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

5 **Charlène Bouchaud · Margareta Tengberg ·**  
6 **Patricia Dal Pra**

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9 **Abstract** The discovery of seeds and textiles from *Gos-*  
10 *sygium* (cotton) in Achaemenian levels of the mid-6th–late  
11 4th century B.C. at Qal'at al-Bahrain, Bahrain and in early  
12 1st millennium A.D. at Madâ'in Sâlih, Saudi Arabia, reveals  
13 the role played by the Arabian Peninsula as a textile pro-  
14 duction centre during the centuries before and after the  
15 beginning of the Christian era. Both these sites were situ-  
16 ated on important trade routes, overseas (Qal'at al-Bahrain)  
17 and overland (Madâ'in Sâlih), and it is likely that at least  
18 part of the cotton production was intended for trade,  
19 complementing and perhaps competing with other sources  
20 of cotton textiles in the contemporary Middle East. In the  
21 arid climate of the Arabian Peninsula, cotton was probably  
22 grown in association with irrigated date palm gardens  
23 where a wide array of other crops was grown, as is shown  
24 by the analysis of charred seeds and wood from occupation  
25 levels at both sites. The present article places these par-  
26 ticular finds in the larger context of cotton cultivation in the  
27 Middle East and India.

**Keywords** Cotton · *Gossypium* · Arabian Peninsula · 28  
Textile production · Achaemenian · Nabatean and Early 29  
Islamic periods 30

**Introduction** 31

Cotton is at present the most widely cultivated fibre crop 32  
in the world. In reality four different species of the genus 33  
*Gossypium* (Malvaceae) were domesticated independ- 34  
ently in different parts of the world (Brubaker et al. 35  
1999; Wendel et al. 1989). Two of these, *G. hirsutum* 36  
L. and *G. barbadense* L. were brought into cultivation 37  
in the Americas. The other two, *G. herbaceum* L. and 38  
*G. arboreum* L. originated in the Old World. Cotton 39  
plants have in common the presence of epidermal hairs 40  
that develop from the seed coat. In nature these hairs 41  
facilitate the dispersal of the seeds. To humans they are 42  
useful for producing yarn and textiles, a quality that has 43  
appealed to different populations at different times and 44  
which has motivated the domestication of the four species 45  
mentioned above. 46

The earliest evidence for the use of cotton known so far 47  
from the Old World comes from Neolithic Mehrgarh in the 48  
province of Baluchistan, Pakistan, where a thread made 49  
from cotton fibres was identified from inside a copper bead 50  
found in a tomb (Moulherat et al. 2002). The discovery of 51  
fibres in another burial context at Shahi Tump, southern 52  
Baluchistan, dated to the 4th millennium B.C., shows the 53  
continuous use of the plant in this part of Asia that has been 54  
suggested as a possible centre for domestication of the 55  
Asian tree cotton, *G. arboreum*. From the Harappan period 56  
in the second half of the 3rd millennium B.C., both fibres 57  
and seeds are frequently found at sites in the Indian sub- 58  
continent, showing the importance of this area for cotton 59

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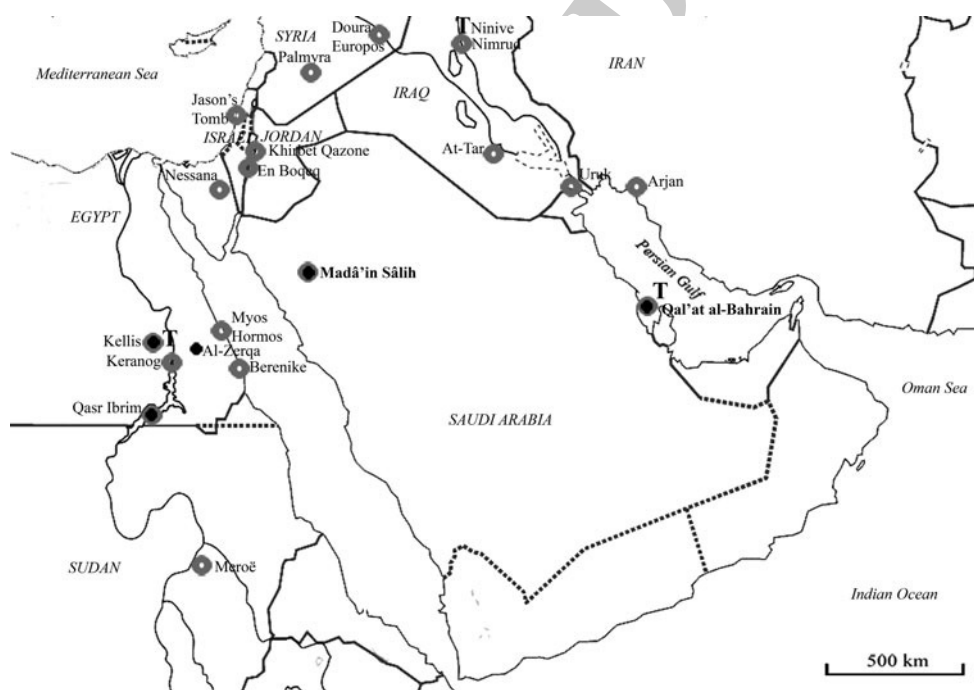
60 production throughout the Bronze Age (for a summary, see  
61 Fuller 2008).

62 The Indian subcontinent also remained a major centre  
63 for cotton cultivation during early historic times, as is  
64 shown by the discovery of fibres and seeds in a dozen  
65 archaeological sites dated to between 600 B.C. and 600 A.D.  
66 (Chanchala 1992, 1995, 2002; Cooke et al. 2005; Fuller  
67 2008; Rahmani et al. 1967; Sankalia et al. 1960; Saraswat  
68 1997). During this period Indian cotton is also mentioned  
69 in written sources from the Graeco-Roman world. Thus the  
70 “woolbearing trees” of India were first described by Her-  
71 odotus in the 5th century B.C. (*Historia* III.106, Legrand  
72 1951), then by Theophrastus (*Historia Plantarum* IV.4 and  
73 8, Amigues 1989) and Pliny (*Naturalis Historia* XII.38,  
74 Ernout 1949). It is likely that the Greek historian Arrian  
75 also made a reference to cotton even though his descrip-  
76 tion of the fabric worn by the Indians is somewhat con-  
77 fused, mixing flax and cotton: “The Indians wear linen  
78 garments [...] the linen coming from the trees...” (*Indica*  
79 XVI.1, Iliff Robson 1949). That part of the Indian pro-  
80 duction intended for export seems clear from other texts,  
81 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 origi-  
nated in India (Wild 1997).

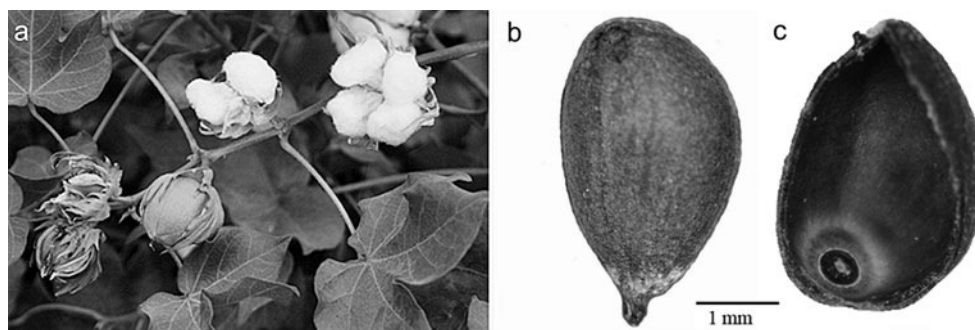
During the centuries before and after the beginning of  
the Christian era, cotton production was not limited to the  
Indian subcontinent, and part of the numerous textile  
remains found on archaeological sites in the Near East, in  
Egypt, as well as in the Mediterranean area, was probably  
produced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

104 However, for the periods of concern in this paper, cotton  
 105 cultivation seems to have been firmly established in the  
 106 northeastern part of the continent. Numerous remains are  
 107 reported from sites in Nubia (Fuller 2008), notably from  
 108 Qasr Ibrim where arid conditions had allowed the preser-  
 109 vation of cotton bolls, seeds, unworked fibres, spun yarn  
 110 and woven fabrics from the 1st century B.C. until the  
 111 abandonment of the site in 1812 A.D. (Clapham and Row-  
 112 ley-Conwy 2007; Clapham and Rowley-Conwy 2009;  
 113 Rowley-Conwy 1989; Wild and Wild 2008). In Egypt,  
 114 cotton was grown in the oases of the Libyan desert  
 115 according to textual sources (Bagnall 1997; Thanheiser  
 116 2002; Wild 1997) and the discovery of seeds and textiles in  
 117 the 2nd–3rd century A.D. site of Kellis in the Dakhla oasis  
 118 (Bowen 2010; Coombs et al. 2002).

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

137 After a more general discussion of the nature of cotton  
 138 remains in archaeological contexts, we will describe the  
 139 finds from two archaeological sites situated in the Arabian  
 140 Peninsula, Qal’at al-Bahrain on Bahrain Island and  
 141 Madâ’in Sâlih in northwestern Saudi Arabia. The signifi-  
 142 cance 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 inter-  
 pretation 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).

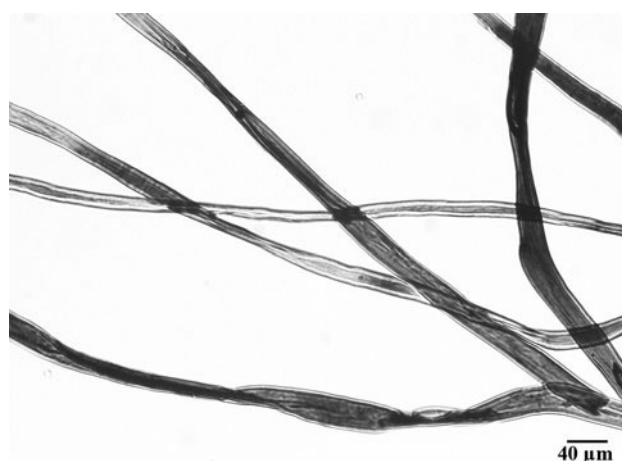


177 The ginned or cleaned seeds are ovoid and somewhat  
 178 pointed in shape, 7–12 mm long (Fig. 2b). The outer epi-  
 179 dermis of the seed coat (or testa), to which are attached the  
 180 fuzz and lint fibres, presents a longitudinal ridge, the raphe  
 181 that ends in a small beak corresponding to the attachment  
 182 point or the funicle. Under the outermost layers of the seed  
 183 coat, an inner layer of palisade cells, perpendicular to  
 184 the seed coat, can be observed. Charring can enhance the  
 185 visibility of these radially elongated cells and allow the  
 186 identification of archaeological specimens. When seeds are  
 187 fragmented, a small button-like structure corresponding to  
 188 the diverting point of vascular tissues irrigating the ovule  
 189 (chalaza) can be observed on the internal surface of the  
 190 seed coat (Fig. 2c; Fuller 2008). The embryo, with two  
 191 well-developed cotyledons, has a smooth and shiny surface  
 192 that is however often distorted when carbonised, because of  
 193 its rich oil content (Hopper and McDaniel 1999; Samuel  
 194 2001).

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

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

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



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

between *G. arboreum* and *G. herbaceum* (Allaby 2010; 230  
 Clapham and Rowley-Conwy 2007, 2009). 231

Fibres, yarns and textiles 232

Microscopically, cotton fibres are characteristically flat and 233  
 convoluted. The helical twist is due to irregularities in the 234  
 fibre wall that is unevenly thick. In transverse section the 235  
 fibres are oval to flattened and have, in most cases, a large 236  
 lumen. However, the aperture of the fibre and the wall 237  
 thickness vary according to the ripeness of the cotton 238  
 (Fig. 3). 239

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

257 Once the fibres are spun, the thread may be made into  
 258 textiles, notably by weaving, which consists of intersecting  
 259 longitudinal threads, the warp, with transverse threads, the  
 260 weft. Three main types of traditional looms seem to have  
 261 existed in the Old World: the horizontal ground loom made  
 262 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

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

267 Yarns and textiles are the most frequently encountered  
268 remains of cotton in the Near East. The majority of these  
269 come from closed funerary contexts where the presence of  
270 metal objects combined with the decomposition of the dead  
271 body favoured the mineralisation of organic matter. In  
272 some cases, textiles are also preserved by desiccation as it  
273 is often the case in Egypt (Clapham and Rowley-Conwy  
274 2009; Wild 1997).

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

## 283 Wood

284 Potentially, charred wood of the cotton plant could be  
285 preserved in archaeological sites. Ethnographic observa-  
286 tions on the Euphrates riverbanks have for example  
287 recorded the use of cotton stems as firewood or for fencing  
288 (D'Hont 1994). Moreover, an Egyptian treatise from the  
289 16th century A.D. recommends the use of cotton stems to  
290 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 cul-  
tivation 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 manu-  
factured from resistant materials (stone, pottery, bone, etc.)  
are frequently found on sites in the Near East and else-  
where. 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)



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

### 336 Early cotton production in the Arabian Peninsula

#### 337 Qal'at al-Bahrain

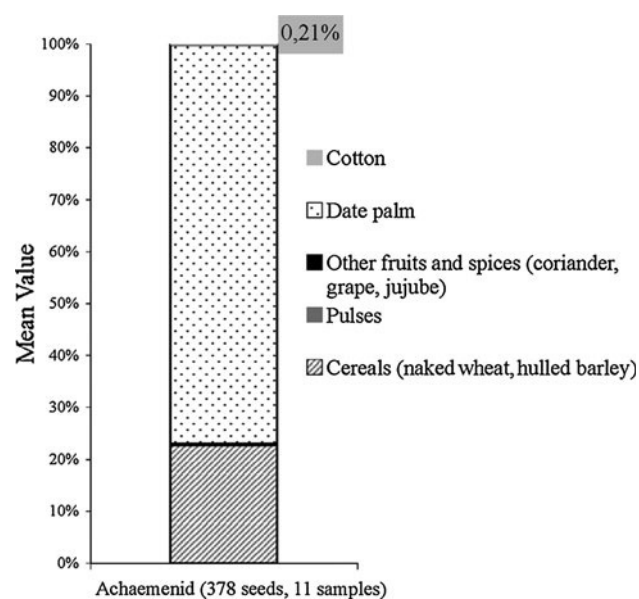
338 Qal'at al-Bahrain (literally the 'castle' of Bahrain) is situ-  
339 ated in the northern part of Bahrain Island, itself located  
340 in the Persian Gulf halfway between the shores of southern  
341 Mesopotamia and the Strait of Hormuz. The excavations at  
342 this site, begun by a Danish team in the 1950s and con-  
343 tinued from 1977 by a French team under the successive  
344 directions of Monique Kevran and Pierre Lombard, both  
345 from the CNRS (*Centre national de la Recherche Scien-  
346 tifique*), have revealed the long occupational sequence of  
347 what was probably the capital of the island during almost  
348 four thousand years, from the mid 3rd millennium B.C. to  
349 the Portuguese occupation in the 16th century A.D. (Fig. 6;  
350 Lombard 1999). Bahrain, known in cuneiform sources as  
351 the land of Dilmun, had two main assets: a strategic  
352 position on the trade routes linking Mesopotamia to the  
353 Oman Peninsula and the Indian subcontinent, as well as the  
354 presence of abundant resources of fresh water flowing from  
355 artesian wells. The landscapes of the northern part of the  
356 island that concentrates the major part of the population  
357 have been entirely transformed by millennia of human  
358 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 Dil-  
mun 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 Achae-  
menian 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. (corian-  
der), *Ziziphus spina-christi* (L.) Willd. (Jerusalem thorn)  
and *Punica granatum* L. (pomegranate). To this we can add  
seven carbonised seeds of *Gossypium* sp. (cotton), repre-  
senting 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*

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

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

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

Madâ'in Sâlih, Saudi Arabia

417

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

427 The Madâ'in Sâlih archaeological project started in  
 428 2001 with a five-year survey project directed by Jean-  
 429 Marie Dentzer (University of Paris 1) and Laïla Nehmé  
 430 (CNRS). From 2008, the surveys were followed by a  
 431 French-Saudi Arabian archaeological and restoration mis-  
 432 sion directed by Laïla Nehmé, Daifallah al-Thali (Saudi  
 433 Commission for Tourism and Antiquities) and François  
 434 Villeneuve (University of Paris 1) (Nehmé et al. 2006,  
 435 2010).

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

447 During the Classical period, between the beginning of  
 448 the 1st century B.C. and the end of the 1st century A.D.,  
 449 Madâ'in Sâlih constituted the southern limit of the Naba-  
 450 taean kingdom and was an important site on the 'Incense  
 451 road' leading from southern Arabia to the capital Petra in  
 452 Jordan. Then, from the 2nd century A.D., the city belonged  
 453 to the Roman imperial province of Arabia. The site was  
 454 still inhabited during the 4th–6th centuries A.D. but was  
 455 abandoned around the beginning of the Islamic era in the  
 456 7th century A.D.

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



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

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

476 Charred cotton seeds were found only in the residential  
 477 area. Most of them were recovered in reliable archaeo-  
 478 logical contexts from domestic fireplaces, mixed with  
 479 charred cultivated food plants, weeds and wild plants.  
 480 They are well preserved with remaining shorter fuzz hairs  
 481 that can be easily observed on the epidermis (Fig. 10).  
 482 Their charring may result from the disposal by fire of  
 483 by-products of ginning or oil extraction. This would then  
 484 suggest that such activities occurred in the domestic area,  
 485 as is also noted in ethnographic examples (Schlingloff  
 486 1974).

487 In general, cotton seeds are well represented among the  
 488 cultivated plants in the residential area. While absent dur-  
 489 ing the first Nabataean occupation, cotton appears in the 1st  
 490 century A.D. according to the chronology from pottery  
 491 analysis; the only radiocarbon date available was from a  
 492 fireplace which contained cotton seeds (81–238 cal. A.D.).  
 493 There were significant proportions (204 seeds, 1.1%,  
 494 Fig. 11) that however decrease through time (21 seeds,  
 495 0.5% for the Roman/late-Roman period, 61 seeds, 0.4% for  
 496 late Antique). During all periods, date stones dominate the  
 497 seed assemblages (representing between 79.7% and 82.9%  
 498 of the cultivated plant remains). Other cultivated plants  
 499 identified at Madâ'in Sâlih are *Hordeum vulgare* (hulled  
 500 barley), *Triticum aestivum/durum* (naked wheat), *Lens*

*culinaris* Medik. (lentil), *Pisum sativum* L. (pea), *Vicia*  
 501 *sativa* L. (common vetch), *Medicago sativa* L. (lucerne),  
 502 *Vitis vinifera* (grape vine), *Ficus carica* L. (fig), *Olea*  
 503 *europaea* L. (olive), *Punica granatum* (pomegranate) and  
 504 *Ziziphus* cf. *spina-christi* (Jerusalem thorn). The general  
 505 picture obtained by the archaeobotanical analysis is similar  
 506 to that of Bahrain, with intensive garden cultivation irri-  
 507 gated from wells (Bouchaud 2010).  
 508

509 Numerous pieces of textile preserved by desiccation  
 510 were found in monumental tombs dating approximately  
 511 from the 1st to the 3rd centuries A.D. (Delhopital and Sachet  
 512 2010). As they are badly preserved, it is difficult to  
 513 determine their function but they are probably fragments of  
 514 garments and shrouds. Most of them are made of flax,  
 515 others of wool and a few of cotton (it is possible that the  
 516 proportion of cotton will increase since the study of the  
 517 textiles is still in progress). Nine cotton fabrics of different  
 518 qualities have been identified (Fig. 12). All the fragments  
 519 except one are tabbies, some of them with remains of  
 520 selvedges, sometimes decorated with fringes. One is dyed  
 521 yellow. All of them are made of single Z-spun threads.  
 522 Fibres have been identified with a microscope either in  
 523 Saudi Arabia or in France. We are very indebted to  
 524 Dominique de Reyer, who made some of the analyses at  
 525 the Laboratoire de Recherche des Monuments historiques,  
 526 at Champs-sur-Marne.

527 Only two stone weights that may have belonged to  
 528 vertical looms were found in the Nabataean and Late  
 529 Antique levels (Fig. 13). As in the case of the tools found  
 530 in the burials at Shakkoura, it is difficult to associate them  
 531 firmly with the manufacture of cotton textiles especially as  
 532 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 Sâlih (© Madâ'in Sâlih Archaeological Project)



533 **Discussion**

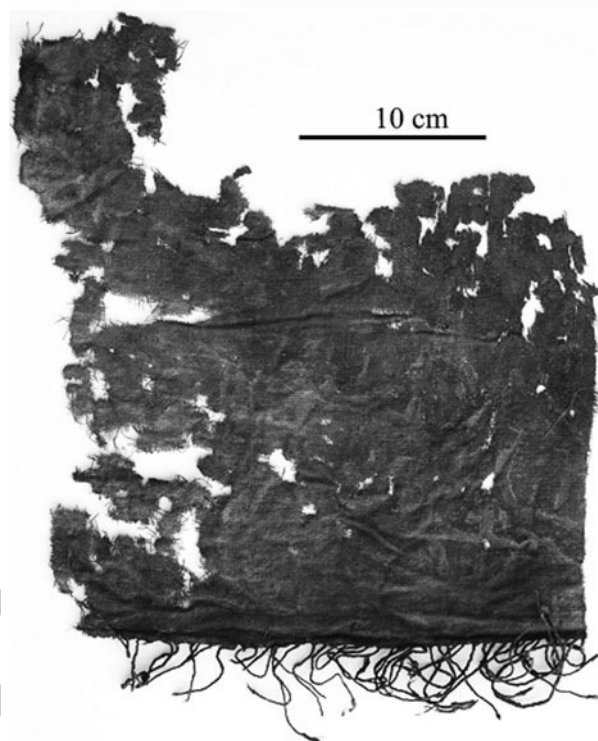
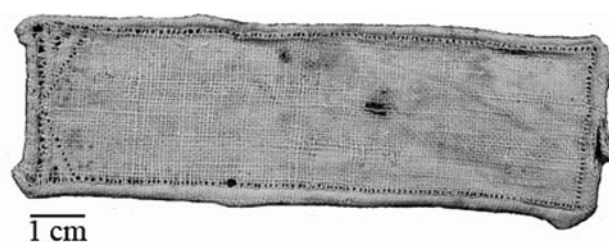
534 Considered one by one, none of the archaeological pieces  
 535 of evidence from Qal'at al-Bahrain and Madâ'in Sâlih  
 536 mentioned above can be claimed to prove alone the local  
 537 cultivation of cotton. Textiles may have been imported.  
 538 Seeds too can travel even if this seems less likely.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

b.c. on Bahrain Island. Literary sources attest to its con- 548  
 tinuous presence during Hellenistic (Theophrastus, men- 549  
 tioned above) and medieval Islamic times (Ibn Battûta, 550  
 14th century A.D., Defremery and Sanguinetti 1990). In 551  
 northeastern Saudi Arabia, cotton cultivation is attested 552  
 from the later Nabataean period (1st century A.D.) until the 553  
 last phases of the Late Antique occupation in the 6th 554  
 century A.D. 555

We do not know the precise origin of the cotton 556  
 plants grown on Bahrain, neither if they belonged to the 557  
*G. arboreum* or *G. herbaceum* species. It is sometimes 558  
 assumed that the description of these plants as 'wool- 559  
 bearing trees' allows their identification as tree cotton 560  
 (*G. arboreum*). In reality the two species are very close 561  
 morphologically and the textual evidence does not seem 562  
 reliable on this point. The frequent contacts between the 563

Author Proof





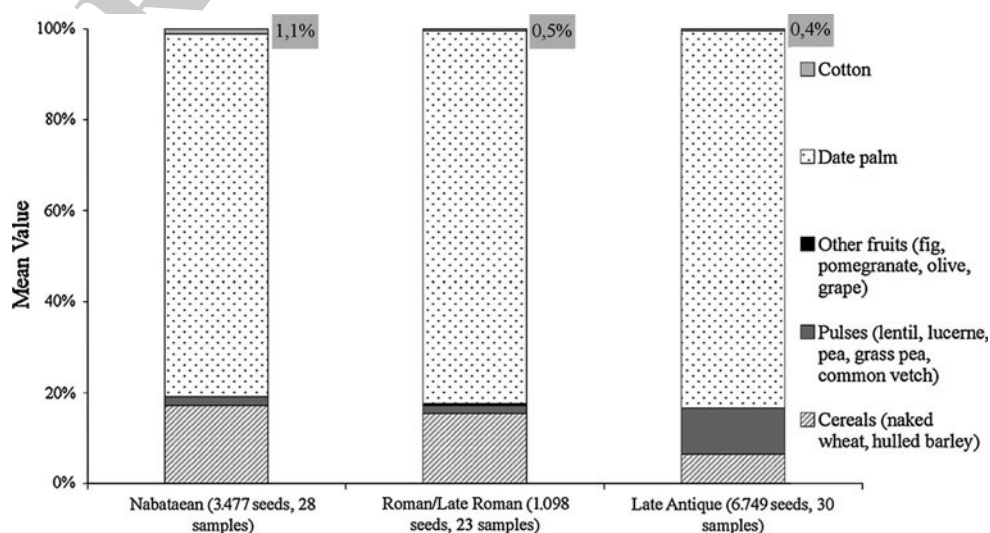
**Fig. 10** Carbonised seed of *Gossypium* sp. (cotton) from Madâ'in Sâlih (MS 10192) (photo C. Bouchaud)

564 Persian Gulf and the Indian subcontinent, since the early  
 565 Bronze Age, would render an origin in the East (*G. ar-*  
 566 *boreum*) more plausible than one in the West (*G. herba-*  
 567 *ceum* from Africa). However, the question is complex and  
 568 numerous exchanges of plant material from different ori-  
 569 gins could have taken place in antiquity.

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

**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)

**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)

577 suitable for cotton growing in the Arabian Peninsula, the  
 578 rainfall is largely insufficient and water has to be brought to  
 579 the fields by irrigation. For this reason, cotton cultivation in  
 580 this part of the Middle East seems to have developed in  
 581 association with the very specific and highly specialised  
 582 agrosystems of irrigated date palm gardens where a wide  
 583 array of crops were grown in a multi-storeyed system, with  
 584 date palms, other fruit trees and annual crops forming the  
 585 different levels. The latter consisted mostly of winter crops  
 586 originating from temperate Asia (barley, wheat, lentil, pea,  
 587 etc.) but the presence of cotton as well as *Sesamum indicum*  
 588 L. (sesame), identified from the middle Bronze Age  
 589 (1450–1350 B.C.) at Qal'at al-Bahrain, shows that summer  
 590 crops were equally a part of this system. As cotton plants  
 591 need a certain amount of light in order to develop it is  
 592 likely that they were not planted directly in the shade of the  
 593 date palms, as may have been the case for other crops, but  
 594 in more open plots that benefited from the same irrigation  
 595 systems. Even today cotton plants are often observed  
 596 growing in date palm gardens in Arabia and North Africa  
 597 even though their occurrence is sporadic and seems most  
 598 often to result from their use as an ornamental plant  
 599 (observations by Vincent Battesti in Tunisia, Algeria and  
 600 Egypt and by the authors in Saudi Arabia and in Oman). In  
 601 Oman, until the 1950s cotton used for textiles and fishing  
 602 nets was traditionally grown in open fields at the margin of  
 603 date palm gardens where it benefited from the same *falaj*  
 604 irrigation (underground galleries) as other crops (Richard-  
 605 son 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 adapta-  
 tion 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 centu-  
 ries 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 destina-  
 tions? 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 sep-  
 arate 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) spin-  
 ning. 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 con-  
 texts, 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, con-  
 temporary 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

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

## 664 Conclusion

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

675 Further archaeobotanical and textile studies in Arabia  
676 will certainly bring new perspectives on local textile tra-  
677 ditions as well as on their role in larger exchange systems.  
678 Finally, reliable methods for distinguishing between the  
679 two Old World cotton species, based on genetics, mor-  
680 phometrics or anatomy are likely to provide more precise  
681 information on the origin and movement of cultivars.

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