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Formation Processes and Paleoethnobotanical Interpretation in South Asia

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ABSTRACT

In order to maximize the information derived from plant remains recovered from archaeological sites, it is essential to understand the processes that have been involved in the formation of those remains. This paper reviews factors that affect the composition of archaeobotanical remains, including pre-depositional processes, deposition, post-depositional processes and methods of analytical reporting. A particularly influential set of factors derived from methods of crop-processing, which have been clarified by numerous ethnoarchaeological studies in recent years. As most remains are preserved by charring one must account for how crop-processing remains, or other plant waste, came into contact with fire and how fire residues were then redistributed on an archaeological site. Post-depositional disturbance and mixing are also reviewed. This paper concludes with a four level classification of the information potential of plant remains based on the nature of the context from which they have been recovered and the detail to which they have been quantified and reported. The most common samples are 'diffuse samples' consisting of charred material mixed through archaeological fills, but these can nevertheless be highly informative when carefully quantified and compared.

Introduction

A crucial aspect of any archaeological investigation is relating the patterns encountered archaeologically with past human activity. As Clarke (1973: 17) observed, "Archaeology in essence then is the discipline with the theory and practice for the recovery of unobservable hominid behavior patterns from indirect traces in bad samples." The development of this theory is what Binford has termed 'Middle Range Theory' (e.g. Binford 1981) and relies on a methodological use of uniformitarianism by providing archaeologists with analogies independent of the archaeological evidence for relating behaviors to material patterns (Bailey 1983). This has helped push the study of biological remains from simply listing species recovered from archaeological sites into a more dynamic enterprise for understanding past cultures. As noted in archaeozoological studies, 'bones are not enough' and a framework of models and assumptions is necessary to make sense of bone assemblages (Gifford-Gonzalez 1991). Increasingly in recent years, there is a growing awareness amongst archaeobotanists/palaeoethnobotanists of the formation processes involved in archaeological plant samples (Mikcesek 1987; Hastorf 1999; Weber 2001b; Fuller 2002: 261–67). While this aspect of archaeobotany has benefited from ethnoarchaeological and experimental studies, there is still much to be done, and the purpose of the present paper is to outline our current state of understanding of archaeobotanical formation processes, in particular as they relate to situations encountered archaeologically in South Asia.

Models of formation processes are important if we are to answer the major questions of past subsistence and environment using archaeobotanical evidence, questions such as: What amongst those species present was used as human food, or for other purposes, and what is 'missing' from archaeobotanical assemblages? What are the biases in archaeobotanical patterns that must be taken into account when using this data for reconstructing human subsistence practices, or past vegetation around an archaeological site? The problem of equifinality besets the interpretation of plant assemblages in which both human activities and post-depositional processes (including non-human processes) affect the composition and location of assemblages.

In this paper we will focus on charred seeds, as these have been the focus of the vast majority of archaeobotanical studies in South Asia (Weber 1991; Fuller 2002). Following the lead of Clarke's (1973) seminal outline of the needed aspects of archaeological theory, including predepositional, depositional and post-depositional theory, we will organize our paper around pre-charring formation of plant seed assemblages, charring and deposition, and post-depositional factors, including the problems of contamination. We will finish the paper with a summary of the types of archaeobotanical samples being collected in South Asia and their interpretive value. We summarize the processes by which seeds enter the archaeological record, what impacts them once there, and ultimately how the process of collection influences their significance in understanding the past.

Pre-charring Activities and Their Importance in Understanding the Archaeobotanical Record

The most common form of archaeological preservation is the carbonization of seeds (and other plant parts such as cereal chaff). It is generally agreed that in almost all cases preservation required exposure to fire (Minnis 1981; Hillman 1981, 1984; Pearsall 1989: 202, 224; Zohary and Hopf 1993: 3–4). Thus, for sites in most environments, excepting regions of extreme aridity and desiccated preservation, waterlogging and occasional silicification, the rule of thumb is to assume that uncharred seeds represent intrusive, modern contaminants in archaeobotanical assemblages (Pearsall 1989; Weber 1991; Lennstrom and Hastorf 1995). The presence of uncharred seeds in flotation samples from archaeological sites suggests contamination of ancient sediments by modern intrusive seeds and raises the spectre of downward movement of charred seeds from later periods, an issue to which we return below.

In thinking through the processes that create pattern in archaeobotanical evidence, we must pay particular attention to the various filtering processes through which the seeds of plants that had been growing in the landscape came to be present on a site where they could have been charred. An important observation made by archaeobotanists after the advent of flotation was that most archaeobotanical remains represent a particularly limited range of ecological plant communities, most often that of arable fields, and therefore archaeological plant remains were most likely to relate to a limited range of human activities, most notably the harvesting and processing of crops (Knörzer 1971; Hillman 1972; Dennell 1976; M. Jones 1988). Thus although there are a wide range of human activities, as well as some natural processes, by which plant seeds may come to an archaeological site (Minnis 1981), the experience of European and Near Eastern archaeobotany – and indeed South Asia as well – has been the recurrence of cereals, often pulses, and a range of herbaceous taxa that might be classed as field weeds. This implies therefore that in general seed remains will tell us about the cultivated environment rather than the environment as a whole, and can provide important insights into arable ecology and agrarian practices (see, e.g. Hillman 1981, 1991; M. Jones 1988; G. Jones 1992). Although gathered plant resources can also be represented archaeologically, they are less common, and for hunter-gatherer periods, the sites we tend to encounter have far fewer plant remains overall.

Once seeds have been taken from the environment, human actions can greatly modify the composition of plant parts and seed types in an assemblage through the activities of processing. Of particular relevance in situations of cultivation are the crop-processing activities, including threshing, winnowing, and sieving that serve to separate the edible grains and seeds from the chaff, straw and weeds. This has been recognised and discussed already in the work of Körber-Grohne (1967) and Dennell (1972, 1974, 1976), and expectations could be outlined as to the probable contents of the products and by-products of the various steps. These approaches, however, had relied on common sense, and an important development was the use of observable relationships between variables within ethnographic contexts as a key to decoding the patterns observed in archaeological assemblages (Hillman 1973).

Crop-processing can be conceived of as a series of filters that act to separate and group particular seed types and chaff parts on the basis of size and weight. While the stages are influenced by technology and cultural practices, they are generally constrained by the morphology of the plants involved, thus providing a set of uniformitarian models from which to interpret past patterns. The best studied plants are wheats and barley. Hillman (1981, 1984) pioneered an ethnoarchaeological approach to studying the effects of crop-processing on assemblage formation through his work on traditional cultivation and harvesting of wheat and barley in Turkey. While his work focused on the presence and proportions of different chaff types, in addition to cereals and weeds, Glynis Jones (1983, 1984, 1987) took a different emphasis to her ethnographic study in Greece, in which she focused on the statistical analysis of the weed components of assemblages in order to identify the various processing stages. Other useful discussions of crop processing focusing on wheat and barley include M. Jones (1985), van der Veen (1992), Viklund (1998), Peña-Chocarro (1999), Murray (2000), and Stevens (2003). In recent years a number of ethnoarchaeological studies of other crop species have been undertaken. Thompson (1996) has discussed the variations in the processing of rice based on ethnographic work in Thailand. Within South Asia, the study of millet processing sequences has been undertaken, by Reddy (1991, 1994, 1997, 2003) in Andhra Pradesh and in Nepal by Lundstrom-Baudais et al. (2002). In addition, information is becoming available from ethnoarchaeological studies on crops from Africa including finger millet (Ruth Young 1999), Ethiopian tef (D'Andrea et al. 1999), and grass pea (Butler et al. 1999). The basic patterns of processing in rice and millets, which can be related to phytoliths as well as macro-remains, are described by Harvey and Fuller (2005).

Most studies of plant-food processing involve cereal grains. The essential variables of crop-processing can therefore be summarized for wheats and barleys (figure 1), and compared with those for rice and millets (figure 2). A crucial distinction is that between hulled cereals, such as the glume-wheats emmer and einkorn or hulled barley, and free-threshing, or naked, cereals, such as bread wheats, durum wheat or naked barley (Hillman 1981, 1984a,b, 1985). The hulled cereals, which are closer to their wild progenitors, require extra processing steps to remove the persistent chaff from the edible grain, whereas naked cereals have evolved a free-threshing morphology in which the chaff readily and easily separates from the grain, thus require less processing. Equivalent to the situation with wheat and barley, are differences between certain varieties of millets (Table 1), which include several hulled species, including all the millets native to Asia, and some free-threshing types, especially millets of African origin which dominate millet cultivation in South Asia in the modern era. Rice is generally similar to a hulled millet, in that it must de-husked, but it has a large seed size which makes problems of weed seed removal similar to the situation for wheats or barley.

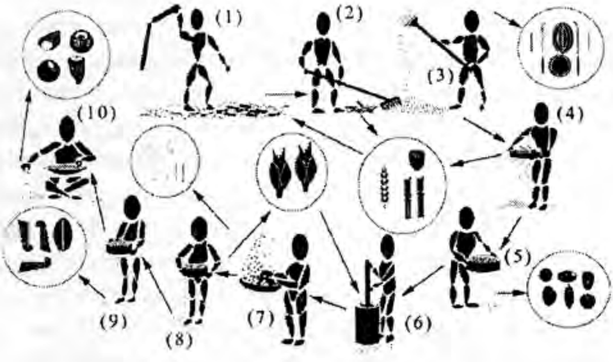

Figure 1 Hulled wheat processing stages. (1) Threshing, (2) raking, (3) first winnowing – light weed seeds and some awns are removed, (4) coarse sieving – weed seed heads, unbroken ears, straw fragments are removed and unbroken ears are rethreshed, (5) first fine sieving – small weed seeds and awns are removed, (6) pounding, (7) second winnowing – paleas, lemmas and some awns are removed, (8) sieving with medium-coarse sieve – spikelet forks and unbroken spikelets – repounded, (9) second fine sieving – glume bases, awns, remaining small weed seeds, tail grain and awns removed, (10) hand sorting – removal of grain-sized weeds by hand (from Stevens 2003).

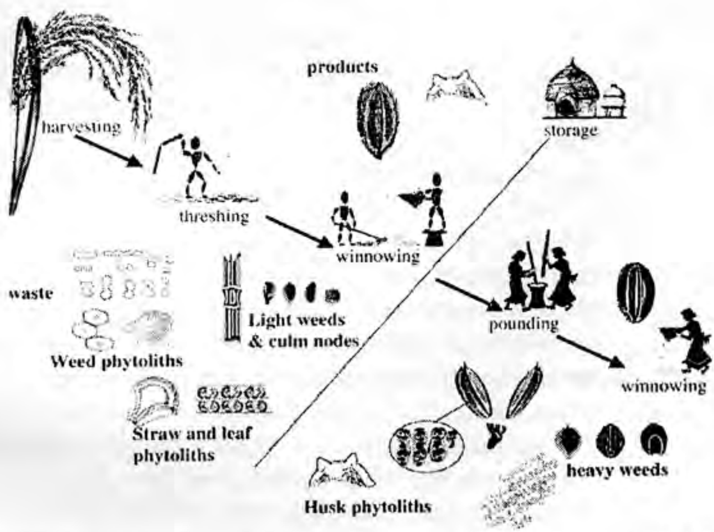

Figure 2 The major processing stages for rice showing the products and waste produced by each process, includuing potential macro-remains in black and phytoliths in white. For example, first winnowing produces grains with spikelets and therefore husk phytoliths, and the waste contains rice leaves and stem (fan-shaped bulliforms and scooped rice bilobes) and various weeds associated with rice cultivation such as grasses (bilobes shown, also saddles, long cells), sedges, and phragmites (keystone bulliform). After dehusking the waste of winnowing includes husks as well as large weeds, which also may be removed by hand picking.(from Harvey and Fuller 2005).

After harvest, crop processing serves to separate the spikelets which contain edible grains from the rest of the harvested plant and as many accompanying weeds as possible. An important variable influencing the composition of seed assemblages is harvesting height, such as whether or not whole cereal stalks (culms) are harvested, or uprooted, as opposed to selective harvesting only of the fruiting spike or panicles. As observed by Reddy (1994), thick stalked cereals, such as pearl millet and sorghum, are often harvested selectively, i.e. cut just below the compact panicle. Such a procedure biases against the incorporation of weeds into the harvest, and might therefore be a factor contributing to archaeobotanical assemblages consisting largely of crops with few or no weeds. For most crops, however, there is some cultural choice in whether to harvest panicles or with straw, as both practices have been observed ethnographically for wheat (Hillman 1984), rice (Thompson 1996), or *Panicum* millets (Reddy 1994, 2003; Lundstrom-Baudais et al. 2002). In addition to cutting individual stalks at their base, they may be harvested in clumps, i.e. as sheaves, which would be expected to incorporate the most weeds of any harvest method. One consideration may be whether or not the additional harvested straw may be desired as an animal fodder. Once harvested, the material is threshed, through some combination of pounding or crushing activity that serves to break up the plant and separate the edible grains or spikelets (or pods) from the other parts (figures 3, 4). Threshing can be carried out by a range of methods, from human power such as beating with sticks or mallets, trampling by domestic animals, or to crushing by heavy wheels or sledges pulled by animals. Once threshed, winnowing, and in many cases sieving, is carried out to remove the grains/spikelets from the by-products of straw and weeds.

Relying on differences between the weight or size of different components, winnowing and sieving add important patterning to the products and by-products of crop-processing. Winnowing is essentially universal, although methods vary including shaking in a basket, throwing, such as with a winnowing fork, or dropping or pouring into the wind from some height (figure 5). In general winnowing separates the crop and heavy components, such as culm nodes, heavy chaff and heavy weeds seeds, from light chaff and light weed seeds. Subsequent sieving plays an important role in traditional wheat/barley processing, but is of less universal importance in millet or rice processing. Reddy (1994, 2003), for example, reported sieving only for the large-seeded *Sorghum* and *Pennisetum* but not for small-seeded *Panicum sumatrense*. Coarse sieving is used to separate very large contaminants from the crop, allowing the crop and smaller components to pass through the sieve (figure 6). For hulled cereals this stage is often carried out in conjunction with a second pounding and winnowing which serves to de-husk the grains, as for example in glume wheats. Fine sieving, by contrast retains the crops, and removes smaller weed seeds and chaff. A final stage prior to preparation of grains for cooking involves hand-picking of weed seeds and other contaminants that are similar in size and weight to the eaten grains, as such components are not easily separated by size or weight.

During the crop-processing sequence, the location in which crop-processing activities are carried out may change, and there is also some choice as to when crops are stored, with further processing being carried out after storage. In general the earlier stages, such as initial threshing and winnowing, are likely to carried out closer to the fields and distal to settlement areas, while later stages are prone to be carried out in domestic areas (see Hillman 1984; Reddy 2003; Thompson 1996). Nevertheless, harvested sheaves may be stored as such, with all processing being carried out in domestic areas in small quantities (e.g. Thompson 1996). As discussed further below, these choices, which sometimes may be constrained by weather conditions but are more likely to be determined by cultural tradition or social factors, may greatly influence which crop-processing stage products/ by-products are most likely to be preserved on archaeological sites (Fuller 2002: 266; Stevens 2003).

Fewer ethnoarchaeological studies are available for pulse processing, although many of the same processes and patterns are involved. A range of harvesting methods are possible (see, e.g. Watts 1908), including uprooting, cutting of individual plants near their base, or selectively plucking individual pods. The latter method might be expected to have been more common with primitive cultivars that were prone to uneven ripening of pods and is still practiced in South Asia for *Lablab purpureus* (Duke 1981) and *Vigna radiata* (Weber 1991: 98). As noted by Jones (1984, 1987) and Butler (1992; Butler et al. 1999), pulses of Near Eastern origin, such as peas, chickpeas and the ethnographically-studied grasspea are essentially free-threshing, the processes involved in their processing is essentially that of free-threshing cereals. Although detailed studies are not yet available for other pulses encountered in South Asia, a provisional model (Fuller 1999), suggests that in addition to some tropical free-threshing pulses, including at least some varieties of hyacinth bean (*Lablab purpureus*) and *Vigna* spp., there are also varieties that can classed as 'pod-threshing' in that their pods adhere tightly to the enclosed seeds and must be intensively pounded after the first series of threshing and winnowing processes, including horsegram (*Macrotyloma uniflorum*), pigeonpea (*Cajanus cajan*), and perhaps more primitive varieties of *Lablab purpureus* (cf. Watts 1908; Kachroo and Arif 1970; Van der Maeson and Sommtmadja 1989). Pod-threshing pulses might sometimes be stored in the pod, with a final pounding and winnowing to remove pods being carried out on a more routine domestic basis.

Charring and Deposition

While crop-processing models allow us to understand the grouping of seed and chaff types, it is also crucial to have some idea about how these assemblages come to be charred and preserved. The mitigating role of fire in preservation means that many plant-based activities will decompose without a trace in the macrofossil record. Those assemblages which do get preserved are likely to be re-deposited as secondary or tertiary refuse, infilling structures or other features (Miksecek 1987). To argue that the plant remains in a structure are a direct reflection of the activities in that structure one must assume more or less *in situ* deposition of charred plant remains resulting from human activities (*de facto* and/or primary refuse, sensu Schiffer 1972, 1987) or the burning of a building or floor preserving plant residues *in situ*. While samples of the latter sort are extremely useful they are also rather rare and for other samples we must consider their possible routes to fire.

The routes through which crop-processing products or by-products may be charred include parching, which may sometimes be part of the processing sequence, or the disposal of by-products into hearths. Parching, that is the drying of spikelets in proximity to fire may be used to make glumes, lemmas or paleas brittle and thus facilitate dehusking. While parching is known to be used sometime for glume wheats (Hillman 1984), it is not a necessary step as other ethnographic observations indicate (Nesbitt and Samuel 1996; Pena-Chocarro 1999). Similarly parching may or may not be used with other crops, including millets, rice or pulses. In addition pulses may be dry-roasted before storage or consumption. Thus, while parching may be a possible route to archaeological preservation it can not be assumed to have been the primary, nor most frequent, route. Of more general occurrence is probably the disposal of processing by-products, which inevitably include some lost grains of the crops, into fires through various routes. This might be simple disposal, as part of the cleaning operation after processing. In addition by-products can be stored for fuel in their own right or used as fodder for animals (N. Miller 1984; Miller and Smart 1984; Bottema 1984; Hillman 1984; Thomas 1989: fig. 6; Van der Veen 1999; Murray 2000). By extension, seeds can enter fires through the burning of animal dung, and there has been considerable debate as to the best means for distinguishing dung-derived seed assemblages from those of crop-processing waste (Miller 1984, 1991, 1997; Hillman et al. 1997; Charles 1998).

During the charring process itself the composition of assemblages may be altered. Some plant components are more likely to survive charring intact and identifiable than others. As charring experiments have shown, characteristics of the seeds of different species, such as whether or not they are oily seeds, can greatly affect their chances of survival (Wilson 1984; Viklund 1998). In addition, charring experiments clearly show that cereal grains are far more resilient than chaff, and thus even if by-products contain significantly more chaff than grain upon charring these proportions may be greatly altered (Boradman and Jones 1990; Van der Veen 1992; Reddy 1994). Thus some degree of differential destruction of the pre-charring plant assemblage of prehistory must be accounted for.

Another important issue regards the relationship between the assemblages of seeds from single charring episodes and the charred assemblages recovered archaeologically. Of primary importance is to assess the extent to which individual samples should be expected to reflect distinct activities or a composite mixture of multiple processes. Hubbard and Clapham (1992) provide a simple classification of samples into three categories. 'Type A' are those that are primary, preserved *in situ* from human activities. Charred examples are such things as storeroom conflagrations. 'Type B' assemblages are those with well-defined contexts that represent primary deposition with minimal mixing, such as hearth deposits. 'Type C' are all the other heterogenous samples in which processes of deposition, destruction and mixing are unclear. By far the bulk of archaeobotanical evidence comes from Type C, such as flotation of charred material from habitational fill deposits. Thus some approach to comparing such samples is necessary. The often-encountered consistency of plant remains within such samples on or even between sites, suggests that a limited number of recurrent processes are responsible for most of such data. It seems likely therefore that repetitive, ('daily') activities with consistent archaeobotanical signatures are likely to have swamped out much of the noise. Perhaps the most probable candidate for these daily activities, drawing on the ethnographic insights of crop processing, is regular processing of crops such as that removed semi-cleaned from stores carried out prior to flour-grinding and/or cooking (Stevens 2003; Fuller et al. 2001; Fuller 2003: 266). This is an attractive assumption because repetitive activities are more likely to produce constant archaeological remains distributed through a site, whereas bulk processing of crop and burning of by-products would seem more likely to occur sporadically in both space and time and lead to a more 'clumped' distribution of archaeobotanical evidence. If the daily-processing hypothesis is accepted then the differences in processing stages represented by assemblages may have more to do with decisions about how much processing to do before storage of the crop, which in turn relates to scale of social organisation for crop processing.

To provide some examples of the role of crop processing in producing archaeobotanical assemblages we may draw upon some archaeological examples. One recent study involves flotation samples from Southern Neolithic sites, such as the site of Sanganakallu (Fuller 1999; Fuller et al. 2001, 2004). Seeds or seed fragments in samples from this site are generally between 30 and 80 percent pulses (or pulse fragments), and five to 20 percent millet grains, with very little preservation of lemmas, paleas or other chaff. In addition, other small seeds that probably come from weeds are present in percentage between eight and 30 percent, but generally greater than millets in the same samples. While other items are present, including fruit/nut fragments, some wheat and barley, and parenchyma tissue fragments, we will consider here only the likely contributing factors to the preservation of pulses, millet grains and weed seeds in the same assemblages. First of all, it must be noted that pulses and millets are not normally processed together, as they have seeds of vastly different sizes, and we must therefore assume that these are mixed assemblages, either mixed at the locus of charring (i.e. in the fire) or subsequently when charred material from the hearth was disposed of and become incorporated within the archaeological sediments. The presence of millet grains without chaff need not indicate that this represents burnt products, as the chaff in by-products, especially from small millets, is fine and should be readily destroyed by charring. The other component we would expect in by-products are the seeds of millet weeds. As most of the weed seeds that are well-preserved are similar in size to the millet grains we can suggest that this represents the by-products from a late processing stage, such as final dehusking, since early stages of threshing and winnowing tend to separate those components that of different sizes from the crop. It is notable that there is a relatively low diversity of weed taxa in these samples, especially in comparison to the ethnographic and archaeological examples of Reddy (1994). This could indicate that harvesting focused on selective panicle cutting and thus incorporated relatively few weeds. Indeed we might expect selective harvesting for these early crops as they may not yet have evolved the even ripening which is associated with many domesticates. Thus we can suggest that the samples represent the composite signature of repeated, routine disposal of millet dehusking by-products into fires where they became mixed with accidentally charred pulse seeds, which could have been charred during parching or dry-roasting. These charred seeds, along with wood charcoal from the fires, was then incorporated into the accumulation of archaeological sediments on the site. In contrast, Reddy's (1991b) study at Oriyo Timbo located in Gujarat, India, nicely demonstrates the variability in archaeobotanical data bases and difficulty in drawing conclusions about any category of plants. She found that while millets were the dominant grain, weeds were not only common but made up a high portion of the seed record. With some chaff and very few pulses, millets and weeds together dominated the archaeobotanical record (Reddy 1991b).

Post-Depositional Factors

While pre-charring activities and the charring process effect the deposition of botanical material, a variety of post-depositional factors are equally important to understand. The depositional environment differently effects the accumulation, distribution and preservation of all archaeobotanical material. The type of soil, its pH or acidity, the moisture content and even the depth of the material all impact botanical material differently, whether charred or not (Pearsall 1989).

Further, just as living organisms and geologic processes impact the material record, they can affect the deposition of plant material. For example, at Rojdi (Weber 1991) we have good examples of seeds being displaced by ants and burrowing animals or even falling down soil cracks. At times it is difficult, if even possible to determine if mixing has occurred. Whenever possible samples from such contexts should be avoided.

Cultural activities also play a part in the post depositional history of a site. People are continuously digging into cultural deposit and mixing contexts or occupations within a site. Subsequently, carbonized plant material representing different contexts are often mixed and difficult to distinguish from other material. The frequent insertion of Early Historic pits into the earlier occupation at Rojdi is a good example of this process (see Weber 1991). Careful excavation techniques and proper recording methods can often minimize this problem. The potential presence of residual or intrusive grains must always be considered carefully.

The only way to be absolutely sure that archaeobotanical material truly represents the time period in question is to carbon date the charred remains themselves. This is often impractical and definitely costly, and fails to resolve issues of contextual shifts within the same temporal period. The alternative approach is to focus analysis on material recovered from within specific features or artifacts, either 'Type A' or 'Type B' samples. General habitational fill samples ('Type C'), are both abundant and most difficult to account for in terms of post depositional processes, but these samples are nevertheless quantitatively useful. Experience shows that such samples often show recurrent patterns in composition which in turn must relate to recurrent patterns in past formation processes and recurrent patterns of plant input.

Archaeobotanical Remains and Their Value

The archaeobotanical record from any archaeological site is a biased and an incomplete reflection of a once living community. The interpretation of this material is subject to deposition, preservation and recovery biases. Only a small portion of the seeds from a site became carbonized, an even smaller number were preserved, and an even smaller number retrieved in excavation. These problems and limitations are exacerbated by varying methods of excavation and sampling strategy, as well as reporting. Different kinds of samples from different locations with in an archaeological site have different interpretive potential.

There is a spectrum of potential for samples to contribute to the reconstruction of past human behaviors, with those samples that provide little more than confirmation of presence of particular species to those which can be analyzed as snapshots of past agricultural or other plant based activities. This spectrum is multi-faceted, including variables of preservation, sampling and recording. For purposes of simplification we can divide this spectrum into four main grades that can be identified amongst the published archaeobotanical record of South Asia:

1. Grade 1: Grab samples. Samples of plant remains from poorly defined or recorded contexts, where behaviors leading to their formation and dating are ambiguous. Also included in this category are assemblages that have been lumped across a site or phase, without any attention to contextual variation.

2. Grade 2: Presence samples. Samples from defined contexts but where presence/ absence is the only interpretive avenue available. While these samples may represent seeds from isolated finds, floated soil, or even pockets of charred material they lack the detailed recording necessary for quantification.

3. Grade 3: Diffuse samples. These samples are from a known context and have a quantitative value but lack a clear behavioral correlation. Behavioral interpretation should be seen as suggestive and needing further confirmation.
4. Grade 4: Behavioral samples. Well-defined context with probable behavioral correlation, with de facto or primary refuse, plant remains quantified in detail.

While these four grades may appear similar to, and to some extent even overlap some of Hubbarb and Calpham (1992) types, they do differ. For example, our Grades 1 to 3 tend to be equivalent to what they classified as Type C samples. Their Type B samples might fall within any of our grades; while their Type A samples are equivalent to our grade 4. What we are introducing here is a way to clarify the range of material presently being collected, found in existing collections, or available in published or unpublished reports and articles. We believe that the archaeological community needs to understand that the interpretive value of archaeobotanical material from South Asian sites varies widely. Not all archaeobotanical material is alike or should be used in the same manner. All archaeobotanical material can be placed in one of these four grades and its value in terms of the level of interpretation or behavioural reconstruction that is possible can be identified.

Grade 1: Grab Samples

Non-floated samples tend to fall into Grade 1, unless they are samples collected in bulk from well-preserved and well-defined contexts, such as burnt storage jars or charcoal lenses. Most material collected in South Asia prior to 1980 fit this category. It was a time when an excavator simply noticed plant material, collected it and sent it to a botanist for identification. While many of these finds represent unusual circumstances when conditions were just right for seed preservation to occur, their contexts were poorly defined. While we may know that a particular plant was recovered at a given site, the lack of clear and unambiguous spatial or temporal knowledge, means that the interpretive value is limited to the statement about only its presence at that specific site. The importance of context is no better demonstrated than at the site of Koldihawa where rice has been identified (Savithri 1976: 141), yet confusion and debate exists over the dating of this material and whether it belongs to the Neolithic, Chalcolithic or Iron age occupation. This represents a Grade 1 type sample with little interpretive value.

Grade 2: Presence Samples

Many samples from throughout South Asia fit this category. Grade 2 samples are those with a known context but lack detailed recording. We would include here any example where the excavator or archaeobotanists properly recorded the provenience of the sample, the condition and environment of the sample, and the associated cultural material. The samples might be floated or from isolated finds. What is lacking in these samples would be material from contexts that imply a specific behavior

(Grade 4) or samples that are quantifiable (Grade 3). Examples here range from the Neolithic site of Hallur (Vishnu-Mittre 1971) to the early excavations at the urban sites of Harappa (Vats 1940). Most excavated sites in South Asia with recovered plant material fit into this category, including such well known sites as Mehrgarh (Costantini 1984), Daimabad (Sali 1986) or Narhan (Saraswat et al. 1994). In these cases, as in all Grade 2 examples, we can nicely document the presence of a particular species at a specific time and associate it with a particular culture. In some cases we can even demonstrate when a particular species first appears or show a decline or increase in its occurrence. Yet these are general trends that are not truly quantifiable. While the presence of a species might be secure, its use and importance within the culture is either unknown or can only weakly be demonstrated.

Grade 3: Diffuse samples

While archaeological sites with Grade 3 samples are limited in number, they are some of the most common sources for charred seeds in South Asia. This is mainly due to the use of a flotation strategy. From the few dozen sites with systematic soil collection and extensive flotation, hundreds of thousands of charred botanical remains have been recovered, such as at Inamgaon (Kajale 1988), Rojdi (Weber 1991), Miri Qalat (Tengberg 1999) or Perur (Cooke et al. 2005). The availability of these large archaeobotanical assemblages and a desire to compare both the relative importance of different taxa present within a sample, and overall contents of different samples to one another, required a means to summarize the data numerically, the result being quantification and statistical analysis.

Grade 3 samples need to be from well defined contexts, and have a quantitative value, but any behavioral interpretation should been seen as suggestive, needing further corroboration. The assumption is that archaeobotanical distributions representing specific contexts have discrete depositional patterns that reflect human behavior (Hastorf 1993). Even when contexts do not represent single behaviors, they are most likely to represent the statistical average of frequent activities and therefore be interpretable in terms of recurrent patterns of activity (Stevens 2003). Thus flotation samples from a variety of contexts within sites, when well-documented and quantified, have become a useful and powerful tool for generating and testing hypotheses about culture.

What distinguishes this grade from the previous is the presence of a large number of systematically collected samples and the use of quantitative methods to help in the understanding of the site formation and plant use processes, and to counteract many of the inherent biases in the data (Popper 1988; Miller 1988). Such quantitative measures as percentage, proportions, standardized density, ubiquity, and sample richness help the tracking of taxa frequency and make the data base more comparable. Since plant products and by-products often reflect different human activities, are impacted differently during the formation process of the archaeological record, and are often collected differently by archaeologists employing different excavation methods, the results of quantification and the use of statistical analysis should only be seen as suggestive and should be verified with further data collection and the identification of recurrent statistical patterns across sites and regions.

A good example of a Grade 3 study is from Rojdi, located in Gujarat, India. At this second millennium site, over 14,000 seeds were recovered from floating 455 samples representing over 2400 liters of soil (Weber 1991). Samples were systematically collected and analyzed from each phase and within each context. Since activities relating to the manipulation of plants and plant products are assumed to be distributed systematically with respect to context type, the samples represented the full range of available structures and features. The quantitative results of this data base lead to the conclusion that a significant shift in millets took place over the occupation of the site. While the archaeobotanical assemblage demonstrates a shift in human activities, there is debate as to its causes (Weber 2001a). Explanations for the shift in the occurrence of millets range from an indication of change in post-harvest processing practices (Fuller 2001) to alterations in cultivation practices and ultimately the subsistence system itself (Weber 1999, 2003). In either case, a behavioral interpretation has been proposed and further studies are needed to confirm or disprove either hypothesis.

Large volumes of systematically collected archaeobotanical material from secure contexts, together with proven methods of quantitative analysis are helping archaeologists understand both the human-plant relationship and the formation processes of the archaeological record.

Grade 4: Behavioral Samples

Behavioral snapshot samples have a rather limited occurrence in the South Asian record and subsequently there are few examples in the literature. The reason is that there are few situations where samples can be recovered from a context that allows for a direct behavioral correlation. The best examples would be seeds from a sealed storage jar or plant residue on the interior surface of a cooking pot. In cases such as these, direct human behavior is easy to infer.

Another, more complex example of a behavioural snapshot sample comes from the recent study of the charcoal assemblages from a Kushana Period fire altar from the site of Sanghol (Pokhaṛia and Saraswat 1997-98). The sample came from an early historical site in which the structural form of the context could be identified with historically attested ritual activity. The charcoal assemblage thus might be expected to contain intentionally chosen species, and in fact wood types and food plants with culturally significant associations are suggested by Sanskrit texts. Indeed the archaeobotanical evidence included selected food grains, edible fruit seeds, spices or medicinal seeds, as well as woods. The assemblage was found to contain a significant number of non-local taxa which must have been specifically selected from available long distance imports, including black pepper (*Piper nigrum*), nutmeg (*Myristica fragrans*) pistacio nuts (*Pistacia* cf. *vera*), walnuts (*Juglans regia*) and almonds (*Prunus amygdalus*) amongst the seed/fruit remains, as well as Himalayan Cedar (*Cedrus deodar*). Amongst the food grains there was a selective representation of cereals and pulses, including wheat, barley, rice but not sorghum, reported from habitational deposits at the site (Pokharia and Saraswat 1998-99) or other millets that may have been grown in the area. Cowpea, another crop of African origin known from the settlement was also absent from the sacrificial deposit.

While rare, Grade 4 samples do offer the best avenue to connect archaeobotanical material to human behavior. Whenever possible archaeologists should collect and analyze such samples as they also serve as a basis for building models about human activities, plants and ultimately culture.

Conclusion

Paleoethnobotany, or the analysis of archaeobotanical remains, has more to offer than simply recording species recovered during the excavation process. Yet without a greater understanding of the natural and cultural processes involved in the development of the archaeobotanical record, even this simple task is risky. As this paper has attempted to demonstrate, the pre-charring activities, the charring process and deposition of the material, its post-depositional history, and the method of recovery and its analysis greatly affects the archaeobotanical material recovered from an excavation. The result of this variation is that unless we can account for it in our analysis, the interpretive value of the material is rather limited.

Over 100 different archaeological sites in South Asia have yielded tens of thousands of archaeobotanical remains. This material is not all of equal value or even comparable. Archaeologists need to be aware that the significance and the interpretive value of the dozens of species identified from these sites vary and cannot be used equally in model building or explaining the past.

Paleoethnobotany (or archaeobotany) is and should remain an active participant in discussions about the past. What we need are greater efforts to distinguish and identify the cultural and natural processes responsible for particular plant remains reaching their point of discovery, and then if we can properly identify and analyze this material, we can more soundly reconstruct past human behavior.

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Table 1 Hulled vs. Free-threshing Cereals

Crops	**Hulled cereals (requiring dehusking)**	**Free-threshing cereals**
Wheats	*Triticum monococcum* *Triticum diococcum*	*Triticum aestivum* (including *T. sphaerococcum*) *Triticum durum*
Barley	*Hordeum vulgare* var. *vulgare*	*Hordeum vulgare* var. *nudum*
Rice	*Oryza sativa*	
Millets	*Sorghum bicolor* race *bicolor* *S. bicolor* race *kafir*	*Sorghum bicolor* race *caudatum*, race *guinea*, race *durra*
	Panicum miliaceum, *P. sumatrense*	*Eleusine coracana*
	Setaria italica, *S. pumila*, *S. verticillata*, etc.	*Pennisetum glaucum* (syn. *P. americanum*, *P. typhoides*)
	Brachiaria ramosa *Paspalum scrobiculatum* *Echinochloa frumentacea* *Digitaria* spp.	