Cotton Cultivation and Textile Production in the Arabian Peninsula during Antiquity: The Evidence from Madâ'in Sâlih (Saudi Arabia) and Qal'at al-Bahrain (Bahrain)

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Cotton cultivation and textile production in the Arabian Peninsula during antiquity; the evidence from Madâ'in Sâlih (Saudi Arabia) and Qal'at al-Bahrain (Bahrain)

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Abstract The discovery of seeds and textiles from *Gossypium* (cotton) in Achaemenian levels of the mid-6th–late 4th century B.C. at Qal'at al-Bahrain, Bahrain and in early 1st millennium A.D. at Madâ'in Sâlih, Saudi Arabia, reveals the role played by the Arabian Peninsula as a textile production centre during the centuries before and after the beginning of the Christian era. Both these sites were situated on important trade routes, overseas (Qal'at al-Bahrain) and overland (Madâ'in Sâlih), and it is likely that at least part of the cotton production was intended for trade, complementing and perhaps competing with other sources of cotton textiles in the contemporary Middle East. In the arid climate of the Arabian Peninsula, cotton was probably grown in association with irrigated date palm gardens where a wide array of other crops was grown, as is shown by the analysis of charred seeds and wood from occupation levels at both sites. The present article places these particular finds in the larger context of cotton cultivation in the Middle East and India.

Keywords Cotton · *Gossypium* · Arabian Peninsula · Textile production · Achaemenian · Nabatean and Early Islamic periods

Introduction

Cotton is at present the most widely cultivated fibre crop in the world. In reality four different species of the genus *Gossypium* (Malvaceae) were domesticated independently in different parts of the world (Brubaker et al. 1999; Wendel et al. 1989). Two of these, *G. hirsutum* L. and *G. barbadense* L. were brought into cultivation in the Americas. The other two, *G. herbaceum* L. and *G. arboreum* L. originated in the Old World. Cotton plants have in common the presence of epidermal hairs that develop from the seed coat. In nature these hairs facilitate the dispersal of the seeds. To humans they are useful for producing yarn and textiles, a quality that has appealed to different populations at different times and which has motivated the domestication of the four species mentioned above.

The earliest evidence for the use of cotton known so far from the Old World comes from Neolithic Mehrgarh in the province of Baluchistan, Pakistan, where a thread made from cotton fibres was identified from inside a copper bead found in a tomb (Moulherat et al. 2002). The discovery of fibres in another burial context at Shahi Tump, southern Baluchistan, dated to the 4th millennium B.C., shows the continuous use of the plant in this part of Asia that has been suggested as a possible centre for domestication of the Asian tree cotton, *G. arboreum*. From the Harappan period in the second half of the 3rd millennium B.C., both fibres and seeds are frequently found at sites in the Indian sub-continent, showing the importance of this area for cotton

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production throughout the Bronze Age (for a summary, see Fuller 2008).

The Indian subcontinent also remained a major centre for cotton cultivation during early historic times, as is shown by the discovery of fibres and seeds in a dozen archaeological sites dated to between 600 B.C. and 600 A.D. (Chanchala 1992, 1995, 2002; Cooke et al. 2005; Fuller 2008; Rahmani et al. 1967; Sankalia et al. 1960; Saraswat 1997). During this period Indian cotton is also mentioned in written sources from the Graeco-Roman world. Thus the “woolbearing trees” of India were first described by Herodotus in the 5th century B.C. (*Historia* III.106, Legrand 1951), then by Theophrastus (*Historia Plantarum* IV.4 and 8, Amigues 1989) and Pliny (*Naturalis Historia* XII.38, Ernout 1949). It is likely that the Greek historian Arrian also made a reference to cotton even though his description of the fabric worn by the Indians is somewhat confused, mixing flax and cotton: “The Indians wear linen garments [...] the linen coming from the trees...” (*Indica* XVI.1, Iliff Robson 1949). That part of the Indian production intended for export seems clear from other texts, notably the *Periplus Maris Erythraei* that describes the

navigation and trade on the Indian Ocean, between Egypt, Arabia and India, during Roman times. This “merchants’ manual” written in Greek by an anonymous author in the 1st century A.D. enumerates, among other trade items imported from India, several types of cotton textiles (Casson 1989). During the excavation of the two main Roman ports on the Egyptian Red Sea coast, Myos Hormos and Berenike (Fig. 1), numerous remains of cotton textiles were identified and it is possible that part of these originated in India (Wild 1997).

During the centuries before and after the beginning of the Christian era, cotton production was not limited to the Indian subcontinent, and part of the numerous textile remains found on archaeological sites in the Near East, in Egypt, as well as in the Mediterranean area, was probably produced elsewhere.

The earliest known evidence of the use of cotton in Africa dates to the 3rd millennium B.C. and consists of seeds and lint from *Gossypium* identified at a Nubian site (Chowdhury and Buth 1971). It is unsure if these remains relate to a cultivated cotton species and even if cotton was used as a textile plant at that time (Zohary and Hopf 2000).

Fig. 1 Map showing cotton finds in the Near and Middle East, 1st mill. B.C.–7th c. A.D.: presence of fibres (grey circles), seeds (black dots) and textual evidence (T). (Al-Zerqa, 1st–3rd c. A.D. (Newton, personal communication); Arjan, 6th c. B.C. (Alvarez-Mon 2005); Berenike, 1st and 4th–5th c. A.D. (Wild and Wild 2001); Doura-Europos, 1st–3rd c. A.D. (Pfister and Bellinger 1945); En Boqeq, 3rd c. A.D. (Sheffer and Tidhar 1991); Jason’s Tomb, 1st c. A.D. (Rahmani et al. 1967); Kellis, 2nd–4th c. A.D. (Bagnall 1997; Bowen 2010; Coombs et al. 2002; Thanheiser 2002); Keranog, 1st–4th c. A.D. (Griffith and Crowfoot 1934); Khirbet Qazone, 1st–3rd c. A.D.

(Granger-Taylor 2000); Madâ'in Sâlih, 1st–7th c. A.D.; Meroë, 1st–4th c. A.D. (Griffith and Crowfoot 1934); Myos Hormos, 2nd c. A.D. (Eastwood 1982); Nessana, 3rd c. A.D. (Bellinger and Pfister 1962); Nimrud, 9th–8th c. B.C. (Alvarez-Mon 2005); Ninive, Inscription Sennacherib, 704–681 B.C. (Joannès and Bachelot 2001); Palmyra, 1st–3rd c. A.D. (Schmidt-Colinet 1995); Qal'at al-Bahrain, 6th–4th c. B.C.; Qasr Ibrim, 1st–4th c. A.D. (Clapham and Rowley-Conwy 2007; Rowley-Conwy 1989; Wild and Wild 2009); Uruk, 1st mill. B.C. (Van Ess and Pedde 1992)

Fig. 2 *Gossypium* sp. (modern cotton); **a** capsules at different stages of ripeness (photo M. Tengberg); **b** seed (*G. herbaceum*) after ginning; **c** the interior of a seed (*G. herbaceum*) showing the characteristic chalaza (photo C. Bouchaud)

However, for the periods of concern in this paper, cotton cultivation seems to have been firmly established in the northeastern part of the continent. Numerous remains are reported from sites in Nubia (Fuller 2008), notably from Qasr Ibrim where arid conditions had allowed the preservation of cotton bolls, seeds, unworked fibres, spun yarn and woven fabrics from the 1st century B.C. until the abandonment of the site in 1812 A.D. (Clapham and Rowley-Conwy 2007; Clapham and Rowley-Conwy 2009; Rowley-Conwy 1989; Wild and Wild 2008). In Egypt, cotton was grown in the oases of the Libyan desert according to textual sources (Bagnall 1997; Thanheiser 2002; Wild 1997) and the discovery of seeds and textiles in the 2nd–3rd century A.D. site of Kellis in the Dakhla oasis (Bowen 2010; Coombs et al. 2002).

According to several classical authors, cotton was also grown in the Arabian Peninsula during late Hellenistic and Roman times. Theophrastus describes the cotton-bearing trees growing on the island of Bahrain as well as in continental Arabia in the late 4th century B.C. (*Historia Plantarum* IV.7–8, Amigues 1989). Despite these explicit mentions, the role of the Arabian Peninsula (including the islands of the Persian Gulf) for cotton production has often been questioned mostly on the grounds of its arid to hyper-arid climate. For example, Wild doubts that “it [the Gulf] could have had an indigenous cotton industry in antiquity based on home-grown fibre and capable of producing for export” (Wild 1997). Discoveries of seeds and textiles during recent years in the Arabian Peninsula now give credit to the ancient texts and suggest that this part of the Middle East may indeed have constituted a cotton production centre, from the mid-first millennium B.C. to late Antiquity.

After a more general discussion of the nature of cotton remains in archaeological contexts, we will describe the finds from two archaeological sites situated in the Arabian Peninsula, Qal’at al-Bahrain on Bahrain Island and Madâ’in Sâlih in northwestern Saudi Arabia. The significance of these remains in terms of local cultivation, textile

manufacture and trade will be discussed with special attention given to the eco-agronomic conditions that allowed the production of cotton in an unfavourable environment.

Archaeological evidence for cotton

The two cotton species domesticated in the Old World, *Gossypium arboreum* and *G. herbaceum*, are both shrubs or sub-shrubs that can grow up to 2–3 m high. The leaves are palmately divided with 3–5 lobes, and the colour of the pentamerous corolla can vary from pale yellow in both species to purple in *G. arboreum* only. The fruits of the cotton plant are capsules, usually called bolls, divided into 3–5 loculi, each containing several seeds (Fig. 2a). The seeds are covered by epidermal hairs, in fact unicellular trichomes, that are of two kinds: short hairs called fuzz and long hairs or lint. Only the latter can be spun and used in textile fabrication.

Different parts of the cotton plant as well as yarns and textiles produced from its fibres are found in archaeological sites. To this we can add tools associated with textile crafts as well as textual sources. Below we discuss briefly the nature of these different types of evidence and their interpretation in archaeological contexts.

Seeds

Traditionally, cotton harvesting is done by hand, picking the seeds and the adhering fibres from the dry bolls still attached to the cotton plant in the field. Immature cotton seeds and dirt are then eliminated before the ginning, the separation of the fibres from the seeds. This separation is usually made in two ways: by picking the lint off by hand, which is an extremely time-consuming process but gives a very fine fibre, or by using one or two cylindrical rollers, made of wood or metal (Samuel 2001; Schlingloff 1974).

The ginned or cleaned seeds are ovoid and somewhat pointed in shape, 7–12 mm long (Fig. 2b). The outer epidermis of the seed coat (or testa), to which are attached the fuzz and lint fibres, presents a longitudinal ridge, the raphe that ends in a small beak corresponding to the attachment point or the funicle. Under the outermost layers of the seed coat, an inner layer of palisade cells, perpendicular to the seed coat, can be observed. Charring can enhance the visibility of these radially elongated cells and allow the identification of archaeological specimens. When seeds are fragmented, a small button-like structure corresponding to the diverting point of vascular tissues irrigating the ovule (chalaza) can be observed on the internal surface of the seed coat (Fig. 2c; Fuller 2008). The embryo, with two well-developed cotyledons, has a smooth and shiny surface that is however often distorted when carbonised, because of its rich oil content (Hopper and McDaniel 1999; Samuel 2001).

In archaeological contexts, cotton seeds are most often found in a charred state but desiccated seeds do also occur (Clapham and Rowley-Conwy 2009). Their presence is generally considered to indicate local cultivation as ginning is supposed to take place before the trading of fibres. However, whole cotton bolls or seeds with the fibres still attached to the testa could potentially also have been transported. Moreover, the seeds present an interest in themselves as a source of oil and fodder and could thus have been considered as an important by-product with a commercial value (Reis et al. 2006). This may be the case, for example, for the 24 desiccated seeds identified at a Roman *praesidium* site in the Eastern Desert of Egypt where local cultivation seems out of question due to the lack of water (Claire Newton, personal communication). However, there is no textual or archaeobotanical evidence for the extraction of oil in antiquity.

The frequent charring of cotton seeds can be explained in several ways. Seeds could have been directly eliminated by fire after ginning and/or oil extraction. Alternatively, their heating in order to reduce the toxic gossypol content (Knowles 1967) could have resulted in the accidental burning of some seeds. Finally, the use of dung as fuel could also explain the presence of charred seeds, for example in combustion contexts. In that case we would however expect an alteration of the seeds by their passage through the intestines of the animal. As for the oil, so far no data clearly indicates the use of seeds as fodder or fuel.

A lack of securely identified modern reference material and of systematic morphometric studies of cotton seeds makes the identification of archaeological cotton to species level difficult, and the remains of seeds and fibres are usually referred to as *Gossypium* sp. only. However, genetic research applied to desiccated cotton remains from Qasr Ibrim, Egypt, is ongoing and aims at the distinction

Fig. 3 Modern cotton fibres showing the characteristic twisting (photo D. de Reyser)

between *G. arboreum* and *G. herbaceum* (Allaby 2010; Clapham and Rowley-Conwy 2007, 2009).

Fibres, yarns and textiles

Microscopically, cotton fibres are characteristically flat and convoluted. The helical twist is due to irregularities in the fibre wall that is unevenly thick. In transverse section the fibres are oval to flattened and have, in most cases, a large lumen. However, the aperture of the fibre and the wall thickness vary according to the ripeness of the cotton (Fig. 3).

After the ginning process the rough cotton fibres are traditionally batted with a wooden bow in order to make them more flexible. The lint can also be carded with a hand comb to separate the fine fibres prior to spinning (Schlingloff 1974; Samuel 2001). The spinning aims at combining the individual fibres into a yarn through a rotating movement. Several techniques can be used, the simplest consisting of rolling the fibres on a surface, for example against the thigh, while gradually adding more fibres to the yarn. The use of a wooden stick (a spindle), equipped with a disc-shaped weight (a spindle whorl) that is made to rotate and twist the fibres together, is a traditional method still used today for the spinning of cotton into thread as well as other fibres such as flax. Two major categories of yarn were produced in the ancient Old World according to whether the spinning was done clockwise to produce Z-spun or anti-clockwise to produce S-spun yarn (Fig. 4).

Once the fibres are spun, the thread may be made into textiles, notably by weaving, which consists of intersecting longitudinal threads, the warp, with transverse threads, the weft. Three main types of traditional looms seem to have existed in the Old World: the horizontal ground loom made of two sticks or bars, the vertical loom with upper and

Fig. 4 Schematic representation of yarns spun with a clockwise (Z-spun) and anticlockwise (S-spun) twisting

lower beams, and the vertical loom with warp weights (Crowfoot 1936). Weaving techniques are very variable, from the simple tabby to extremely complex compositions (Wild 1988).

Yarns and textiles are the most frequently encountered remains of cotton in the Near East. The majority of these come from closed funerary contexts where the presence of metal objects combined with the decomposition of the dead body favoured the mineralisation of organic matter. In some cases, textiles are also preserved by desiccation as it is often the case in Egypt (Clapham and Rowley-Conwy 2009; Wild 1997).

While this type of remain is fundamental for the study of textile techniques, it is not necessarily indicative of local cotton cultivation as textiles were often, as already mentioned, among valuable items that travelled along the trade routes both overland and overseas. This is probably the case for the textiles found in a very early context (5th–4th millennia B.C.) at Dhuweila, Jordan, in an area where cotton cultivation does not seem possible (Betts et al. 1994).

Wood

Potentially, charred wood of the cotton plant could be preserved in archaeological sites. Ethnographic observations on the Euphrates riverbanks have for example recorded the use of cotton stems as firewood or for fencing (D'Hont 1994). Moreover, an Egyptian treatise from the 16th century A.D. recommends the use of cotton stems to heat public baths (Coussonnet et al. in press). The presence

of *Gossypium* wood in an archaeological site would be a strong indication, even more than seeds, for the local cultivation of cotton. However, archaeological examples have yet to be identified.

Few anatomical descriptions of cotton wood exist in the literature (Metcalf and Chalk 1950). A first examination of stems from *Gossypium arboreum* and *G. herbaceum* comes to the conclusion that the wood anatomy of the two species is very similar and that the distinction between them from carbonised wood remains may be illusory. However, the genus *Gossypium* can be identified through a certain number of characters (Fig. 5a–c): in the transversal section, the wood is diffuse-porous without distinct growth boundaries. The vessels show a tendency to two different diameter classes, from medium to small size, and are commonly organised in radial rows of 2–3(7) cells. In the longitudinal sections, the vessels have simple perforation plates and minute and alternate intervessel pits. Fibres are of medium wall thickness and marginal parenchyma is present. Rays are (1)3–4 cells wide and of heterocellular composition with procumbent and upright cells. Axial parenchyma and vessel elements are characteristically storied.

Tools

Tools clearly identified as being used in the production of textiles (spindle whorls, loom weights, etc.) and manufactured from resistant materials (stone, pottery, bone, etc.) are frequently found on sites in the Near East and elsewhere. However, the problem is that a clear association cannot always be made between these tools and a particular fibre, for example cotton, as the preparation of other fibres that were important in the Near East such as flax, often required similar equipment. The same tools may also have been used for both fibres as is shown by a unique example at Qasr Ibrim of the direct association of a loom heddle with both cotton and linen threads (Clapham and Rowley-Conwy 2009). Still, some authors argue that for example the vertical loom would for technical reasons have been more adapted to the weaving of cotton rather than flax (Breniquet 2008).

Fig. 5 Microscopic photos of the wood structure of *Gossypium arboreum*. **a** transversal section; **b** longitudinal tangential section; **c** radial section

Fig. 6 Aerial view of the archaeological site of Qal'at al-Bahrain with the 16th c. A.D. Portuguese fortress in the foreground. The capital of Bahrain, Manama, in the background. Photo P. Lombard, in Mongne (2004)

Another complication is that many tools involved in these crafts would have been made of perishable materials, mainly wood, which would have therefore disappeared, except in particularly favourable conditions such as those found at Qasr Ibrim.

Early cotton production in the Arabian Peninsula

Qal'at al-Bahrain

Qal'at al-Bahrain (literally the 'castle' of Bahrain) is situated in the northern part of Bahrain Island, itself located in the Persian Gulf halfway between the shores of southern Mesopotamia and the Strait of Hormuz. The excavations at this site, begun by a Danish team in the 1950s and continued from 1977 by a French team under the successive directions of Monique Kevran and Pierre Lombard, both from the CNRS (*Centre national de la Recherche Scientifique*), have revealed the long occupational sequence of what was probably the capital of the island during almost four thousand years, from the mid 3rd millennium B.C. to the Portuguese occupation in the 16th century A.D. (Fig. 6; Lombard 1999). Bahrain, known in cuneiform sources as the land of Dilmun, had two main assets: a strategic position on the trade routes linking Mesopotamia to the Oman Peninsula and the Indian subcontinent, as well as the presence of abundant resources of fresh water flowing from artesian wells. The landscapes of the northern part of the island that concentrates the major part of the population have been entirely transformed by millennia of human presence and agricultural activities. The natural vegetation

has been eradicated and replaced by urban settlement and date palm gardens. In the southern part of the island, less influenced by human activities, the vegetation is composed mainly of xeric scrubland.

A total of 116 archaeobotanical samples corresponding to 706 l of sediment were collected from various contexts at the site, dating from the Bronze Age until the Hellenistic period, and treated by flotation. The analysis of charcoal fragments ($N = 475$) and seeds/fruits ($N = 543$) has shown that since the earliest occupation in the early Dilmun period (c. 2500–1800 B.C.), *Phoenix dactylifera* L. (date palm) and other crop plants were cultivated in what were probably traditional date palm gardens (Lombard and Tengberg 2001). The richest floral remains date to the 1st millennium B.C. and particularly to the period of Achaemenian influence, c. 600–400 B.C., from which 473 seeds/fruits have been identified. Together with numerous date remains (76.8% of the 378 cultivated seeds, Fig. 7) the following crop plants have been identified: *Hordeum vulgare* L. (hulled barley), *Triticum cf. aestivum* L. (naked hexaploid wheat) identified from rachis segments, *Vitis vinifera* L. (grape vine), *Coriandrum sativum* L. (coriander), *Ziziphus spina-christi* (L.) Willd. (Jerusalem thorn) and *Punica granatum* L. (pomegranate). To this we can add seven carbonised seeds of *Gossypium* sp. (cotton), representing 0.21% of the cultivated seed remains and extracted by flotation from an ashy layer containing what seems to have been domestic refuse in the form of shellfish, bones and potsherds.

The identification of cotton seeds from Qal'at al-Bahrain suggests that the plant was grown in the irrigated gardens that thrived in the northern parts of the island. This

Fig. 7 Results of seed analysis. Graph of the mean value of cultivated plant at Qal'at al-Bahrain during the Achaemenian period (6th–4th c. B.C.); the frequencies of the various plants are indicated after the calculation of a mean value (see van Zeist et al. 2000) in order to render the results more easily comparable: $M = \sum N \times n/N$ where $\sum$ = total number of seeds of taxon in group, N = number of samples in group, n = number of samples in which taxon is represented. All the results are expressed in percentages of the cultivated plants; 0.21% represents 7 carbonised seeds of *Gossypium*

salicornicum

discovery is particularly interesting as it corroborates the observations made in the time of Alexander the Great's military expedition to India one or two centuries later. The original narration has disappeared but was quoted by the contemporary naturalist Theophrastus. We thus learn that "...the island also produces the 'wool-bearing' tree in abundance. This has a leaf like that of the vine but small, and bears no fruit; but the vessel in which the 'wool' is contained is as large as a spring apple, and closed, but when it is ripe, it unfolds and puts forth the 'wool' of which they weave their fabrics, some of which are cheap and some very expensive" (*Historia Plantarum* IV.7, Amigues 1989)

The mention of weaving is interesting, as this suggests that cotton was not only cultivated on the island but the fibres were also spun and made into textiles locally. Evidence for textile crafts, whether concerned with cotton or other fibres, comes from a burial ground called Shakkoura situated a few kilometres southwest of Qal'at al-Bahrain and used during the Hellenistic period. In tombs dated from the 1st century B.C. to the 1st century A.D. the archaeologists found several spindles and spindle whorls made of ivory (Lombard 1999).

Finally, several textile fragments of which some are tentatively identified as cotton were deposited in a bathtub coffin dated to the Achaemenian period at Qal'at al-Bahrain (Højlund and Andersen 1994).

Madâ'in Sâlih, Saudi Arabia

Until recently, the 1st millennium B.C. find of cotton at Qal'at al-Bahrain constituted the only known example of local cultivation of the plant in Arabia. However recent scientific literature has suggested that other sites in this part of the Middle East may have developed similar production and perhaps even trade strategies during Classical times (Boivin and Fuller 2009; Wild 1997). The discovery of cotton remains at Madâ'in Sâlih now provides direct evidence to corroborate this assumption.

The Madâ'in Sâlih archaeological project started in 2001 with a five-year survey project directed by Jean-Marie Dentzer (University of Paris 1) and Laïla Nehmé (CNRS). From 2008, the surveys were followed by a French-Saudi Arabian archaeological and restoration mission directed by Laïla Nehmé, Daifallah al-Thali (Saudi Commission for Tourism and Antiquities) and François Villeneuve (University of Paris 1) (Nehmé et al. 2006, 2010).

Madâ'in Sâlih, the antique site of Hegra, is located in northwest Saudi Arabia, in a wide desert plain surrounded by mountains. Arid conditions with ± 50 mm of mean annual precipitation are modified by mountain runoff that supplies subterranean groundwater. Today, the natural vegetation around the site is typical of the Saharo-Sindian phytogeographical region, dominated by the *Haloxylon salicornicum* community. Scattered trees of *Acacia tortilis* ssp. *tortilis* (Forssk.) Hayne, *A. tortilis* ssp. *raddiana* (Savi) Brenan and *Tamarix* spp. grow along wadis where water is more plentiful (Fig. 8).

During the Classical period, between the beginning of the 1st century B.C. and the end of the 1st century A.D., Madâ'in Sâlih constituted the southern limit of the Nabataean kingdom and was an important site on the 'Incense road' leading from southern Arabia to the capital Petra in Jordan. Then, from the 2nd century A.D., the city belonged to the Roman imperial province of Arabia. The site was still inhabited during the 4th–6th centuries A.D. but was abandoned around the beginning of the Islamic era in the 7th century A.D.

Four main sectors have been recognised at the site: a residential area (c. 2nd/1st centuries B.C.–6th century A.D.) surrounded by a mud brick wall and containing dense Nabataean and Late Antique domestic occupations (Fig. 9). In and around the residential area, there are monumental tombs that were cut into the sandstone cliffs during the Nabataean period in the 1st century A.D. and which were still used in the 3rd century A.D. Many rock-cut monuments—mostly niches with betyls, altars and basins—characterise cultic areas. Finally, agricultural land is defined by the areas that could potentially be irrigated from the 132 wells dug mainly during the Nabataean period

Fig. 8 View of the site of Madâ'in Sâlih (photo C. Bouchaud)

(Courbon 2008). Sediment samples were collected in the excavated areas. A total of 145 samples (1,509.8 l) were processed by flotation. 33,102 fruits and seeds were identified and classified into three chronological period, Nabataean (1st century B.C.–1st century A.D.), Roman/late Roman (2nd/3rd centuries A.D.) and late Antique (4th/6th centuries A.D.).

Charred cotton seeds were found only in the residential area. Most of them were recovered in reliable archaeological contexts from domestic fireplaces, mixed with charred cultivated food plants, weeds and wild plants. They are well preserved with remaining shorter fuzz hairs that can be easily observed on the epidermis (Fig. 10). Their charring may result from the disposal by fire of by-products of ginning or oil extraction. This would then suggest that such activities occurred in the domestic area, as is also noted in ethnographic examples (Schlingloff 1974).

In general, cotton seeds are well represented among the cultivated plants in the residential area. While absent during the first Nabataean occupation, cotton appears in the 1st century A.D. according to the chronology from pottery analysis; the only radiocarbon date available was from a fireplace which contained cotton seeds (81–238 cal. A.D.). There were significant proportions (204 seeds, 1.1%, Fig. 11) that however decrease through time (21 seeds, 0.5% for the Roman/late-Roman period, 61 seeds, 0.4% for late Antique). During all periods, date stones dominate the seed assemblages (representing between 79.7% and 82.9% of the cultivated plant remains). Other cultivated plants identified at Madâ'in Sâlih are *Hordeum vulgare* (hulled barley), *Triticum aestivum/durum* (naked wheat), *Lens*

culinaris Medik. (lentil), *Pisum sativum* L. (pea), *Vicia sativa* L. (common vetch), *Medicago sativa* L. (lucerne), *Vitis vinifera* (grape vine), *Ficus carica* L. (fig), *Olea europaea* L. (olive), *Punica granatum* (pomegranate) and *Ziziphus* cf. *spina-christi* (Jerusalem thorn). The general picture obtained by the archaeobotanical analysis is similar to that of Bahrain, with intensive garden cultivation irrigated from wells (Bouchaud 2010).

Numerous pieces of textile preserved by desiccation were found in monumental tombs dating approximately from the 1st to the 3rd centuries A.D. (Delhopital and Sachet 2010). As they are badly preserved, it is difficult to determine their function but they are probably fragments of garments and shrouds. Most of them are made of flax, others of wool and a few of cotton (it is possible that the proportion of cotton will increase since the study of the textiles is still in progress). Nine cotton fabrics of different qualities have been identified (Fig. 12). All the fragments except one are tabbies, some of them with remains of selvages, sometimes decorated with fringes. One is dyed yellow. All of them are made of single Z-spun threads. Fibres have been identified with a microscope either in Saudi Arabia or in France. We are very indebted to Dominique de Reyer, who made some of the analyses at the Laboratoire de Recherche des Monuments historiques, at Champs-sur-Marne.

Only two stone weights that may have belonged to vertical looms were found in the Nabataean and Late Antique levels (Fig. 13). As in the case of the tools found in the burials at Shakkoura, it is difficult to associate them firmly with the manufacture of cotton textiles especially as other types of fabrics were also identified at the site.

All of the highlighted text should be indicated as footnote (in addition to the previous sentence) or at least in brackets

Fig. 9 Map of the archaeological features at Madâ'in Salîh (© Madâ'in Sâlih Archaeological Project)

Discussion

Considered one by one, none of the archaeological pieces of evidence from Qal'at al-Bahrain and Madâ'in Sâlih mentioned above can be claimed to prove alone the local cultivation of cotton. Textiles may have been imported. Seeds too can travel even if this seems less likely. Tools used for spinning and weaving could apply to cotton as well as to other fibres. However, taken together—seeds, textiles, tools and textual mentions for Bahrain; seeds, textiles and tools at Madâ'in Sâlih—these converging data seem to establish the presence of 'wool-bearing' trees in Arabia as well as a local textile craft industry. From now on, the Arabian Peninsula can thus be placed firmly on the map of cotton producing areas of the ancient Middle East. This production started at least in the mid-1st millennium

B.C. on Bahrain Island. Literary sources attest to its continuous presence during Hellenistic (Theophrastus, mentioned above) and medieval Islamic times (Ibn Battûta, 14th century A.D., Defremery and Sanguinetti 1990). In northeastern Saudi Arabia, cotton cultivation is attested from the later Nabataean period (1st century A.D.) until the last phases of the Late Antique occupation in the 6th century A.D.

We do not know the precise origin of the cotton plants grown on Bahrain, neither if they belonged to the *G. arboreum* or *G. herbaceum* species. It is sometimes assumed that the description of these plants as 'wool-bearing trees' allows their identification as tree cotton (*G. arboreum*). In reality the two species are very close morphologically and the textual evidence does not seem reliable on this point. The frequent contacts between the

Fig. 10 Carbonised seed of *Gossypium* sp. (cotton) from Madâ'in Sâlih (MS 10192) (photo C. Bouchaud)

Fig. 12 Fragments of cotton textiles found at Madâ'in Sâlih (Tomb IGN 20, *loci* 50045_T04, *top* and 50045_T05, *bottom*) (© Madâ'in Sâlih Archaeological Project)

Persian Gulf and the Indian subcontinent, since the early Bronze Age, would render an origin in the East (*G. arboreum*) more plausible than one in the West (*G. herbaceum* from Africa). However, the question is complex and numerous exchanges of plant material from different origins could have taken place in antiquity.

The cotton plants are well adapted to tropical and subtropical conditions. They require ample light, temperatures reaching at least 15°C and an equivalent of 500 mm of rainfall during their development (Samuel 2001). Rain-fed cultivation may occur in regions where precipitation is abundant and well timed, as in the case of the Indian monsoon belt (Reis et al. 2006). While temperatures are

Fig. 11 Results of seed analysis. Graph of the mean value of cultivated plants at Madâ'in Sâlih during the Nabataean (1st c. A.D.), Roman/late Roman periods (2nd–3rd c. A.D.) and Late Antique period (4th–6th c. B.C.)

Fig. 13 Weight found in a Late Antiquity occupational level in the residential area of Madâ'in Sâlih (MS2010o1250B) (© Madâ'in Sâlih Archaeological Project)

suitable for cotton growing in the Arabian Peninsula, the rainfall is largely insufficient and water has to be brought to the fields by irrigation. For this reason, cotton cultivation in this part of the Middle East seems to have developed in association with the very specific and highly specialised agrosystems of irrigated date palm gardens where a wide array of crops were grown in a multi-storeyed system, with date palms, other fruit trees and annual crops forming the different levels. The latter consisted mostly of winter crops originating from temperate Asia (barley, wheat, lentil, pea, etc.) but the presence of cotton as well as *Sesamum indicum* L. (sesame), identified from the middle Bronze Age (1450–1350 B.C.) at Qal'at al-Bahrain, shows that summer crops were equally a part of this system. As cotton plants need a certain amount of light in order to develop it is likely that they were not planted directly in the shade of the date palms, as may have been the case for other crops, but in more open plots that benefited from the same irrigation systems. Even today cotton plants are often observed growing in date palm gardens in Arabia and North Africa even though their occurrence is sporadic and seems most often to result from their use as an ornamental plant (observations by Vincent Battesti in Tunisia, Algeria and Egypt and by the authors in Saudi Arabia and in Oman). In Oman, until the 1950s cotton used for textiles and fishing nets was traditionally grown in open fields at the margin of date palm gardens where it benefited from the same *falaj* irrigation (underground galleries) as other crops (Richardson and Dorr 2003).

The cultivation of cotton in irrigated gardens does not seem restricted to Arabia as we note the same scheme in the Egyptian oases, as in Kellis (Bagnall 1997; Thanheiser 2002). In the hot desert areas of the Old World this type of water-intensive agrosystem seems thus to have constituted the mandatory framework for the success and spread of cotton cultivation during pre-Classical and Classical times. The spread of cotton cultivation to more northern regions during late Sasanian and Islamic times implies an adaptation to cooler climatic conditions perhaps achieved by the development of new hardier varieties and/or the transition from perennial to annually growing plants (Watson 2008). Thus, cotton cultivation seems to have been established in the middle Euphrates valley in Syria from the mid 8th century A.D. (Samuel 2001), in Iran from the 10th century A.D. (Alvarez-Mon 2005) and appears in the central Asian oasis city of Merv, Turkmenistan from the 6th–7th centuries A.D. (Nesbitt 1993, 1994).

While the presence of a local cultivation of cotton associated with textile crafts seems established by recent finds in Qal'at al-Bahrain and Madâ'in Sâlih, the question of the destination of this production still has to be posed. Did the cotton textiles manufactured here only satisfy local needs or did they also enter into trading systems through which they were exported to more or less distant destinations? In that case, cotton would have constituted an actual 'cash-crop' cultivated for commercial purposes (Fuller 2008). There is no clear-cut answer to this question yet, but several elements can be used in trying to distinguish separate textile-producing spheres (Wild 1997). A first clue can be the way threads were spun. Indeed, there seem to be a certain geographical and cultural consistency in the choice between clockwise (Z) and anticlockwise (S) spinning. Thus, Egyptian craftsmen, whether dealing with linen or cotton, seemed to have preferred the second option as most textiles identified from the Nile valley and Nubia are of this type. Z-spun yarn appears only in particular contexts, notably among the textiles from the port sites of the Red Sea coast (Wild 1997). If they actually belong to another textile tradition, from where could they have been imported? India has usually been considered as their place of origin even though we do not really know if Z-spinning was a rule in the subcontinent. At Madâ'in Sâlih, contemporary with Berenike and Myos Hormos, most of the linen, and all of the cotton textiles are Z-spun, which could have been a characteristic of the Nabataean textile industry of which we still know very little. Against this background it cannot be excluded that some of the textiles found in Egypt and at sites of the Levant (Fig. 1) were imports from the Arabian Peninsula. However, using the sole criterion of spin direction to trace the origin of a textile (or a thread) seems insufficient, while we do not know more precisely the habits of different production centres. The study of

weaving techniques, more complex and probably more characteristic of a particular technical and cultural environment, would certainly be more useful in this context as advocated by Wild (1997). However, such a study would bring us far beyond the scope of this article.

Conclusion

The recent discoveries made in Qal'at al-Bahrain and Madâ'in Sâlih add to our knowledge of the history of cotton in the Middle East during antiquity and show that the Arabian Peninsula, like India and north-eastern Africa, was a centre of cultivation and textile production. In this respect it may have contributed to regional trade networks, substituting or complementing Egyptian and Indian productions. Irrigated date palm gardens seem to have been the common agrosystem associated with this crop in the arid Arabian Peninsula as in the deserts of Egypt.

Further archaeobotanical and textile studies in Arabia will certainly bring new perspectives on local textile traditions as well as on their role in larger exchange systems. Finally, reliable methods for distinguishing between the two Old World cotton species, based on genetics, morphometrics or anatomy are likely to provide more precise information on the origin and movement of cultivars.

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