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Iron Age Cultigen? Experimental Return Rates for Fat Hen (*Chenopodium album* L.)

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Abstract

Archaeological finds of fat hen (*Chenopodium album* L.) from later prehistoric sites in Europe indicate that the plant was deliberately collected, perhaps even cultivated. Experiments are described involving the collection and processing of the plant, allowing the return rate to be calculated. The return rate is probably similar to that of cultivated cereals, which may produce more seed per unit area but require much more processing. *Chenopodium album* was therefore a viable potential cultigen.

Keywords: CHENOPODIUM, RETURN RATE, COLLECTION, PROCESSING, CEREALS

Introduction

The role of plants in prehistoric economies is of major importance to our understanding of how prehistoric societies worked. One question often raised concerns plants that are believed to be of substantial potential value but which are regarded as weeds today: might they have been of major importance in the past? Might they even have been cultivated?

These are questions which have been raised with regard to *Chenopodium album* L. Hans Helbæk discussed the matter in a series of publications (Helbæk 1951; 1954; 1960). Various prehistoric finds from Denmark struck him as particularly important in this respect. A deposit of 1670 cc of seeds, calculated to comprise some 2.4 million seeds, came from the site of Nørre Fjand. This find dates from the first few centuries AD, "demonstrating the separate gathering (or cultivation?) of these seeds for food" (Helbaek 1954, 255). Seeds of *C. album* were also common in the stomach contents of the contemporary bog corpses from Tollund (Helbæk 1950) and Grauballe (Helbæk 1958). Whether the plants for these last meals were deliberately collected (Glob 1969, 32–35) or represent crop processing waste (Hillman 1986) is currently under discussion, but the Nørre Fjand find must represent deliberate human action: "it is clear that the seeds were not sifted from the grain; undoubtedly the Iron Age farmers went over the fallow land and collected the entire plants for subsequent threshing and drying" (Helbæk 1960, 18). Large concentrations of *C. album* seeds are now known from as early as the Late Bronze Age, at the site of Voldtofte (Rowley-Conwy 1982, 2000).

In support of his contention that the plant was an important food source in antiquity, Helbæk cited recent European practice: "seeds [of *Chenopodium album*] were collected and added to cereals to a certain extent by people in southeastern Russia until recent times, particularly in bad crop years

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and in wartime", (Helbæk 1951, 69); "in Jutland... the practice of mixing weed seeds into food continued until recent times. H.P. Hansen reports that a woman told him that she could remember that... seeds of *Spergula arvensis* L., *Bilderdykia convolvulus* (L.) Dumort. and *Rumex acetosella* L. were added to rye flour when bread was baked" (Helbaek 1951, 70, both quotes translated by PR-C). The closely-related perennial *C. bonus-henricus* L. (Good King Henry) was formerly cultivated for its leaves, which were eaten in a manner similar to spinach (Gill and Vear 1966).

Helbæk was also aware that closely related species had been domesticated elsewhere in the world, and much recent work has extended our knowledge of these. Quinoa (*C. quinoa* Willd.) was an early domesticate in the Andes, and remains important today (Pearsall 1992). In Mexico, three varieties of *C. berlandieri* ssp. *nuttalliae* are cultivated, one as a grain crop, one for its leaves eaten like spinach, and one for use as a broccoli-like vegetable (Wilson and Heiser 1979). In both species the genetic changes brought about by domestication are similar to those in cereals, namely larger seeds and low dormancy (Simmonds 1976). Recent work in eastern North America has demonstrated that *C. berlandieri* ssp. *jonesianum* was widely cultivated before and after the arrival of maize, but cultivation had ceased before the arrival of Europeans and the cultivar is now extinct (Smith 1987; 1995; Fritz 1995; Fritz and Smith 1988; Riley *et al.* 1990). Its cultivated status is shown by the reduced thickness of the testa (seed coat), indicative of reduced dormancy (Fritz and Smith 1988, Smith 1995). At the site of Marble Bluff in Arkansas dated to c. 3000 BP, three bags were found filled with thin-testa seeds, perhaps seed stock intended for planting, alongside a much larger deposit of seeds of several species dominated by *C. berlandieri* Moq. with intermediate-thickness testae, perhaps a weedy variety cached as food (Fritz 1997).

It is however difficult to discuss prehistoric *Chenopodium album* further because we know so little about its nutritional value and energetic returns of collecting it. Because of the importance of wheat, much effort has been devoted to understanding various aspects of the harvesting (e.g. Harlan 1967; Russell 1988; Hillman and Davis 1990) and processing (Hillman 1981; Hillman 1984; Jones 1984) of the various species. No corresponding work has however been done on plants that might once have been of much greater importance than they are now.

The purpose of this contribution is to begin to redress this imbalance. It describes experiments designed to quantify the energetic returns of exploiting *Chenopodium album*.

Experimental Collection and Processing

The experiments took place in June 1992, in fields close to Aberkinsey Farm, near Dyserth in the Vale of Clwyd, North Wales. The field containing *Chenopodium* had been planted with stubble turnips and Italian rye grass intended to be eaten *in situ* by sheep. Consequently the spectacular infestation by *C. album* was not a problem, and the plants were allowed to grow unchecked. In 1991 barley was grown; in 1990, potatoes; and in the preceding years back to 1985, barley or wheat. In each of these years the crop was sprayed, which would have killed all *Chenopodium* seedlings. Before 1985, the field had been under pasture for many years.

Seven experimental areas each of $1m^2$ were marked out. Smith's (1987) experimental collection of *C. berlandieri* involved 16 stands, most of which were also tested by $1m^2$ samples although a few were substantially larger. Our seven test areas were deliberately placed in areas of varying density of *C. album* in order test how such variation affected collection rate. The number of plants in each square metre was counted, and their approximate average height noted. The experiments were carried out when the plants were fully ripe.

Table 1 gives the results. The seeds were collected by stripping: the stem of the plant was grasped below the seed head using the left hand (both experimenters are right handed), and the right hand was then pulled up over the head of the plant several times in order to detach the seeds. The plant was held so that it sloped towards the experimenter, the seeds falling into the space between the plant and the experimenter's body. A container was held here, one side supported in the left hand along with the plant stem. The majority of seeds fell into the container, but a proportion missed and fell to the ground (a result which ensured that many seeds were available for germination the following year). Stripping was judged to be more practical than attempting to harvest the plant with a sickle as if it was a cereal. Many more seeds would have been shaken free and lost during sickling, and the cut heads would then have had to be processed to release those remaining. The stripping method resulted in some leaf and stem fragments landing in the container, but these were easily removed (see below); essentially the stripped seeds were partially threshed during the stripping process, retaining only the soft enclosing perianth. No attempt was made to maximise stripping efficiency or speed, each experimenter making a judgement as to what constituted a "reasonable" rate. P.S. tended to strip plants more rapidly but less completely, while P.R.-C. tended to remove seeds more thoroughly, thus increasing collection time. This variation between

sample	1	2	3	4	5	6	7
experimenter	PS	PR-C	PS	PR-C	PS	PR-C	PS
seed heads per m^2	104	93	193	20	80	164	130
average plant height (cm)	110	105	100	95	100	90	105
stem base thickness, mean of 10 (mm)	3.9	5.7	3.7	10.5*	4.4	2.9	3.4
1. seed collecting time (seconds)	128	188	185	158	130	133	210
2. seed heads stripped per minute	52	30	62	8	38	75	36
3. weight collected material (g)	61.5	68.0	111.5	43.0	83.0	41.0	101.0
4. hand cleaning time (seconds)	12	0**	22	12	28	6	20
5. sieving time (seconds)	25	15	29	12	34	14	35
6. total cleaning time (rows 4+5)	37	15	51	24	62	20	55
7. cleaning rate (g/second) (rows 3/6)	1.7	4.5	2.2	1.8	1.3	2.0	1.8
8. seed weight after cleaning (g)	54.4	65.0	93.0	40.5	71.5	38.0	87.5
total time to prepare 100g clean seeds (seconds)	303	312	254	449	269	403	303
return rate (kcal/hour)	4586	4223	5187	2935	4898	3269	4349

* only 8 stem bases were present - these diverged higher up to give the 20 heads in this square.
** none was necessary.

Table 1. The Chenopodium album experiment: basic data, and calculated time it would take to collect, hand clean and sieve 100g cleaned seed.

experimenters however made little difference to the end result. Fig. 1 shows that density of seed heads per m^2 was of much greater importance.

Subsequent processing was simple. The samples were spread out, and large visible contaminants that had fallen into the container during collection were removed by hand. This took very little time (see "hand cleaning time" in Table 1). The seeds were then sieved through a 2 mm granulometry sieve to remove any other items larger than this size. After being sieved, the seeds were clean except for the perianth. At this stage they are essentially edible without further preparation. It seems unlikely that *Chenopodium* seeds were ground: the oil content would result in the formation of a thick paste rather than a flour. This suggestion fits with the quotes from Helbæk (1951 – see above), to the effect that *seeds* were what was added to cereal flour.

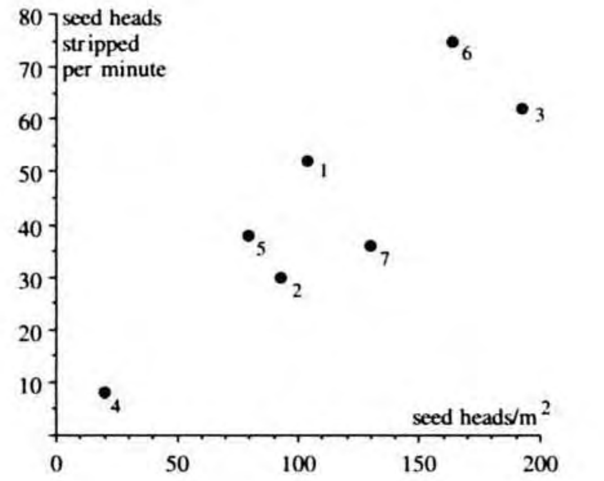

Figure 1. Relationship between density and stripping rate of seed heads (data and plot numbers from Table 1).

Return Rates

The total time it would take to collect and process 100 g cleaned seed is calculated in Table 1, and plotted against seed head density in Fig. 2. It emerges clearly that given reasonable quantities (>50g) of the plant, a time of 4–5 minutes suffices to collect and process 100g seed. This collection rate, yielding a kilo in under an hour, falls within the range of 0.41–1.6 kg/hr achieved for wild *C. berlandieri* by Smith (1987).

This allows the calorific return rate to be calculated. Five calorific determinations were obtained for us by Ian Watson of the Department of Biological Sciences, University of Durham. They are: 386, 378, 380, 361 and 325 kcal/100g. Using the mean value of 366 kcal/100g, the return rates can be calculated

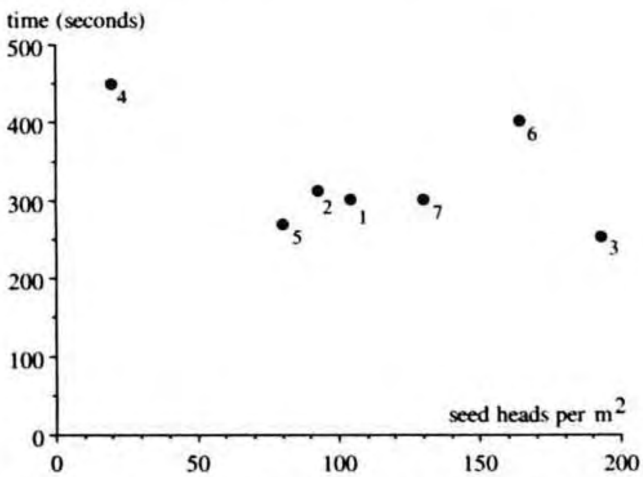

Figure 2. Graph of calculated time to collect, hand clean and sieve 100 g cleaned seed of Chenopodium album (from Table 1), plotted against seed head density (from Table 1). Plots are numbered as in Table 1.

and are listed in Table 1. It can be seen that they vary from about 3000 to about 5000 kcal/hour. In favourable circumstances, one hour's collection can thus produce the approximate daily kcal requirements of two people.

Comparison with Cultivated Cereals

Productivity figures are fraught with problems but can give a general indication of scale. The seven square metres described in this experiment produced c. 450g cleaned seeds, the equivalent of some 643 kg per hectare. This figure should not be taken literally because of the small sample size, and variability from patch to patch, region to region, and year the year, but it is useful as an indication of the order of magnitude. It falls towards the lower end of the range of 276–2854 kg/ha reported by Smith (1987) for wild *C. berlandieri*.

Russell (1988) presents many useful data for cultivated cereals. The difficulties of assessing what wheat production might have been under early regimes are large – Russell (1988, 111) assumes around 500 kg/ha, but the experimental cropping by Reynolds of emmer and spelt sometimes produced several times this amount, ranging from 400 kg/ha to 3700 kg/ha (Reynolds 1981). What can be said is that the little information available does not suggest that *C. album* production is necessarily greatly inferior to that of emmer wheat.

Labour costs per unit of return are probably more important. The average collection time (not including processing) per square metre for *C. album* was 162 seconds. One hectare would at this rate take 1,620,000 seconds or 450 hours. This compares unfavourably with a mean figure of about 70 hours per hectare quoted by Russell (1988, Table 20) for cutting cereals with an iron sickle. However, the additional labour costs in gathering and binding the cereal increase the overall estimate for wheat to c. 200 hours per hectare (Russell 1988, 117); no such labour is necessary for stripped *C. album* because the seeds fall straight into a container.

Processing costs are also important. Seeds are notoriously high in processing time (for an Australian example see O'Connell and Hawkes 1981). Russell's estimates for cereals confirm this. For threshing and winnowing, he suggests 3.6 minutes/kg for free-threshing cereals, and 6 minutes/kg for hulled wheat. Grinding the cereals to flour then takes an average of 18 minutes/kg (Russell 1988, 126–127). Each kilo of cereal thus takes 22–24 minutes processing, and this does not include sieving or hand cleaning; these are essential but time consuming aspects of cereal processing (Hillman 1981; 1984; Jones 1984). For *C. album*, the 450g seed collected took a total of 264 seconds to hand clean and sieve (Table 1); one kilo would thus take 587 seconds, or approximately 10 minutes, to process – much less than the cereals.

A hypothetical overall comparison between wheat and *C. album* may now be calculated. For each, the starting assumption will be 1 ha producing 500 kg clean seed. For *C. album* this would necessitate 450 hours seed stripping and 83 hours processing, or 533 hours in all. The 500 kg seed would yield (at 3660 kcal per kilo) some 1,830,000 kcal, giving an hourly return rate of 3433 kcal/hr. Free-threshing wheat would (following Russell) necessitate 200 hours sickling, gathering and binding and another 192 hours processing, or 392 hours in all. The 500 kg seed would yield, using Harlan's (1967; 198) estimate of 3567 kcal/kg for einkorn, a total of 1,783,500 kcal, giving an hourly return rate of 4550 kcal/hour. The wheat figure again does not include sieving or hand cleaning.

The figures for the two species are thus broadly comparable. However, it must be remembered that altering the initial assumptions would alter the outcomes. The assumed production of 500 kg wheat/ha is well below the mean quantity produced experimentally by Reynolds (1981); greater quantities would increase processing time *pro rata* but would increase harvesting time less, so wheat would become more energetically efficient with higher production. Although we sampled varying densities of *Chenopodium* within the field, the overall density was probably in the high end of the range for this plant. If overall densities were substantially reduced, for example towards those tested in sample 4, the plant would become a less efficient food source (see Fig. 2). The figures calculated here may therefore be towards the top end of the *C. album* range, and towards the bottom end of the wheat range.

Conclusions

The experiments described here have demonstrated that *Chenopodium album* can provide a viable alternative to cultivated cereals because the return rates are broadly similar. That the seeds were sometimes deliberately collected is shown by the caches of seeds mentioned above. Whether the seeds were deliberately resown is not clear; they might equally have been collected from any area that naturally produced a bumper growth of the plant – such as the field used for this experiment. The experimental figures indicate that the return rates for *C. album* overlap with those for cultivated cereals, so that in a poor cereal year, and/or when *C. album* flourishes particularly strongly, the latter plant becomes a viable replacement for cultivated cereals. *Cheno-*

podium album is therefore a viable potential domesticate which could have been deliberately cultivated in prehistoric Europe. Smith (1987) obtained a broadly similar result for wild *C. berlandieri* in comparison to cultivated maize – a significant result because *C. berlandieri* was definitely domesticated.

One future avenue for research might be a close examination of the *C. album* seeds from Nørre Fjand. Since domestication of *C. berlandieri* caused reduced dormancy and a thinner testa in ssp. *jonesianum*, it is possible that the same might have been true of *C. album* if it too was domesticated. If similar thin testae are present in the Nørre Fjand sample, the case for cultivation of *C. album* would be greatly strengthened.

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