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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).

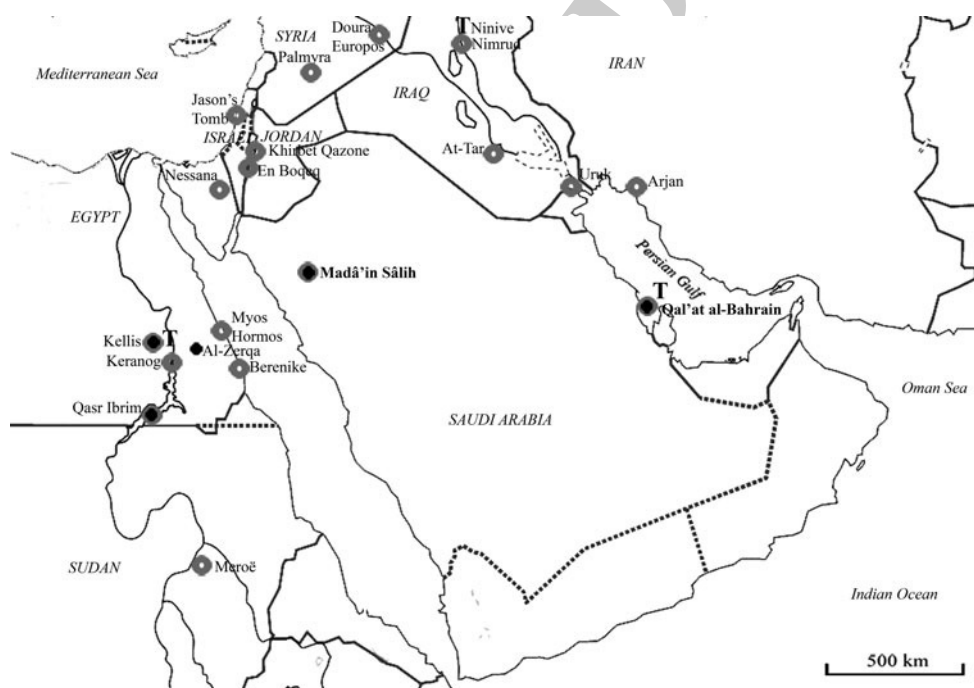


Fig. 1 Map showing cotton finds in the Near and Middle East, 1st mill. B.C.–7th c. A.D.: presence of fibres (grey circles), seeds (black dots) and textual evidence (T). (Al-Zerqa, 1st–3rd c. A.D. (Newton, personal communication); Arjan, 6th c. B.C. (Alvarez-Mon 2005); Berenike, 1st and 4th–5th c. A.D. (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)

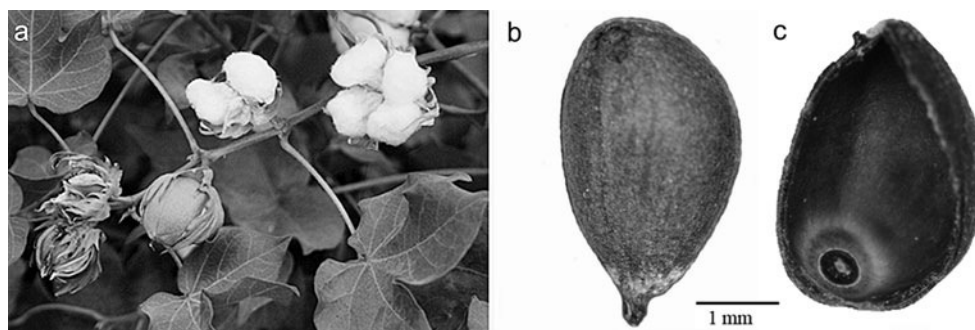


Fig. 2 *Gossypium* sp. (modern cotton); **a** capsules at different stages of ripeness (photo M. Tengberg); **b** seed (*G. herbaceum*) after ginning; **c** the interior of a seed (*G. herbaceum*) showing the characteristic chalaza (photo C. Bouchaud)

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

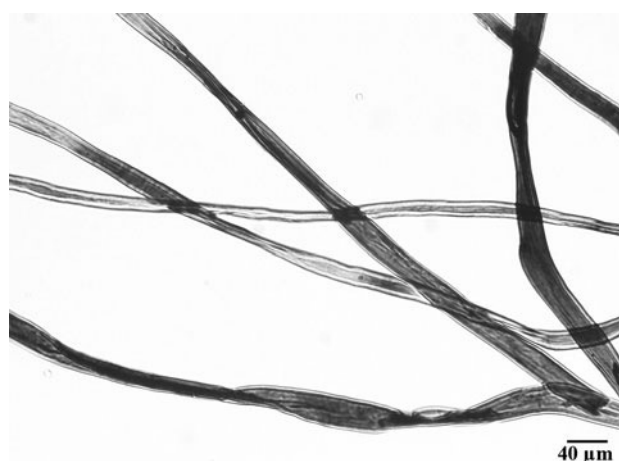


Fig. 3 Modern cotton fibres showing the characteristic twisting (photo D. de Reyer)

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

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

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

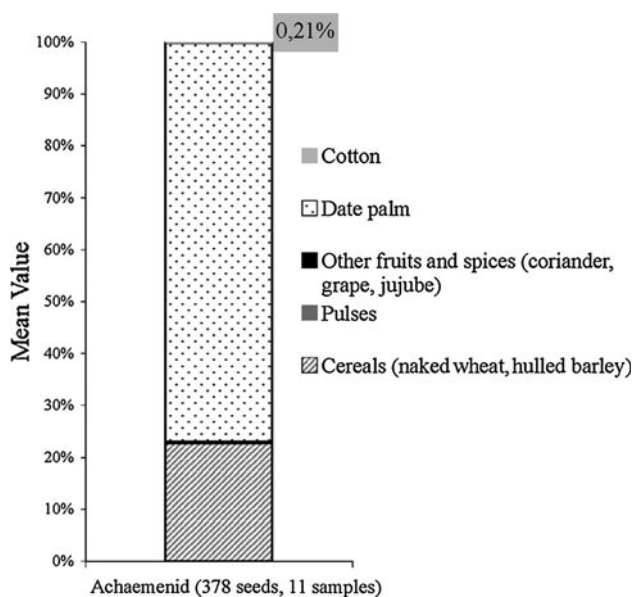


Fig. 7 Results of seed analysis. Graph of the mean value of cultivated plant at Qal'at al-Bahrain during the Achaemenian period (6th–4th c. B.C.); the frequencies of the various plants are indicated after the calculation of a mean value (see van Zeist et al. 2000) in order to render the results more 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 ± 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*

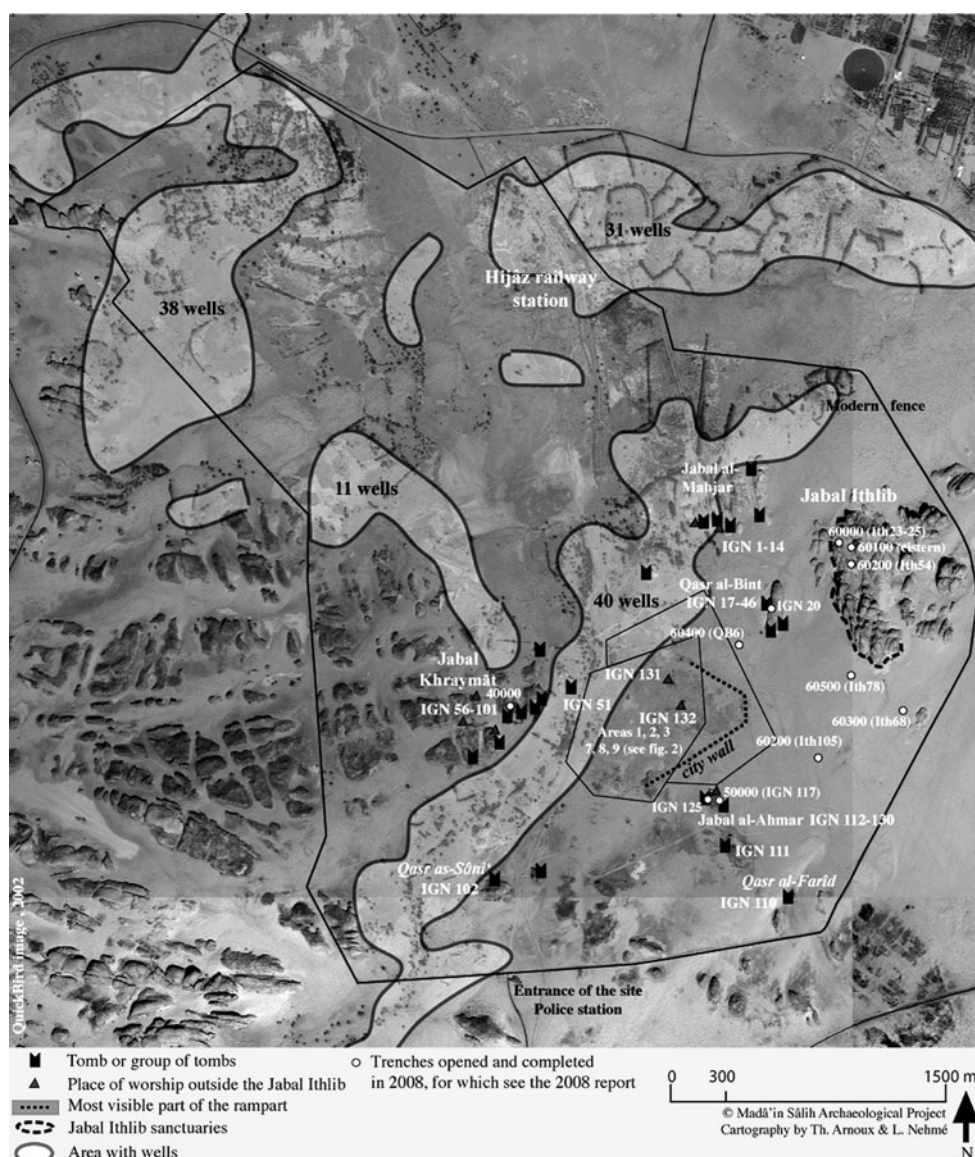
culinaris Medik. (lentil), *Pisum sativum* L. (pea), *Vicia*
501 *sativa* L. (common vetch), *Medicago sativa* L. (lucerne),
502 *Vitis vinifera* (grape vine), *Ficus carica* L. (fig), *Olea*
503 *europaea* L. (olive), *Punica granatum* (pomegranate) and
504 *Ziziphus* cf. *spina-christi* (Jerusalem 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)



Author Proof

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

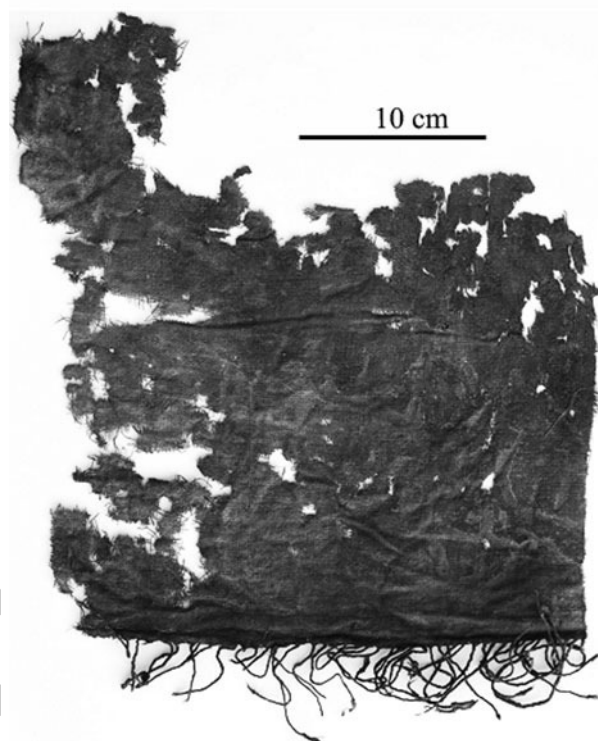
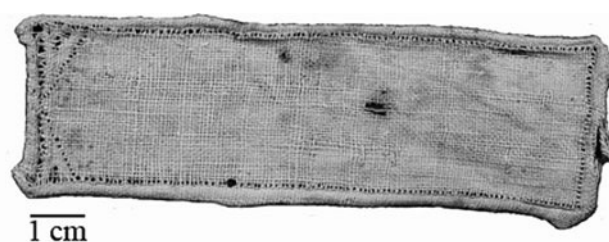


Fig. 10 Carbonised seed of *Gossypium* sp. (cotton) from Madâ'in Sâlih (MS 10192) (photo C. Bouchaud)

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.)

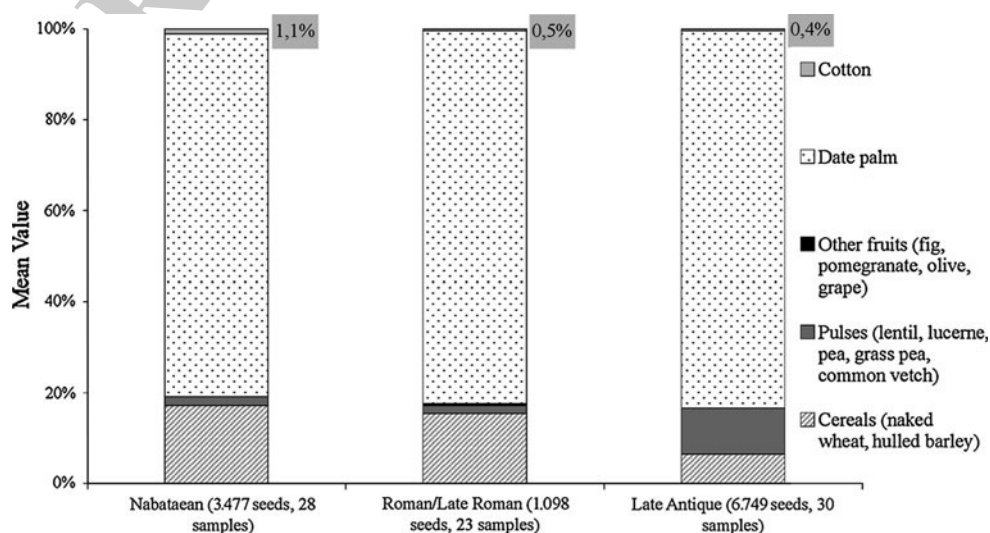




Fig. 13 Weight found in a Late Antiquity occupational level in the residential area of Madâ'in Sâlih (MS2010o1250B) (© Madâ'in Sâlih Archaeological Project)

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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