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New evidence for jute (*Corchorus capsularis* L.) in the Indus civilization

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Abstract In this paper, we report the results of an analysis of a preserved structure of jute on a ceramic artifact from the site of Harappa that is dated to 2200–1900 (cal.) BC (Fig. 1). Jute cloth has not previously been identified at this early date in the Indus civilization. Since fiber remains are rare in prehistoric South Asia, we briefly review the evidence for seed and fiber remains used in textile production in this region.

Keywords Jute cloth · *Corchorus capsularis* L. · Indus civilization

Introduction

The study of archaeological textiles produced from plant crops in South Asia has advanced significantly in the past decade as a result of archaeobotanical studies of seed remains and analyses of fibers. These advances are the result of the integration of the systematic collection of plant remains in field studies, technical developments in high-resolution microscopy, and archaeological methods that allow trace evidence to be preserved. The discovery of the preserved structure of jute fibers on an artifact securely dated to 2200–1900 (cal.) BC is the earliest evidence for the use of this plant for textiles in the Indus civilization.

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Evidence for plant fibers in the Indus and beyond

Evidence for cloth produced from plant fibers is rare before the third millennium BC at Indus-related sites. The earliest evidence for the use of plant fibers is from cotton (*Gossypium arboreum* L.) found as a mineralized thread inside of a copper bead from a Neolithic burial at the site of Mehrgarh dated to the 6th millennium BC (Moulherat et al. 2002). Other evidence for cotton from Mehrgarh is from charred seed remains dated to the 5th millennium BC (Costantini 1984). Elsewhere, identifications of cotton date to the mid to late third millennium BC in the form of pollen (Balakot), pseudomorphs or mineralized fibers (Mohenjo-daro), and charred seeds (Banawali, Harappa, Kanmer, and Kunal sites) (Fuller 2008:6). Flax (*Linum usitatissimum* L.) has been identified from charred seeds that date to the fourth millennium BC at Miri Qalat (Tengberg 1999) Other seed remains are known from 2800 to the end of the millennium BC at Babar Kot, Balathal, Kunal, Harappa, Miri Qalat, Nausharo, and Rojdi (Fuller 2008:8). Notably, there is evidence for jute cloth seeds from the site of Rojdi in Gujarat dated to approximately 2200–2000 BC (Weber 1991:62). No other evidence for the use of bast fiber plants has been identified from the Indus region.

The earliest known evidence for bast fibers used for textiles are from nearby Seistan in eastern Iran at the site of Shahr-I Sokhta, where 100 textile and fiber specimens derived from vegetable fibers have been discovered (Good 2007). Of these, 23 were identified as bast fibers. Sixteen were from sunn

Fig. 1 Map showing sites referred to in the text

hemp (*Crotalaria juncea* L.), two from "rush" (*Scirpus* sp.), and three undetermined bast plants (Ibid:171). The sunn hemp may have been imported since "paleoenvironmental and botanical studies of Seistan do not support the idea that it could have been grown locally" (Good 2007:171). Two examples of twine netting discovered in a trash pit were dated to 2800–2400 BC and identified as jute (*Corchorus* sp.) (Ibid.). No additional identifying specifics were determined and it is unknown whether the jute was grown in the area or introduced as a trade item.

Ceramics at Harappa and a preserved jute structure

The new evidence for jute described in this paper is from one of a group of ceramic shards from the same vessel (Catalog No. H88/368 feature 27) discovered in a street context at Harappa on its Mound E, initially occupied in 3300 BC until as late as 1300 BC (Kenoyer 1998). Typologically it conforms to a category referred to as a dish on a stand, a vessel comprised of a dish form set on a pedestal (Dales and Kenoyer 1986). Production of this type involved several manufacturing steps that included forming the pedestal and dish on a potter's fast wheel. Each form was produced separately and dried until leather hard. The dish was attached to the pedestal by roughening its upper surface on to which the dish was joined.

The evidence for jute is presented in the form of a cloth structure preserved at the rim edge of one of the shards (Fig. 2). Its presence in this location may be explained by a common pottery practice of draping damp cloth over areas susceptible to fast drying in order to slow the drying rate. A thin application of clay slip appears to have been washed over the surface of the cloth, coating each of the individual fibers of the threads with a thin film of clay. The cloth was still in place when the dish was fired, burning out the fibers but leaving the clay coatings intact.

The use of cloth and string as tools in ceramic production is common on the pottery at Harappa, the typical evidence of which originates when these perishable materials are in contact with damp clay and are preserved as impressions in the fired product. Practically all large Harappan vessels were wrapped with string around their mid-section either for lifting or stabilizing, which left string impressions in the still damp clay. Other forms, such as flat, square, and rectangular shaped slabs were set to dry on cloth, which similarly left impressions of plain-woven (simple one-over-one-under) textiles. This dish fragment is significant because it presents the first example of a feature that was sufficiently preserved to allow not only for basic textile characterization, but also for fiber identification.

The survival of clay-coated elements is also uncommon, in part because of the fragility of the cloth-like structure once the fibers are incinerated during the ceramic firing process. While similar structures have been observed in the study of archaeological composite materials from Mesoamerica, formed from cloth and clay slip (Beaubien et al. 2002), what makes the Harappan example so significant is the detailed preservation of fiber microstructure. The mechanism proposed here is based upon clay's ability as a fine slip to form exceedingly thin films because of its ultrafine grain size and platy microstructure, and attraction to materials offering multiple bonding sites, such as cellulose. Colored clays, for example, have been used as modern cloth colorants, and as coatings on now-absent fibers reported recently for archaeological textile fragments found at Gordion (Ballard et al. 2010). In the Harappan example, the delicate clay coatings survived even with loss of the fibers themselves during firing.

Fig. 2 Ceramic shard from Period 3C at Harappa

Fiber identification

The cloth feature was examined under a binocular microscope to determine the details of the thread and weave (see Fig. 3). It should be noted that, as with all textile evidence

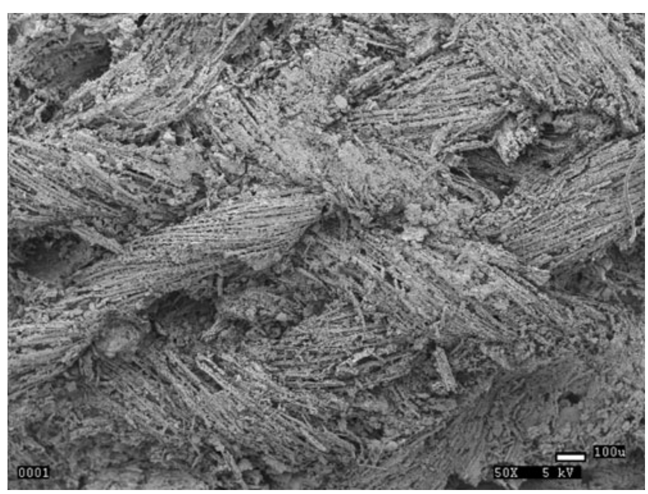

Fig. 3 Scanning electron micrograph of jute textile feature at low magnification

preserved in clay, the clay shrinks (5% to 10%) during firing thereby affecting fiber, thread, and weave measurements (Bird 1956:375). The measurements presented here are not intended to reflect the exact original condition of the cloth, but rather are for comparative purposes. The fine threads, consisting of multiple fibers, averaged 0.35 mm in diameter, were single ply, and loosely z-spun (counterclockwise) with a low degree of tightness. The cloth was of simple manufacture, in a balanced (i.e., the same number of threads per centimeter were present in both the warp and weft) plain weave, with few if any visible errors, measuring 12×13 threads per square centimeter. The fiber used in the cloth could not be identified to species using light microscopy.

To obtain high-resolution images of the fibers, the remnant textile was examined at the Plant Research Laboratory at the New York Botanical Garden using a JEOL 5410 LV scanning electron microscope (SEM). Clay is largely a non-conductive material so this sample represented some challenges during examination by electron microscopy. The SEM used, however, was able to record images when operated in the low vacuum mode even though the material was of low conductivity. The low voltage capability obviated the need for heavy-metal coatings, which otherwise would have been required to make the surface more conductive. In this analysis, the use of metal coatings was not employed because they would have altered the surface texture of a unique artifact. Upon closer inspection of the Harappan cloth impression (Fig. 3), it became obvious that the fibers were not derived from cotton, a fiber plant known from other Indus sites (Janaway and Coningham 1995:170; Weber 1999; Fuller 2008). Cotton fibers have the distinctive appearance of miniature, twisted, and flattened tubular structures with numerous kinks. Silk also has been identified at ancient Indus Valley sites (Good et al. 2009), but its fibers have the obvious and distinctive longitudinal striations that are not evident in our sample. The fibers of the Harappan cloth were coarse and straight (Fig. 4), strongly resembling the bast fibers from flax (*L. usitatissimum*) and jute (*Corchorus* sp.), both of which have been recorded at other Indus sites (Weber 1999 and Weber 1991, respectively). As noted above, sunn hemp (*Crotalaria juncea*), another bast fiber, has been observed at sites contemporary with the Indus civilization, but those fibers also have twisted and striated fiber walls unlike those seen in our sample. The dimensions of the fibers in our Harappan textile average about 13 μm in diameter, well within the range of jute and flax fibers (Catling and Grayson 1982:77; Ghosh 1983:18) although somewhat on the small side possibly due to shrinkage during the ceramic manufacturing process. True hemp (*Cannabis sativa* L.), in contrast, has much thicker fibers (30 μm on average) (Bergfjord and Holst 2010).

In taphonomic terms, the cloth had been infused with or covered by clay as seen through light and electron microscopy. The feature had the same color as the vessel and under SEM, the tiny plates that clay often form were visible (Fig. 5). As noted above, the cloth was consumed when the pot was fired, leaving only the clay structures intact. In our ceramic sample, there were numerous broken fibers periodically located in the cloth feature. These breaks occurred before the firing so the clay slip coated not only the outer surfaces of the fibers, but also the interior surfaces and broken ends. Parenthetically, these numerous broken ends are characteristic of jute which is known for its brittle fibers. The broken fibers are part of what makes jute unpleasant for use in garments; cloth made from this brittle fiber has a scratchy feel to it (Simpson and Orgorzaly 1986). The broken end pieces from the Harappan textile (Fig. 5) consistently show that the fibers had large lumina (hollow spaces in the fiber center), which are typical of jute fibers

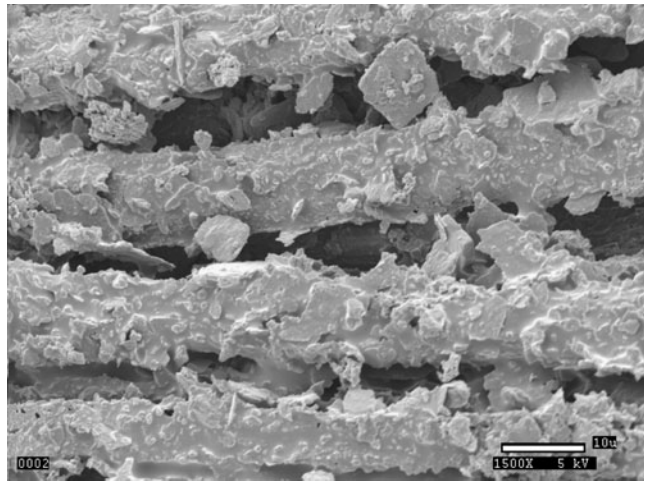

Fig. 4 Scanning electron micrograph of jute fibers from the textile feature, showing the straight configuration of the fibers and their dimensions

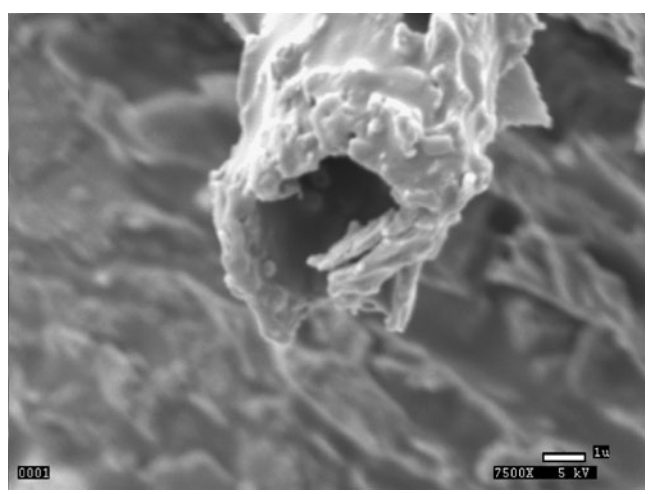

Fig. 5 Scanning electron micrograph of jute fiber feature, showing the size of the lumen in relationship to the width of the fiber

(Houck 2009). Flax fibers, by contrast, have tiny lumina and thick walls. The external width of the Harappan fibers is in the range of flax and jute, but the large lumina indicate that the fibers were jute and not flax. Dislocations, or regions in the fiber cells showing evidence of compression damage, occur regularly in the Harappan textile fibers, another characteristic of jute (Catling and Grayson 1982:41). Of the possible two species, *Corchorus capsularis* L. and *Corchorus olitorius* L., *C. capsularis* tends to have smaller fibers than *C. olitorius*, and is the basis for our evaluation that the fibers in the cloth are from *C. capsularis*. This assessment is reinforced by the facts that *C. olitorius* was domesticated in Africa and is generally grown in upland sites, whereas *C. capsularis* is believed to be from South Asia and grows well in low-lying and occasionally flooded areas (Prance and Nesbitt 2005), habitats that are common in the Indus Valley.

The specimen described in this paper is the first identification of jute fiber from Indus Valley contexts, although seed remains of jute have been discovered at the site of Rojdi in Gujarat, from contexts that correlate chronologically with the vessel type bearing our Harappan textile evidence. Jute, because of its ease of cultivation and low labor costs in production, would have provided an ideal type of cloth for the mundane requirements of the potter's industry.

Jute in modern context—from fiber to cloth

Jute is now grown extensively in India, especially along the Ganges where several million acres are devoted to its production. *C. capsularis* originated in South Asia (Prance and Nesbitt 2005) and it appears likely that it was introduced into the Indus Valley sometime prior to 2000 BC.

Jute fibers are derived from the highly lignified sclerenchyma cells in the phloem tissue of mature stems that grow to a height of 2 to 4 m. The plant thrives in rich, loamy alluvial soils that are well watered. Generally, it takes about 100 to 120 days for jute to mature before harvest usually in June in lowland areas in India (Ghosh 1983:94). During harvest, plants are cut close to the ground and then sorted according to stem thickness. Cut and sorted stems are stacked to dry in the field and tied into bundles. After 3 days, the dried stems are defoliated by hand and then transported to an area with flowing water. This step is crucial because subsequent retting cannot be performed without a reliable source of moving water. Retting is a 10–16-day process of soaking the stems in specially prepared tanks or ditches. This allows microbial action to remove the rot from the soft tissues surrounding the fibers. Fiber extraction, or decortication, is performed by hand stripping that is often by beating with a wooden mallet to loosen the desired fibers from the residual unwanted tissues. Bundles of fibers are washed then dried on racks in partial sun (Ibid.:100). The clean, dry fibers are ready for spinning into thread. Today, jute threads are woven into cloth or made into ropes and twine that serve many different purposes (Catlin and Grayson 1982:8).

Once the fiber itself has been processed into a usable form, the production of jute cloth is much the same as the process used for other bast fibers (Hochberg 1980:60). The jute fibers must first be spun into thread. Bast fibers may be spun using two methods. In the first method, long bast fibers are first spliced together end to end and the resulting long fibers are spun into thread, much as the ancient Egyptians produced flax thread (Barber 1991:44–48). In the small sample of the cloth feature examined here, however, there were no tell-tale splices or knots of the type found in Egyptian cloth (Barber 1991:47). In the second method, the one most likely used at Harappa, the thread is produced by spinning the unspliced/unmodified bast fibers directly into thread (Barber 1991:46–47). Both processes would have entailed the use of a spindle whorl (a weight attached to a stick) that provides the necessary tension to twist fibers together into thread (Barber 1991:42).

Although few objects defined specifically as spindle whorls have been described from Harappa (Meadow et al 1996), several other artifacts identified as wheels, weights, and beads, all of which were produced from clay, may actually have served as spindle whorls. It is also possible that whorls may have been made of wood and therefore did not preserve (Mark Kenoyer, personal communication), a factor that remains to be investigated. Spinning bast fibers in general requires whorls weighing over 109 g for fine fibers and up to 150 g for coarse fibers to create adequate tension (Barber 1991:393). Judging from the looseness of the thread in the sample examined here, the spinner likely used a whorl with a wider diameter to produce the degree of twist described (Barber 1991:53).

Once an adequate amount of fiber has been spun into thread, they are interwoven into cloth through the use of a loom. One set of threads, the warp, is held taut by the loom frame, and the other set of threads, the weft, are passed over and under the warp. In the sample from Harappa, the threads were passed singly over and under only one warp thread at a time, creating a plain or tabby weave cloth. As noted above, use of the same number of threads per centimeter in warp and weft results in a balanced weave. The balanced plain weave is the most basic of weaves (Emery 1980:76).

The cloth in this sample, though small, is of moderate density, measuring 12×13 threads per square centimeter. The weave is fairly open (there are spaces between the threads), but the threads themselves are fine and evenly spun. Thread fineness is determined by the quality of the fiber and by the skill of the spinner. Producing cloth from fine threads generally entails more labor than coarser cloth for three reasons. First, extra care must be taken during the production and processing of fiber to ensure its high quality. Second, the spinner must produce a greater amount of thread because more threads per square centimeter are generally needed to produce cloth from fine thread. Finally, weaving takes longer because more passes of the weft are required to create a length of cloth. The mundane use of the cloth in the Harappan sample and the fineness of the thread suggest that cloth of this quality and the labor to produce it were widely available.

Discussion

Although the cloth sample presented here is small, there are implications for future research on textile production that can be drawn from the results of the analysis. These include its relevance to the movement of species from one area to another, the understanding of textile technology in the Indus civilization, the traces of cloth structures on ceramic shards, methods of research that can be employed in their study, and the implications for the expansion of agricultural practices.

The identification of a jute textile at Harappa provides new information on textile production during the peak of urbanization in the Indus and should be incorporated into the study of cloth in this region. These studies indicate that research on the specific fibers used in cloth production most likely will be limited to rare remnant products, such as on the ceramic studied, mineral replacements on metal artifacts, and the identification of rarely encountered actual cloth remains. Thus far the plant remains from the Indus of relevance to this study are from Harappa and Rojdi. Based on these various forms of evidence, we can characterize cloth production as follows: First, as we have indicated, jute cloth has not previously been identified, although plant seeds have been found at Rojdi. Second, pseudomorphs on metal objects at Mohenjo-daro (Janaway and Coningham 1995:170) and a mineralized thread from a bead at Mehrgarh have been identified as cotton. No other cotton textiles are known from any other Indus site. Third, wild silk fibers were exploited at Harappa (Good et al. 2009) and possibly flax. Finally, the evidence for the use of wool for textiles is uncertain. The presence of terracotta figurines that depict sheep with woolly coats (Richard Meadow, personal communication) may indicate its use in textile production. Taken together, this evidence suggests that possibly three or four kinds of fibers were being utilized for cloth at Indus sites.

Despite the general scarcity of evidence for textile production at Harappa, this discovery provides important information for future research. One way in which to study fibers in the absence of cloth remains is to conduct analyses of spindle whorls. There is a demonstrated correlation between the weight of spindle whorls, the fiber being spun, and the type of thread being produced (e.g., Parsons and Parsons 1990; Barber 1991; Keith 1998, Kimbrough 2006). Identification and analysis of spindle whorls and their weights would demonstrate varied fiber use and thread production. By examining the spatial distribution of whorls, conclusions may be drawn about the organization of textile production at the site.

Finally, there are implications for the development of agricultural practices. This evidence for the production of jute coincides with a general expansion of the inventory of crops that has been documented for the period discussed (Weber 1999, 2003). In future studies, jute production should be considered as a component of the diverse array of crops exploited by people in the Indus civilization. The expansion of crop inventory forces a reconsideration of the scheduling, planning, and land use choices that were necessary to fulfill both food and fiber requirements in the complex agro-pastoral and craft producing economy of the region (Wright 2010).

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