Archeobotany

Archaeology, Percival, and the problems of identifying wheat remains

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Abstract

In Britain Percival had already established the study of crop remains from archaeological sites by the early 1920s. However, the archæobotanical record of the wheats continues to be problematic, with identifications often being based on poorly-researched criteria. Agricultural botanists should therefore treat archæological evidence with caution. Examples are cited of problems in identifying charred remains of the free-threshing wheats and approaches that have been explored in their resolution. Particular emphasis is given to the potential of chemical fingerprinting based on infrared spectroscopy for both supplementing and testing the use of morphological criteria. Morphological criteria for distinguishing hexaploid and tetraploid wheats are summarised in an appendix.

PERCIVAL’S CONTRIBUTION TO ARCHAEOBOTANY

In Britain, it was Percival who initiated the study of plant remains from archaeological sites, and his interests in archæobotany have been maintained in Reading’s Department of Agricultural Botany ever since. Hugh Bunting, for example, fought (unsuccessfully) to recruit Hans Helbaek, Europe’s pre-eminent pioneer of archæobotany, to the Department’s research staff, and ensured that his teaching staff
included others active in archaeobotany such as Barbara Pickersgill. He also personally tutored his students in the role of archaeobotany in agricultural botany, as did Barbara Pickersgill in teaching crop evolution. Indeed, the involvement of Mark Nesbitt and myself in the subject was a direct result of this policy. Thereafter, under Peter Caligari, the Department has continued to support archaeobotanical studies in the hands of key researchers such as John Letts.

Percival did not himself publish many of his analyses of plant remains from archaeological sites. Notable exceptions include his 1936 paper on “Cereals of Ancient Egypt and Mesopotamia” and a chapter on “ancient British wheat” in his book *Wheat in Great Britain* published in 1934. However, it is clear from Wendy Carruthers’ catalogue of Percival’s Reading-based archives of archaeological plant remains (Carruthers, 1992) that he completed analyses of ancient remains of cereals from a vast array of sites in countries including India, Egypt, the then Palestine, Syria, Iraq, Turkey and Switzerland, and from over 40 sites scattered across the British Isles. We correspondingly find his identifications cited in the reports of excavators such as Mallowan, Caton-Thompson, Carter, Wheeler, Childe, and Pitt-Rivers.

In identifying ancient remains of cereals, Percival had the clear advantage of a comprehensive familiarity with the living wheats. Furthermore, the range of primitive forms available to him then was significantly greater than anything we can find in genebanks today. This became particularly apparent when Terry Miller and I explored his own set of the Percival wheat collection for dense-eared, short-grained *dicoccums* and *durums* of a sort that we find archaeologically, but which neither of us had encountered in living populations, whether under traditional cultivation or in genebanks. We quickly discovered that Percival had indeed collected several forms of both, albeit under names that inevitably pre-dated a modern understanding of wheat’s genomic constitution.

**WHEAT IDENTIFICATION IN ARCHAEOBOTANY TODAY:**

**A WARNING**

There is a tendency among agricultural botanists to accord greater credibility to archaeological evidence than it deserves. This is particularly true in studies of ancient wheats, a point appropriately inferred by Miller (1992). The uncomfortable reality is that (a) archaeobotanical evidence is often paltry, (b) progress in identifying archaeological remains of wheats has often been limited by Percival’s archaeobotanical successors lacking his close familiarity with the morphology of modern wheats, and (c) there is disarray in the nomenclature appropriate for those remains of ancient wheats that have no exact modern counterparts.

On most archaeological sites wheats survive only as charred grains, as charred fragments of the densest bits of chaff, as impressions in pottery or adobe, or as phytoliths (opaline silica-bodies from the epidermis). Clearly, John Letts’ remains of smoke-blackened thatch represent a remarkable exception here. Each of these classes of remains can present significant problems of identification. The problems have been further compounded by the reluctance of most archaeobotanists to commit sufficient time to examining a broad spectrum of populations of living wheats and their over-readiness to accept the identifications appended by seed stations to modern
reference specimens. This, in turn, has resulted in identifications of ancient specimens that are based on poorly-researched criteria. The net effect has been the publication of many dubious identifications and occasionally the publication of remains as “new species” when they represent no more than minor variants of modern taxa.

This might sound bleak, but in fact not all remains are so problematic, and even in the difficult groups secure identifications are often possible if we undertake appropriate studies of modern equivalents. An example of some of these problems and of approaches to their resolution comes from attempts to distinguish rachis remains of free-threshing tetraploids and hexaploids.

AN EXAMPLE FROM THE FREE-THRESHING WHEATS

From the late 1960s the use of flotation to extract charred remains of plants from archaeological deposits allowed the recovery of crop-processing waste, particularly cereal chaff. This had seldom been present in the grain caches and pottery imprints available to Percival and Helbaek. These chaff remains sometimes included wheat rachises. While the morphology of grains had often proved to be of limited value in distinguishing free-threshing tetraploids and hexaploids (Rothmaler, 1955; Schiemann, 1948; van Zeist, 1976; but see Kosina, 1984), the more intricate morphology of rachis remains offered grounds for greater hope.

Predictably, perhaps, the rachis features initially proposed by archaeo-botanists for distinguishing free-threshing tetraploids and hexaploids were based on rather paltry studies of living material, and they not only offered little diagnostic potential, but also spawned many misidentifications. The first more systematic study of rachises to be published was that undertaken by Willem van Zeist (1976). After examining a range of accessions from seed banks, he concluded there was complete overlap between the two ploidies in respect of each of the potentially diagnostic criteria that he examined. However, it was clear from his illustrations of the modern specimens he had used that several of them had been misidentified or mis-labelled by the source seed stations. This problem is familiar to many of us working in this field. For example, in a consignment of cereals that I received from one European seed station, 60% of them were mis-labelled at even the level of ploidy, a fact confirmed from chromosome counts in root-tip squashes.

However, more extensive studies of rachis morphology which were started in 1970 had already indicated that certain features were diagnostic of ploidy level after all. The rationale that I adopted in this study was an obvious one, and was a mirror image of the taxonomic analysis used by Sarkar & Stebbins (1956) in the hunt for the B genome donor. I took a range of populations of the D genome donor, Aegilops squarrosa; examined them for features that could be traced in hexaploid wheats but which were absent in free-threshing tetraploida; tested the usefulness of these features in distinguishing the rachises of living free-threshing hexaploids from those of a wide array of equivalent tetraploids; and then used the most reliable of them to identify ancient rachis remains. From the outset of the work, the identity of all the living specimens was established using independent (non-rachis) criteria.
After examination of some hundreds of specimens, it became apparent that at least five different features of rachis morphology allowed clear separation of free-threshing tetraploids and hexaploids (Hillman, 1983). The one notable exception was *Triticum carthlicum* which, despite its tetraploid complement of $2n = 28$ chromosomes, manifested several features seemingly traceable to the D genome, as well as four minor features peculiar to itself. The distinctiveness of *T. carthlicum* would seem to accord with genetic evidence for hexaploid involvement in its evolution (Vavilov & Jakushina, 1925; Kuckuck, 1979), notwithstanding the suggestion of Muramatsu (1986) that the Q gene of *carthlicum* and *aestivum* is shared by tetraploids such as *durum* and *dicoccum*. More minor exceptions included a distinctive race of Turkish *durum* in which some of the principal tetraploid rachis features were poorly developed. (The principal differences distinguishing hexaploids from most of the tetraploids, excluding *carthlicum*, are summarised in an appendix to this paper.)

Identifications of free-threshing wheat rachises at the level of the other classical "species" within ploidy also proved to be possible in some cases. For example, rachis internode proportions can often distinguish the more extreme forms in what appears from rachis morphology as a cline of variation represented by the classic *turgidum*, *durum* and *turanicum*, although sub-basal rachis fragments of the pyramidal *durum* inevitably overlap with medial rachis segments of the *turgidum*. In distinguishing these last taxa, therefore, rachis criteria would appear to be less specific than the morphological criteria used by Anna Filatenko (pers. comm., 1999) and Dorofeev & Migushova (1979), which indicate *turgidum* to be a discrete entity entirely distinct from *durum*.

Following the isolation of these rachis criteria in the early 1970s, and their presentation at the International Workgroup for Palaeoethnobotany in 1983, they have provided a means of identifying the ploidy level of charred rachis remains of free-threshing wheats from sites in both SW Asia (e.g. Hillman, in French, 1972; Hillman, 1978; Nesbitt, 1993, 1995; Moulins, 1997) and in Europe (Jacomet, 1987; Near, 1992; Maier, 1996; Schlumbaum & Jacomet, 1998; Letts, 1999). In SW Asia this new possibility of accurate identification to ploidy level has allowed a reappraisal of the evolution of hexaploid wheats generally (Nesbitt, this vol.), and in Europe they have allowed archaeobotanists to overturn the long-held assumption that all the early remains of free-threshing wheats were hexaploids (Maier, 1996; Nesbitt, this vol.).

So far, all of these remains of free-threshing wheats appear to represent species that are still extant, albeit with some different infra-specific variants. It is therefore disconcerting to see the erection of a "new species", *T. parvicoccum* Kislev (Kislev, 1980, 1981) on the basis of charred remains of rachis that appear to represent merely a short-grained form of dense-eared types of *durum* or *turgidum*. Although Percival (1921) described an Egyptian form of one such wheat as *T. pyramidalare* Pers., and had incorporated related forms into his wheat collection under other names, all such forms were thereafter recognised as no more than "ear-types" within either *durum* or *turgidum* (Vavilov, 1931; Zhukovskii, 1923/1951; Flaksburger, 1935; Gökgöl, 1939; Schiemann, 1948). Indeed, Kuckuck & Peters (1964) more recently produced just such forms as induced mutants from *dicoccum*. (Following Vavilov's observation that these dense-eared tetraploids appeared to parallel the variation found in the hexaploid
compactums, Schiemann (1948) designated them as forms within subspecies under the headings Åhrentyp duro-compactum and Åhrentyp turgido-compactum).

THE GLUME WHEATS

It is also often possible to distinguish some of the glume wheats reliably, so long as we have the remains of the grains and the spikelet forks (= glume bases + rachis nodes) that occur in abundance on many archaeological sites. For example, we can generally (but not always) distinguish between the glume wheats of different ploidies (Hillman et al., 1996; Jacomet, 1987). Within a single ploidy level, however, disentangling domestic forms from their wild progenitors can be more problematic than is often assumed, not only when we use grain morphology, but also when we use features linked with rachis fragility (Hillman & Davies, 1990, 1992; Kislev, 1992; Zohary, 1992). In our attempts to detect the start of cultivation and unravel the processes of domestication, these problems clearly represent a serious impediment. Again within ploidy, in trying to separate AAGG from AABB tetraploids, we often face considerable difficulties in distinguishing charred spikelet forks and grains of timopheevii from those of the dicoccum range, and we have made no progress at all in distinguishing charred remains of araraticum from dicoccoides. Within the diploids, criteria for distinguishing equivalent remains of boeoticum and uratu also continue to elude us.

As for distinguishing remains of glume wheats from free-threshing wheats within the same ploidy level, it is often very difficult from charred remains of grains, but is generally feasible from remains of chaff. Nevertheless, we still sometimes face problems with chaff remains of a) speltiform aestivalis of the sort described by Kuckuck (1964) and collected by us in eastern Turkey, and b) semi-brittle-eared durums of the sort that we have also found growing in Turkey. Examples of identifications of charred remains based on morphological criteria are discussed in the paper by Mark Nesbitt.

CHEMICAL CRITERIA

Several of the problems of identification based on morphological criteria are now beginning to be resolved by the use of chemical finger-printing. Several approaches have been explored using thin-layer chromatography, infrared spectroscopy (including fourier-transform infrared spectroscopy), pyrolysis mass-spectrometry, and gas-chromatography mass-spectrometry. By far the most useful so far has involved the use of infrared spectroscopy, particularly the results from Frances McLaren (McLaren, Evans & Hillman, 1989; McLaren, 1999; Hillman et al., 1994; Cave, 1999; Letts et al., 1994). Seven years of analyses have enabled McLaren to assemble a substantial library of IR spectra of modern wheats of known identity, and these are providing a basis for identifying ancient specimens using equivalent spectra derived from extracts from charred grains or chaff fragments. The technique allows the separation not only of ploidies, but also of species such as urartu from boeoticum, and timopheevi from dicoccum. Indeed, it can even distinguish domestic forms from their wild ancestors, and other closely related forms such as turgidum from durum. In addition, comparisons of identifications based on chemical and morphological criteria applied independently
to the same specimens have allowed us to test the reliability of some of the morphological criteria.

Studies of DNA sequences recovered from charred remains of wheat grain also now offer the possibility of distinguishing ploidy levels, albeit at considerable expense (Brown, 1999; Brown et al., 1998). Eventually, such techniques will doubtless allow more precise identifications.

OTHER FORMS OF PRESERVATION

In marked contrast to the problems posed by charred remains, when archaeobotanists such as John Letts have wheat remains in the form of whole plants as in his smoke-blackened thatch, then identification is possible at an altogether more sophisticated level, allowing the resolution of an entirely different set of questions of the sort explored in his paper (Letts, 1999).

In summary, after uncertain beginnings, the reliability of archaeobotanical data is slowly improving and is allowing us to address new questions concerning wheat evolution and the origins of agriculture of relevance to both agricultural botany and archaeology. Some of these questions form the subject of the following paper by Mark Nesbitt.

REFERENCES


Letts JG. 1999. Smoke blackened thatch: a unique source of late medieval plant remains from Southern England. Reading: English Heritage and the Department of Agricultural Botany and Rural History Centre, University of Reading.


Nesbitt RMN. Wheat evolution: integrating archaeological and biological evidence. (This volume).

Vavilov NI. 1931. The wheats of Abyssinia, and their place in the general system of wheats. *Bulletin of Applied Botany. Supplement* 51. [In Russian with English resumé]

**APPENDIX**

**Summary of rachis criteria for distinguishing 4x and 6x wheats**

The criteria for distinguishing rachis remains of hexaploid and tetraploid wheats (excluding *T. carthlicum*), as presented at the International Workgroup for Palaeoethnobotany in Groningen (Hillman, 1983) are summarised below. The criteria are intended primarily for distinguishing free-threshing members of either ploidy, but criteria numbers 2, 3, 4c and 5 can also be used to help distinguish their glume-wheat equivalents.

<table>
<thead>
<tr>
<th>T. DURUM GROUP (including <em>T. turgidum</em>, <em>T. turanicum</em> and <em>T. polonicum</em>)</th>
<th>T. AESTIVUM GROUP (including <em>T. compactum</em> + <em>T. sphaerococcum</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram of rachis criteria" /></td>
<td><img src="image2.png" alt="Diagram of rachis criteria" /></td>
</tr>
</tbody>
</table>
1. **shape of rachis node immediately below point of glume insertion**

Node often with a conspicuous rounded lump beneath each glume-insertion, with or without a thin fissure across the lump. (This feature is poorly developed in some small-eared pyramidal central Anatolian *durums*.)

Node with either (a) no lumps at all, and merely a narrow ridge below glume insert; or (b) weakly developed lower halves of lumps, in which the upper halves give the impression of having collapsed.

2. **Shape of rachis internode – in lax-eared forms only.** (In dense-eared forms of either ploidy, there is insufficient room for internode shape to be properly expressed.)

Rachis internodes forming ± straight-sided trapeziums, with only a slight incurved narrowing immediately below the node, even in extremely lax-eared tetraploids such as *turanicum* and *polonicum*.

Rachis internodes conspicuously shield-shaped, with a strongly curved widening of the upper third of the internode, and a more steeply curved narrowing just below the node.

3. **Presence/absence of longitudinal lines near the outer edge of the convex (abaxial) race of rachis internodes.**

(This feature has so far proved the most reliable of all those listed here.)

No trace of lines, except those resulting from occasional wrinkles due to shrinkage if the ears were cut while still green.

Clear longitudinal lines present, often bearing hairs. The lines often have the following form in T.S.

Ridge often with hairs (The lines are just as conspicuous in compact/ dense-eared forms.)

4. **Glume-based morphology.** Three linked features can be used here:

(a) Pieces of glume-based tissue commonly survive attached to rachis node. Such fragments then clearly exhibit features 4b and 4c.

(b) Glume-base never crumpled across primary nerve/keel. At most, has a very weak fold, and this only in spikelets with 3 or more fertile florets.

(c) Acute angle on any surviving glume-base tissue (when viewed from above), with a keel often clearly discernible.

(a) Glume-based deciduous, except for an extremely narrow crescentic band of inwards-sloping crumpled tissue attached to the rachis node. (This represents the lowest part of the fold of glume-base tissue described under 4b.)

(b) Glume-base with crumpled fold across base of glume, with the fold extending right across the primary nerve + adjacent tertiary nerves. (Described by Schiemann, 1948, as “fältig eingezogen”.)

(c) Generally an obtuse angle on glume-base scar (viewed from above) and with no trace of a keel.
5. Roundness of rachis edge in transverse section.

Rachis edge in T.S. generally rounded. Rachis edge in T.S. generally attenuated.