals is because these early wheat varieties are stable as opposed to hybrid plants. Modern plant breeding programmes amongst other attributes have produced cereals which grow to a much more uniform height in order to reduce the quantity of straw which is superfluous to today's requirements. Where

Emmer wheat is grown today as a basic food resource in north-east Turkey, the same range of stand heights are observable (pers.comm. G.Hillman). The real point of this reference is that today's Emmer wheat is the direct descendant in an uninterrupted line from the remote past. Morphologically it is exactly similar in all its measurable aspects to its prehistoric ancestor. It is possible but unlikely that its behavioural characteristics have altered slightly. The iconographic evidence for the early cereals shows it to grow unusually tall but the range is unclear.

The stand height range has particular significance for the harvesting process. Exactly how harvesting took place in, for example, the Iron Age is not known. Strabo refers to the practice of gathering the spikes or heads of the cereals. Sickles of many different types have been recovered which are attributed to harvesting (Steensberg, 1943). This has led in turn to explanatory illustrations of a hand grasping a bunch of spikes with a sickle about to cut through the stems. In reality it is not quite so simple. Because of the stand height disparity it is not at all easy to grasp a bunch of spikes. Usually only three or four spikes come conveniently to hand, the rest being out of reach.

The key to understanding the presence of mixed seed assemblages within a settlement must lie in the harvesting techniques adopted because the plant communities are to be found in the fields, not within the settlement itself. The physical process of harvesting can be simply analysed into a limited number of categories each one of which has direct implications for the transfer of the harvest to the settlement and the subsequent treatments required for consumption and storage.

HARVESTING TECHNIQUES:-

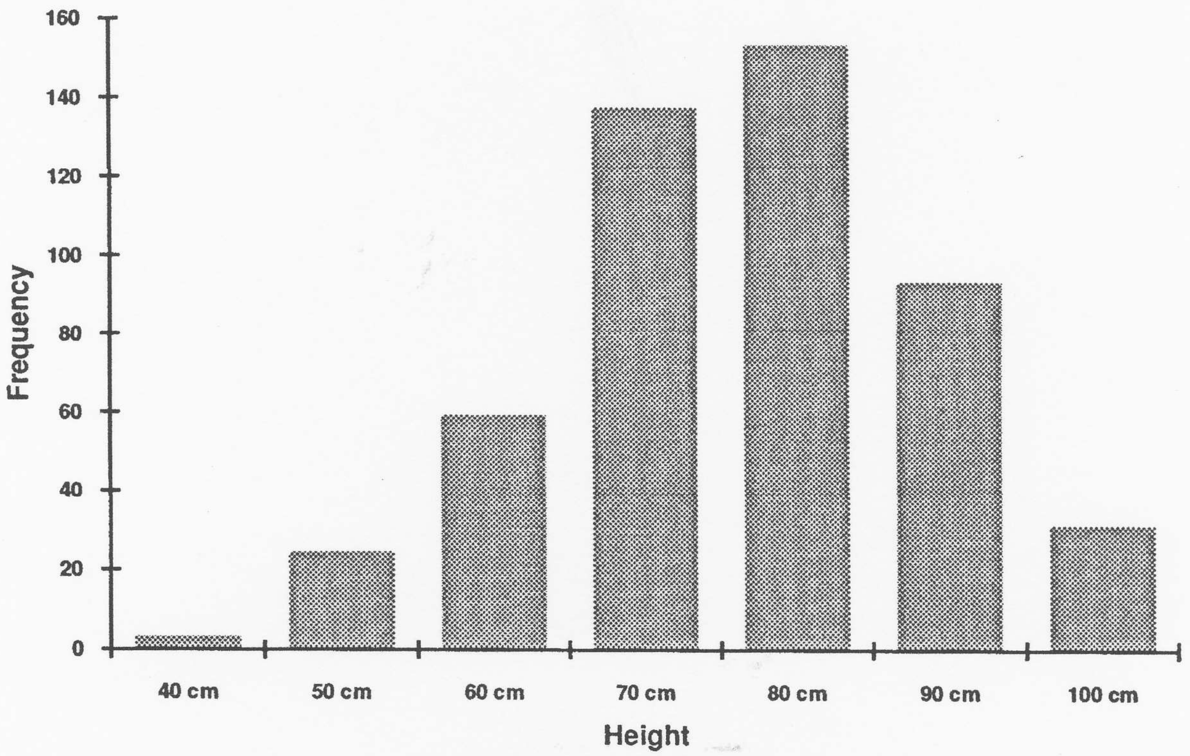
1) a. Cutting off the ear/spike with a hand sickle
   b. Picking off the ear/spike by hand
2) Cutting straw at mid-height with a hand sickle
3) Cutting straw at base
4) Uprooting whole plants.

Cutting off the ear/spike with a hand sickle.

This method referred to above is the most inefficient and time consuming. On a series of occasions groups of volunteers have been supplied with replica sickles of Iron Age type and asked to reap a field of Emmer wheat in this fashion. On every occasion the method was rejected as completely inoperable. The disparity of stand height defeated the method. However, it gave rise to a perfectly simple alternative.

Picking off the ear/spike by hand.

When Emmer wheat is ripe and ready to harvest, the culm internode, the joint between the straw and the ear, becomes extremely brittle and snaps off easily. In fact, when trying to reap with a sickle the hand grasping the ears often comes away with the ears before the sickle makes contact with the straw stems. Harvesting by hand picking is fast and efficient. The harvester equipped with an apron sack can use both hands to pick and usually misses very little. It takes a very short while to realise that each plant has a range of stand heights and the collection of all the visible ears quickly becomes automatic. In the ethnographic record there are a few variations on this theme, notably from the Asturias region in northern Spain. Here the harvester used a special tool. This comprised two wooden spars about forty centimetres long and jointed together at one end. By clamping these spars around the straw stems like closing a pair of jaws and pulling upwards the ears were neatly pulled off. To avoid uprooting the plant the harvester's leg was intertwined with



1990 Stand Heights
Plot 1 Emmer Spring Sown

the straw, the foot pressing down on the root. While sounding awkward, the process is quick and efficient and has the advantage that the clamp can start low down on the stems and thus collect the lower of the stand height range. Another alternative is the small half-moon flint blade which sits in the crook of the index finger and nicks off the ear at the culm internode. This has the advantage of saving damage to the nails, particularly the thumb nail, when a plant is not at the final stage of maturity. The brittleness of the culm internode is another feature of stability of the plant in that it is the device by which the plant ensures its survival. At absolute ripeness the ears fall off the straw stems and the awns on the ear entangle it in the soil surface. A simple trial was carried out where a small plot of Emmer wheat was left unharvested. Within a space of six weeks all the ears had been shed. The new growth appeared four weeks later and the following year quite a respectable crop ensued.

Cutting the straw at mid-height with a hand sickle.

This system of harvesting allows the use of a sickle and assumes the harvester wishes to avoid the majority of the weed flora found normally within the crop. The stand height histogram (Figure 1) shows that this reaping height would average at about forty to fifty centimetres above the ground.

Cutting the straw at the base.

This method involves the total take of the crop and in common with the preceding method assumes sheaves being bundled up prior to transporting the crop to the settlement...

Uprooting whole plants.

Exactly as the above method but without any cutting at all.

It is most unlikely that it will be possible to prove that any one system was used exclusively in any one area in time; the probability is that all these systems in part, in whole or in combination were used in different places at different times. There are, however, a number of direct implications to be drawn from each and every system.

It is not unreasonable to dismiss the cutting of the ears with a hand sickle as being totally impracticable. The method of picking the ears has, on the other hand, a number of clear advantages. In particular it ensures a relatively pure harvest. From over twenty years of practical trials only three arable weeds are regularly found as contaminants of the harvest. These are in descending order of frequency, Black Bindweed (*Bilderdykia convolvulus*), Fat Hen (*Chenopodium album*) and Common Cleavers (*Galium aparine*). The first and last of these are climbing plants using the cereal stems as a ladder to the light. In prehistoric and, indeed, historic times there would have been a few others like, for example, Corn Cleavers (*Galium tricornutum*) which are now virtually extinct in the British landscape. Except for the plants which entwine themselves around the cereal ears, the rest of the not inconsiderable weed flora are easily avoidable. With regard to Black Bindweed, it is commonly found in carbonised seed assemblages but it does have the advantage that it can be eaten without any harmful effects (Winton, 1932). *Galium aparine*, also frequently found, may well be an indicator that crops were autumn sown. The product of this method of harvesting is a virtually pure harvest of ears which can be transported back to the settlement for further processing without having to be further cleaned. There is no doubt but that a small proportion of ears are missed in the harvest. These are the lowest in the stand height range. These ears are often small but equally as ripe as the other ears. Nor is there a significant difference in the size of the seeds themselves so it is not possible to determine from individual seeds their position on the plant. The actual percentage of the crop lost in this way is extremely difficult to calculate but it is probably less than one percent gross. Harvesting the ears in this way also agrees with Strabo's description of the Celtic harvesting technique. The result in the field after the harvest of the ears is a crop of standing straw. Picking the ears does not overly damage the straw especially if it is dealt with immediately. That the straw is an important part of the crop is undeniable. Undoubtedly it was required for thatching houses, bedding, animal feed, matting and basketry and a myriad of other purposes. Its harvest involved either cutting with sickles at the base and leaving a stubble in the field or else uprooting, the straw being bundled into sheaves and either stacked in the field or else transported back to the settlement and stacked there against the time of its use well after harvest. Within these sheaves there would have been a full range of arable weeds except when the straw was cut, in which case those ground-hugging species like the Field Pansy (*Viola arvensis*) could well be missed.

In the case of uprooting, a full range of all species would be likely to find their way into the settlement. Even had the straw not represented a needed product it would have to have been removed from the field since it would have been impossible to plough with an ard. In this connection two further possibilities of treatment arise. The stubble and remaining arable weed trash in the field could have been grazed off by sheep and/or cattle in the process of which the field would have been dunged. Alternatively the stubble could have been fired to clean up the field prior to ploughing. In this context it would be interesting to investigate surviving ancient fields for enhanced magnetic susceptibility on the one hand, on the other for the presence of carbonised seed.

In the case of harvesting by cutting the straw at mid-height, the worst condition is achieved. The sheaves are awkward to handle because of the disparity of straw length and while they may be largely free of weed flora, each sheaf has to be re-processed inside the settlement to remove the ears. The straw from this reprocessing is of little functional value for manufacturing other items and lends itself only to stock feed and perhaps bedding. The field is left with half-cut straw which has to be cleared prior to ploughing. This is even the case if the field is grazed off because the straw is comparatively unpalatable at this time of year and when trodden into the soil does not rot fast enough before ploughing takes place. Any bulk of fibrous material contained in the plough soil very quickly clogs an ard and makes it unusable.

Cutting the straw at the base and bundling sheaves which are then carted and stacked is the traditional view of harvesting and, therefore, the easiest to understand. This method of harvesting is best achieved by using a scythe. However, there is a huge amount of ethnographic evidence of harvesting in this manner with sickles. Indeed, in a large number of Mediterranean countries where a peasant economy is practised sickle harvesting is carried out today. The product has the major disadvantage of needing to be re-processed either in the field or in the settlement but at least the straw is preserved in long enough lengths to be fully utilisable. The field area is also left relatively clean and, given grazing, will be easy to plough. This system also allows the possibility of culling a complete harvest since all the ears at whatever height they may have been in the growing crop will have been harvested and brought back,

The last method of uprooting the crop has the same effects as cutting at the base except that soil and organic material are continually being removed from the field and depletion will soon take place. In all the other methods the organic content is not radically depleted. Long term trials have demonstrated that this type of agriculture does little damage to the soil structure and brings into question the whole theory of soil exhaustion in an Atlantic climate.

An alternative source of carbonised seed evidence was the direct result of this consideration of harvesting techniques. If the method of picking the ears was that in normal use as implied by Strabo, the straw sheaves represent a secondary but nonetheless important harvest. The practice of picking the ears has, in fact, been the usual method of harvesting for many years at the Ancient Farm. It has all the advantages listed above but is particularly useful in that thatching straw is obtained every year. In fact, it was because straw was used for thatching that sheaves were first subjected to analysis. Initially an attempt was made to ascertain the number of arable weed species and seeds in a sheaf but so much was lost from each sheaf as it was transported from field to laboratory as to make the exercise meaningless. Critically, however, when the straw was harvested from the field it was possible to see occasional ears of Emmer lodged in amongst individual sheaves. The great majority of these were from the lowest stand height range but inevitably ears were missed by the reapers from the higher levels. The first serious analysis was carried out in 1978. Twenty sheaves, randomly selected from the harvest of Field 1, were systematically sorted and all the cereal seeds collected. These included complete ears, half ears and, very commonly, the basal seed bearing spikelets still firmly attached to the culm. The results of this analysis can be seen in Table 1.

Thereafter, because the analysis took so long at an extremely busy time of year, it was decided to sample straw harvests on a reduced basis and biennially rather than annually. The argument was sustained by the small standard deviation achieved from the first analysis. These subsequent analyses can be seen is Table 2.

The immediate observation after the first analysis was that a number of seeds totally unassociated with the actual seed harvest was probably being transported into the settlement. The alternative of straw stacks being built within the confines of the field system is not unattractive in the sense of a pleasing rural scene but it does leave a valuable commodity beyond the direct control of the farmer. An unlikely practice at any time of agricultural development! The supplementary question posed concerned any activity which would involve the separation of this seed from the straw and provide potential circumstances for its accidental burning. Only one specific hypothesis emerged, the preparation of straw for thatching purposes. All the other possible uses of the straw harvest either did not require any further processing like bedding or animal feed or else were extremely minor like making mats. The preparation of straw for thatching had an even greater attraction in that not only would cereal seeds be removed but also any other plant material as well.

When straw is used as thatch it has to lie carefully prepared. All other material including the leaves around the straw stems is stripped away and pure bundles of straw stems called yealms are made. The purpose behind this careful preparation is not so much aesthetic as practical. Any seeds, cereal or weed, will attract rodents and birds into the finished roof. This leads to the ties being chewed away, holes made for nests and general loosening of the thatch. Similarly leaves and pithy stems of plants like the Sow Thistle (*Sonchus arvensis*) will wither and dry and also affect the tied bundles. Any looseness in a finished roof is prey to the first gale and a tiny gap can quickly become a gaping hole. It is not unknown for one small hole in a roof to cause the total stripping of that roof in a storm force gale. The actual method of yealm preparation in prehistory can only be guessed at but that it was done is more or less certain. The longevity of the houses indicates that a straw roof must have lasted the minimum of ten years and probably the historic average of fifteen years. It is most unlikely that the annual thatching practice seen in the recent past in the Scottish Highlands, the west coast of Scotland and the offshore islands and the west coast of Ireland was the general system in the remote past. Here the process was quite deliberate in order to provide an annual source of manure for the infield. The typical roof comprised a layer of straw over a sod cover, all of which was stripped off each spring and spread on the fields as fertiliser. Naturally this material was rich in decayed humus and soot from the open fireplace. The prehistoric roundhouses really are not comparable, not least because of their design, size and nature of construction. It is most unlikely that many were clad with a sod roof simply because of the span of the building and the sheer weight of turf (Reynolds,1989).

One interesting system of yealm preparation is described by Thomas Hardy in Tess of the d'Urbevilles, written in 1891. Since Hardy was by profession an architect it is not unreasonable to assume his description was based upon personal observation. Old women are described as pulling the straws to make into yealms from a stack of sheaves carefully set between two upright posts and weighed down with a heavy baulk of timber. The sheaf stack was doused with water to make the pulling of the straws easier. Such a system is likely to have been quite traditional. With regard to the archaeological evidence from the Iron Age, there is no shortage of pairs of postholes for which there is no adequate interpretation. Should this have been the practice most houses would have had such a pair of posts somewhere in its vicinity.

It is the waste product from yealm preparation which is of significant interest. It comprised all seeds both of cereal and arable weeds, short lengths of straw, straw leaves, stems of arable weeds and, of course, grasses. This rubbish material in all likelihood would also have been damp. The question of its disposal is pivotal to the present hypothesis. Having prepared yealms for thatching on a number of occasions, experience has shown that the rubbish generated at least equals the finished straw yealms. In effect half the straw harvest is waste. The farmer's way of getting rid of this type of material is to dump it into the nearest paddock or animal pen as feed. However, the other option explored here is its disposal by fire. A bonfire is quite the normal way of clearing up and in the case of the dismal picture painted by Hardy would have provided at least a modicum of warmth for the miserable women workers. It was from such a clearing bonfire that the hypothesis was raised. Having burnt most of the waste, a bonfire was left overnight to smoulder away. The following morning, rather than immediately begin the process all over again, idle inspection of the remains of the fire, initially boot-stirred, revealed a considerable quantity of carbonised seeds. Closer analysis followed by sampling and counting showed not only a large number of cereal grains but also a fair number of arable weed seeds to have been carbonised. The quantification, however, was of singularly little value since it was an output without a known input. All that had been realised was that carbonised seed resulted from such a bonfire and the product was simply a partial presence list in the sense that the seed which survived did not fully represent the range of plants known to have been in the waste material.

Arising from this experience it was decided to construct a simple experiment in order to quantify the survival rate particularly of cereal seeds from a bonfire. The design of the experiment, so that it could be replicated as many times as possible, had a series of straightforward guidelines. The underlying argument suggests that an admixture of carbonised seeds, both of cereals and arable weeds, would result from the disposal of thatchers waste by bonfire. Therefore each bonfire would follow the same pattern. A quantity of straw waste and green plant material with a known number of cereal seeds mixed in would be burned in a contained area. The cereal seed would be in the form of complete spikes, broken spikes and individual spikelets simulating the nature of the "lost" harvest, those spikes missed or damaged by the reapers. In the case of Emmer and Spelt wheats it is relatively easy to count precisely the number of seeds in a spike or spikelet by touch. The bonfire would be allowed to burn away completely, the resultant ash remains would be collected and subsequently analysed for carbonised seed. The carbonised seed found would be expressed as a percentage of the original fresh seed. As many replications of the experiment as possible would be carried out with the results averaged to give an indication of the survival rate of seed in carbonised form.

The experimental series has, to date, been in process for over ten years with well in excess of a hundred completed trials. Given the simplicity of the experiment, it has been used primarily as a teaching practical research trial for students. The results from all the trials conducted to date are reported in their entirety below. Initially large numbers of seed were introduced into the bonfires but the figures were reduced principally to avoid seed wastage but also to test the theory to its fullest potential. By the same token modern cereal seeds were regularly used with very similar results. Characteristically the modern wheat can compare with Club wheat (*Tr. aestivo-compactum*) and Old Bread wheat (*Tr. aestivum*) neither of which wheat types has actually been used in these trials because of their scarcity.

The limitations of this experiment lie particularly in the nature of a bonfire. Many trials have been carried out to carbonise seed in order to establish the nature and amount of distortion which takes place. Of necessity these are held under controlled conditions where individual seeds can be exactly studied against specific temperatures. In this experiment such control and detailed observation is quite impossible. Each bonfire is unique unto itself, subjected as it is to the vagaries of the natural conditions prevailing at the time of the trial. Similarly the recordings of temperatures within the fire are at best general because the essence of fire is its instability. Temperatures have regularly been recorded for the bonfires, typical examples of which are reported below (Table 3), but it is uncertain whether the resultant carbonised seeds were actually exposed to these temperatures and if so, for how long.

The actual mechanics of a straw bonfire are extremely interesting and, in this case, critical to the understanding of why so many seeds survive. In the creation of a bonfire it is necessary to start the fire with a "heart". Normally this is achieved with a few dry twigs. Once these are alight and burning well the straw waste is heaped on. Even if a little damp, very quickly the fire turns into a flame rather than a smouldering fire. Given the loose nature of the material and the speed at which it is consumed, small dense objects quickly fall through the interstices into the base of the fire. For Emmer and Spelt wheats, the beard or awns rapidly burn away allowing the relatively heavy spike and spikelet to fall through the matrix of straw and vegetation. Equally swiftly, the burned straw falls as a fine layer of ash and in a short time an appreciable bed of ash is formed which tends to cover the starter twigs and any heavier material which has fallen through and continues to fall through like the seeds and heavier plant stems. Further additions of straw simply increase the layer of ash. This ash bed provides the ideal conditions for carbonisation. The material is still burning but in an anaerobic state. Only at the interface between the surface of the ash layer and the new material is there a free flow of oxygen. When bonfires have been fitted with thermocouples, these are initially placed in the middle of the fire. As the structure of the fire changes they quickly gravitate downwards and either lie on the surface of the ash layer or become embedded n it. Table 3 shows the typical temperature pattern across five fires burned at the same time on the same day. Fire number 2, where the temperatures are relatively low, represents an occasion when the thermocouple was forced down to the base of the fire being disturbed only at the final session. In fact, this table demonstrates the normal period of the bonfire trial. After ninety minutes the fire ceases to be fed and is allowed to cool prior to the remains being collected and transported back to the laboratory for analysis. Perfectly adequate temperatures were recorded in all the fires to cause carbonisation. In practice, during the subsequent analysis the first task is to remove all the fragments of carbonised twigs which were used to start the fire. These mechanics of the bonfire are neatly illustrated by one series of trials in which naked Emmer wheat seeds were introduced into the straw waste (Table 6). In this case in the complete absence of awns or glumes, the seed fell through the fire almost immediately. In one trial over 92% of the seed became carbonised in the soft ash layer. The overall average of 87.6% survival is extremely high and probably quite unrealistic except for demonstrating this argument. Nonetheless a similar but much lesser effect is obtained with the modern free-threshing wheat (Table 5) which gives a slightly higher average and smaller standard deviation than either Emmer or Spelt wheats.

However, the most remarkable aspect of all the trials is the sheer quantity of seed which survives in the carbonised state. Despite understanding the mechanics of the bonfire, it is still surprising that from a flaming mass of straw with temperatures in excess of 600°C, so much will survive. Table 4 presents the results of all the fires notwithstanding the type of wheat except that all were in various form of spikelet. The overall average is a 63% survival with a standard deviation of +/- 12%. This figure is slightly distorted by the greater number of trials with modern wheat. This is redressed in Table 5 where the results are presented for the separate wheat types used in the trials. The fewer trials for Spelt wheat are brought about purely by seed scarcity. Nonetheless, seventeen replicates is a fair series of trials. Both Emmer and Spelt wheat behave in a very similar fashion with 62% and 61% survival averages with a standard deviation of +/- 13%.

Examination of the carbonised seed has to date been minimal in comparison to the number of burning trials. However, several analyses have been carried out of which the following example is typical. After the simple count of surviving seed from trials involving Emmer and Spelt wheats, a total of one hundred seeds from each species were randomly selected. These were measured in two dimensions, their length and their maximum width from ventral to dorsal sides. To provide a comparative standard, fifty seeds were randomly selected from the same harvest and measured in exactly the same way. All the measurements are in millimetres and achieved with a micrometer. The results are shown in Tables 7 and 8 for the fresh seed and Tables 9 and 10 for the carbonised seed. The fresh seed measurements show a reasonable conformity with an average standard deviation of 0.5mm. Remarkably the width of Emmer wheat seed in the sample has a minimal standard deviation of just 0.15mm. The carbonised seeds similarly show a fairly close standard deviation of c. 0.5mm with the exception of the length of Emmer wheat seeds with a 1.13mm which indicates considerable variability. In the case of both Emmer and Spelt, the average results indicate a slight shrinkage in length of 2.2% and 5.2% respectively. The greatest change as might be expected to takes place in the width, the distance between the ventral and dorsal sides. Emmer wheat showed by far the greatest change, swelling by some 34.7% while Spelt swelled by 20.7%. It is virtually impossible to monitor the temperatures inside a bonfire comprehensively and even if it were, it would be impossible to associate individual seeds to precise locations and temperature changes. The variability of change of the seeds is undoubtedly caused by a combination of differential temperature experience and original moisture content of the seeds. With regard to this last, the average moisture content of the seed from the harvest in the field ranges from 14% to 16%. Safe storage of seed requires a maximum of 14% and ideally slightly less.

With regard to the carbonisation of other types of seed, one specific experiment was carried out by request (A. Fairweather, H.B.M.C. Edinburgh) to examine the changes in dimensions of flax seed (*Linum usitatissimum*) from fresh to carbonised state in a bonfire environment. As might be expected, the survival rate of this oil-bearing seed is remarkably low at just 8% (Table 11). This was assumed before the trial and determined the high numbers of introduced seeds. Had lower quantities been used, a negative return could easily have occurred. The size measurements based on a sample of five hundred fresh against two hundred and fifteen surviving carbonised seeds of their maximum length and widths are as follows:

Fresh	average length	5.0mm	average width	2.3mm
Carbonised	average length	4.4mm	average width	2.13mm

Given the oil content, the uniform shrinkage is only to be expected but importantly the reduced measurements could cause identification difficulties with the possible confusion with pale flax (*Linum bienne*).

Various other trials have been made for other plant species, in particular for arable weeds, but none in such detailed form as for the cereals. One of these trials comprising a series of thirteen replicates concerned Corn Cockle (*Agrostemma githago*). From the analysis of carbonised seed assemblages from prehistoric sites in England Corn Cockle is regularly found. The seed itself contains a poisonous glucoside, githagen, with a bitter taste and a narcotic effect (Korsmo,1981). It would undoubtedly have been carefully extracted in any food preparation. As an arable weed it is an annual depending upon the seed at maturity being spilled from the open seed capsule by disturbance, either wind or the harvesting process itself. Normally it ripens before harvest in common with all the other annual weed species but not infrequently unripe plants survive beyond harvesting time. Given their stand height range of 300mm – 900mm, it is perfectly reasonable to expect them to be harvested along with the cereals and transported back to the settlement. Thereafter their disposal by fire is most likely. The results from the bonfire trials are given in Table 12. An average survival rate of just 27% is quite low for a seed which is small and hard but the variability in the results ranging from 4.5% to 82.0% suggest that the seeds are highly susceptible to temperature change. Further research needs to be carried out for this and a range of other species of arable weeds.

One further trial examined the behaviour of Buckwheat (*Facopyrum esculentum*). Evidence for its cultivation is scant until the mediaeval period when it was regularly used as a wheat substitute. The results of a series of ten replicates are presented in Table 13. In contrast to Corn Cockle the average survival rate of 35% is a fair reflection of all the individual results.

In conclusion, the hypothesis explored above seems to provide a reasonably plausible alternative source of carbonised seed in prehistoric settlements to that of cereal and food processing. The number of trials and the uniformity of the results imply a remarkably rich survival rate of carbonized cereal seed and given the nature of the waste material being burned would provide exactly similar assemblages to those regularly reported. Because the cereal seed survival is so high, averaging some 60%, the actual quantities of source seed may have been relatively low to furnish the typical component found in archaeological deposits. Further work needs to be done particularly with regard to arable weed seeds as evidenced in order to establish a comparable relationship. Presently only a relationship between the wheat and Corn Cockle could be assessed with the *caveat* expressed above about Corn Cockle but with an increased range of typical arable weeds focussing upon those which flourish at the mid-range stand height between 300mm-900mm a fuller picture could emerge. However, in order to indicate how a relationship might be explored, the present results for the cereals and Corn Cockle have been used. At the outset it must be stressed that within any such calculation it is critical to take into account the normal seeding patterns of the plants in question. For example, a yield of one ton per acre (c.2.4 tonnes per hectare) of Emmer wheat gives between thirty two and thirty six million seeds (seventy seven to eighty six million per hectare). Given the average seed yield of Corn Cockle at two hundred seeds per plant and a frequency rate of five plants per square yard the yield per acre gross would be about five million (about twelve million per hectare) of which only some ten percent would ripen post-harvest. As stated above approximately one percent of the cereal harvest would escape being reaped which would leave a relationship ratio of 7:1 cereal seeds to Corn Cockle seeds. Given the results of the bonfire trials the adjustment would lead to a carbonised seed ratio of 42 (60% of 7 x 10) : 2.7 (27% of 1 x 10). There are, of course, so many variables involved that such a computation might prove to be quite spurious. Certainly a greater number of arable weed species need to be included before it could be accepted as a working hypothesis. Should it be accepted it could lead to a reasonably substantiated assessment of the weediness of prehistoric fields on the one hand, on the other the frequency of different weed species within the field plant communities.

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Table 1
Sheaf analysis Emmer Wheat Straw Field 1 1978
Number of cereal Seeds per Sheaf

190	247	234	238
282	263	268	116
210	199	184	301
167	272	193	150
189	315	212	117

Average: 217.45
Standard Deviation: 56.79
Average Sheaf Weight: 5kg

Table 2
Remanent Cereal Seeds per Sheaf

Field No:	VII	VI	VII	II	V11
Year	1980	1982	1984	1986	1988
Sample 1	152	215	173	99	241
Sample 2	310	186	210	180	183
Sample 3	222	272	221	137	199
Sample 4	94	230	162	167	213

Overall average number of seeds per sheaf: 193
Average Sheaf Weight: 5kg

Field Treatments:		
	I	Continuous rotation beans v wheat
	II	Continuous wheat crop non-matured
	VI	Continuous wheat crop biennially manured
	VII	Continuous wheat crop annually manured

(For further details of cropping trials at the Ancient Farm, see Year Books 1986, 1987, 1988, 1989, 1990.)

Table 3
Bonfire Temperatures in degrees Celsius

Minutes after ignition	5	30	60	90	Seed Input	Seed Output	Seed Survival
Bonfire No 1	210	65	455	445	904	301	33.3%
2	100	180	150	450	1765	1027	58.2%
3	180	540	550	365	1942	1364	70.2%
4	320	400	360	475	1234	787	63.8%
5	220	350	470	450	1009	739	73.2%

Average Survival 59.7%

Table 4.
Spikelet Form. All cereals.

Input	Output	Survival %	Input	Output	Survival %
5500	3849	69,98	1100	629	57,18
5600	2760	49,29	1500	1007	67,13
5650	3231	57,19	1250	852	68,16
5450	2974	54,57	1300	989	76,08
5430	3901	71,84	260	191	73,46
3960	3015	76,14	323	201	62,23
4000	2484	62,10	384	266	69,27
3800	2762	72,68	286	237	82,87
373	253	67,83	256	206	80,47
377	204	54,11	250	130	52,00
372	248	66,67	580	263	45,34
538	250	46,47	630	474	75,24
376	219	58,25	750	520	69,33
999	743	74,37	400	263	65,75
505	207	40,99	595	219	36,81
592	383	64,69	500	372	74,40
760	512	67,37	650	437	67,23
643	234	36,39	700	551	78,71
846	192	22,69	650	419	64,46
497	427	85,91	580	307	52,93
889	639	71,88	315	165	52,38
823	572	69,50	300	149	49,67
791	459	58,03	260	116	44,62
550	446	81,09	295	176	59,66
650	184	28,31	350	189	54,00
500	219	43,80	270	161	59,63
525	365	69,52	345	184	53,33
480	322	67,08	330	203	61,52
500	292	58,40	300	221	73,67
524	409	78,05	240	191	79,58
573	437	76,26	410	297	72,44
455	385	84,62	367	284	77,38
600	378	62,99	904	301	33,30
615	412	66,99	1765	1027	58,19
543	315	58,01	1942	1364	70,24
500	370	74,00	1234	787	63,78
450	280	62,22	1009	739	73,24
550	411	74,72	1700	1157	68,06
400	160	40,00	4200	1455	34,64
350	204	58,28	3600	2506	69,61
350	230	65,71	1788	878	49,11
445	295	66,29	2680	1957	73,02
1275	763	59,84	5028	3419	68,00
980	602	61,42	4962	2837	57,17
1000	687	68,70	5500	3261	59,29
1200	711	59,25	5010	2612	52,14

Table 4 cont.

Input	Output	Survival %	Input	Output	Survival %
4600	2989	64,98	680	414	60,88
240	167	69,58	820	629	76,71
265	142	53,58	816	598	73,28
230	183	79,57	760	462	60,79
300	175	58,33	804	411	51,12
284	201	70,78	798	543	68,05
310	226	72,90	764	484	63,35
275	191	69,46	804	417	51,87
288	206	71,53	809	526	65,02
292	119	40,75	713	382	53,58
300	183	61,00	983	791	80,47
324	207	63,89	957	588	61,44
306	219	71,57	401	321	80,05
288	199	69,10	467	268	57,39
276	177	64,13	476	393	82,56
298	203	68,12	446	286	64,13
225	142	63,11	200	109	54,50
180	103	57,22	210	139	66,19
316	179	56,33	206	128	62,14
424	207	48,82	190	138	72,63
402	237	58,96	204	121	59,31
388	191	49,23	168	99	58,93
434	222	51,15	175	93	53,14
480	296	61,67	230	157	68,26
468	303	64,74	220	166	75,46
360	172	47,78	215	154	71,63
440	268	60,91	180	110	61,11
482	371	76,97	214	134	62,62
396	246	62,12	80	35	43,75

Average %: 62.9039
Standard Deviation: 11.699599

Table 5.
Modern Wheat Spikelet Form

Input	Output	Survival %	Input	Output	Survival %
5500	3849	69,98	550	411	74,72
5600	2760	49,29	400	160	40,00
5650	3231	57,19	350	204	58,28
5450	2974	54,57	350	230	65,71
5430	3901	71,84	445	295	66,29
3960	3015	76,14	1275	763	59,84
4000	2484	62,10	980	602	61,42
3800	2762	72,68	1000	687	68,70
500	370	74,00	1200	711	59,25
450	280	62,22	1100	629	57,18

Input	Output	Survival %
1500	1007	67,13
1250	852	68,16
1300	989	76,08
260	191	73,46
323	201	62,23
384	266	69,27
286	237	82,87
256	206	80,47
250	130	52,00
5028	3419	68,00
4962	2837	57,17
5500	3261	59,29
5010	2612	52,14
4600	2989	64,98
300	183	61,00
324	207	63,89
306	219	71,57
288	199	69,10
276	177	64,13
298	203	68,12

Input	Output	Survival %
225	142	63,11
180	103	57,22
316	179	56,33
360	172	47,78
440	268	60,91
482	371	76,97
396	246	62,12
680	414	60,88
820	629	76,71
816	598	73,28
760	462	60,79
804	411	51,12
798	543	68,05
764	481	63,35
804	417	51,87
809	526	65,02
713	382	53,58
983	791	80,47
957	588	61,44

Average %: 64.126441
Standard Deviation: 8.8667388

Emmer Wheat. Spikelet Form

Input	Output	Survival %
373	253	67,83
377	204	54,11
372	248	66,67
538	250	46,47
376	219	58,25
999	743	74,37
505	207	40,99
592	383	64,69
760	512	67,37
643	234	36,39
846	192	22,69
497	427	85,91
889	639	71,88
823	572	69,50
791	459	58,03
550	446	81,09
650	184	28,31
500	219	43,80
525	365	69,52
480	322	67,08
500	292	58,40

Input	Output	Survival %
524	409	78,05
573	437	76,26
455	385	84,62
600	378	62,99
615	412	66,99
543	315	58,01
580	263	45,34
630	474	75,24
750	520	69,33
400	263	65,75
595	219	36,81
500	372	74,40
650	437	67,23
700	551	78,71
650	419	64,46
580	307	52,93
904	301	33,30
1765	1027	58,19
1942	1364	70,24
1234	787	63,78
1009	739	73,24

Input	Output	Survival %
240	167	69,58
265	142	53,58
230	183	79,57
300	175	58,33
284	201	70,78
310	226	72,90
275	191	69,46
288	206	71,53
292	119	40,75
424	207	48,82
402	237	58,96
388	191	49,23
434	222	51,15
480	296	61,67
468	303	64,74
401	321	80,05

Input	Output	Survival %
467	268	57,39
476	393	82,56
446	286	64,13
200	109	54,50
210	139	66,19
206	128	62,14
190	138	72,63
204	121	59,31
168	99	58,93
175	93	53,14
230	157	68,26
220	166	75,46
215	154	71,63
180	110	61,11
214	134	62,62
80	35	43,75

Average %: 62-217162
Standard Deviation: 13.366327

Spelt Wheat. Spikelet Form

Input	Output	Survival %
315	165	52,38
300	149	49,67
260	116	44,62
295	176	59,66
350	189	54,00
270	161	59,63
345	184	53,33
330	203	61,52
300	221	73,67

Input	Output	Survival %
240	191	79,58
410	297	72,44
367	284	77,38
1700	1157	68,06
4200	1455	34,64
3600	2506	69,61
1788	878	49,11
2680	1957	73,02

Average %: 60.724706
Standard Deviation: 12.725619

Table 6
Triticum dicoccum. Naked Form

Input	Output	Survival %
500	390	78,0 %
1000	923	92,3 %
1000	880	88,0 %

Input	Output	Survival %
1000	896	89,6 %
1000	901	90,1 %

Average Survival %: 87.6

Table 7.
Emmer Wheat *Triticum dicoccum*
Seed Dimensions Fresh (mm)

Length	Width	Length	Width	Length	Width	Length	Width
7,4	2,8	7,2	2,6	8,1	2,6	7,7	2,4
7,6	2,5	6,6	2,2	8,0	2,6	7,7	2,5
8,4	2,6	7,5	2,3	8,1	2,7	7,7	2,4
8,1	2,9	7,4	2,5	7,5	2,6	7,5	2,5
8,9	2,8	7,5	2,7	8,6	2,5	8,3	2,6
7,7	2,6	7,8	2,6	8,0	2,4	8,5	2,5
8,3	2,8	7,9	2,5	8,2	2,4	7,9	2,4
9,1	2,6	8,0	2,7	8,0	2,5	8,1	2,8
7,8	2,7	8,5	2,5	8,5	2,6	7,1	2,1
8,8	2,5	7,7	2,5	8,7	2,7	7,3	2,2
8,2	2,5	7,4	2,6	8,7	2,6	7,7	2,2
7,2	2,5	7,8	2,5	7,2	2,4		
7,6	2,6	8,1	2,5	8,1	2,5		

Average Length: 7.914 mm
Standard Deviation: 0.5174545

Average width: 2.536 mm
Standard Deviation: 0.1638317

Table 8:
Spelt Wheat *Triticum spelta*
Seed Dimensions Fresh (mm)

Length	Width	Length	Width	Length	Width	Length	Width
7,6	2,4	8,3	2,6	7,9	2,6	7,4	2,4
7,8	2,4	8,8	2,6	8,4	2,8	8,6	2,6
8,4	2,5	7,4	2,2	7,9	2,6	8,5	2,9
8,3	2,7	7,7	2,6	8,2	2,7	8,8	2,8
8,8	2,7	8,7	2,6	8,4	2,7	8,6	2,6
7,1	2,8	8,3	2,7	7,8	2,6	8,9	2,6
8,4	2,7	8,3	2,7	8,8	2,8	8,5	2,7
7,9	2,5	8,1	2,7	8,5	2,5	8,7	2,5
8,9	2,5	8,7	2,8	8,6	2,5	7,6	2,7
8,3	2,3	8,3	2,8	7,7	2,5	8,7	2,6
8,4	2,6	8,3	2,8	8,1	2,8	9,0	2,7
7,7	2,4	8,1	2,9	8,4	2,5	8,2	2,6
8,0	2,2	8,4	2,8	7,8	2,6	8,4	2,7

Average Length: 8.262 mm
Standard Deviation: 0.4439572

Average width: 2.614 mm
Standard Deviation: 0.4439572

Table 9
Emmer Wheat *Triticum dicoccum*
Seed Dimensions Carbonised Seed

Length	Width	Length	Width	Length	Width	Length	Width
8,2	3,4	7,6	3,4	9,2	3,8	8,8	3,4
7,0	3,2	9,0	3,2	8,4	3,8	8,2	3,7
6,8	4,8	5,2	4,1	8,8	3,2	9,0	3,3
9,0	5,0	9,0	4,2	7,2	3,0	8,2	3,2
7,0	4,0	8,0	4,1	8,4	3,2	8,4	3,8
5,8	3,2	8,2	4,0	8,4	3,6	8,2	3,6
6,0	3,8	9,0	4,6	7,2	2,8	8,0	2,7
6,8	2,8	9,9	4,8	8,6	3,0	7,6	3,0
7,0	3,8	8,0	3,5	9,0	3,0	8,2	3,4
7,6	3,2	7,0	3,5	8,0	3,4	9,2	3,8
6,8	4,0	7,1	3,6	8,0	2,4	9,4	3,1
6,8	3,6	7,0	3,0	7,0	2,8	9,4	3,4
6,2	4,2	7,0	3,0	7,2	2,4	8,8	3,6
6,4	3,4	7,1	3,5	8,4	3,4	9,2	3,3
5,4	4,1	8,0	4,2	7,0	2,4	7,0	3,2
6,4	2,6	7,0	4,0	9,2	3,2	8,2	3,0
7,0	3,4	7,1	4,1	9,2	4,0	9,0	2,9
9,0	4,2	5,0	3,2	8,8	3,1	8,4	2,8
7,8	4,2	6,0	5,0	8,6	3,2	8,4	3,1
6,8	3,2	4,2	3,2	8,4	2,9	8,6	2,8
6,0	2,8	7,0	4,6	8,2	2,6	8,4	2,6
8,2	3,0	7,0	3,2	8,9	3,2	9,0	3,1
7,8	4,2	7,0	3,0	8,0	3,2	8,6	3,0
6,0	3,8	6,0	4,0	8,0	2,8	8,9	2,7
6,4	2,8	7,0	3,1	7,8	3,2	8,6	3,5

Average Length: 7.742 mm
Standard Deviation: 1.1272273

Average width: 3.424 mm
Standard Deviation: 0.5799896

Table 10.
Spelt Wheat Triticum spelta
Seed Dimensions. Carbonised

Length	Width	Length	Width	Length	Width	Length	Width
7,2	3,4	8,0	3,1	7,0	3,1	7,6	3,4
7,0	2,3	8,0	2,9	8,2	3,4	7,0	2,4
8,4	3,1	8,1	3,2	8,1	3,5	7,1	2,6
8,1	3,3	7,5	3,1	7,5	3,2	8,4	3,9
8,2	3,1	7,4	2,7	8,0	3,4	8,5	3,3
8,0	2,6	7,5	2,5	6,5	2,6	7,4	3,6
8,1	3,1	8,1	3,5	7,1	3,2	8,3	3,7
8,4	3,3	7,5	2,6	8,5	3,5	7,9	3,1
8,2	3,1	7,3	3,2	8,1	3,5	6,4	2,3
8,0	3,6	6,4	3,7	7,5	3,5	7,6	3,1
7,9	3,2	6,2	3,3	8,2	3,3	6,1	3,7
8,1	3,0	8,1	3,2	8,1	3,6	8,1	3,2
8,1	2,7	8,4	3,1	8,0	3,6	7,4	3,0
8,0	3,0	8,2	3,0	8,5	3,7	8,0	3,0
8,5	3,1	8,3	3,3	9,0	3,8	8,1	3,2
8,0	3,2	8,1	2,8	7,4	3,4	8,4	3,4
7,5	2,6	8,0	3,0	8,0	3,7	8,1	3,6
6,6	2,7	8,5	3,2	8,6	3,4	8,0	3,6
7,1	2,5	8,6	3,1	7,4	3,3	8,3	4,1
8,2	3,3	8,2	3,2	8,1	3,6	7,2	3,6
8,0	2,7	7,6	2,6	9,1	2,7	9,0	3,9
8,1	2,8	7,5	2,4	7,6	2,6	6,6	2,7
7,5	2,6	7,1	2,8	8,0	2,4	8,0	3,9
8,4	3,1	7,2	2,5	8,2	3,1	8,1	3,7
8,0	3,0	6,6	2,4	8,4	3,5	8,7	3,4

Average Length: 7.834mm
Standard Deviation: 0.6195828

Average width: 3.148 mm
Standard Deviation: 0.4157214

Table 11.
Linum usitatissimum

Input	Output	Survival %
2600	215	8.3
2000	249	12.5
2500	196	7.5
1000	42	4.2
1000	76	7.6

Average Survival: 8.1%

Table 12
Agrostemma githago

Input	Output	Survival %
200	80	40.0
200	164	82.0
200	109	54.5
200	10	5.0
200	45	22.5
200	80	40.0
200	45	22.5
200	97	43.5
200	103	51.5
200	9	4.5
200	67	33.5
200	20	10.0

Average Survival: 27.4%

Table 13.
Fagopyrum esculentum

Input	Output	Survival %
200	68	34.0
200	82	41.0
250	103	41.2
250	98	39.2
260	87	33.5
200	44	22.0
280	118	42.1
230	74	32.2
250	59	23.6
200	75	37.5

Average Survival: 34.6%