ANCIENT BIOMOLECULES INITIATIVE

Molecular Signatures from the Past

Who tamed sorghum?

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Qasr Ibrim, in southern Egypt, has provded some spectacularly well-preserved sorghum. The artificial Lake Nasser now surrounds this otherwise extremely arid site.

Sorghum is now the fifth most important world cereal, after wheat, rice, maize and barley. It is grown widely in tropical and sub-tropical latitudes, and is used for fodder, bread and beer making. Little is known of its early ancestry, so we used DNA from ancient and modern sorghum to find out more.

The establishment of early civilisation depended crucially upon the development of agriculture, particularly the domestication of crops and farm animals. For many crop plants, the date and place of domestication, and even the identity of the wild parent plants, is shrouded in mystery. The cereal crop sorghum is no exception.

We extracted ancient DNA from sorghum to try to learn about its domestication.

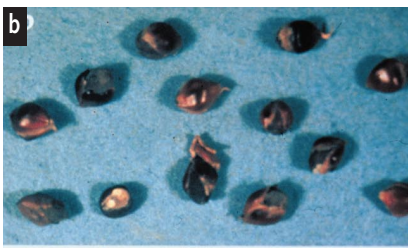
Just as DNA fingerprinting of modern human genes can match a suspect to a crime scene, the DNA of plant genes reveals similarities to its relatives. By isolating DNA from preserved plants, and comparing it to modern examples, it is possible to establish the parentage of a domesticated crop, and the site and approximate date of domestication.

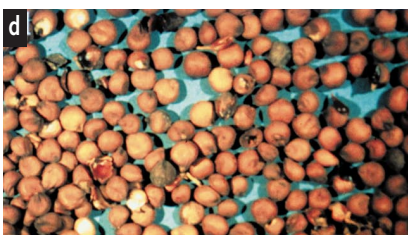
However, DNA is not a stable molecule, and in moist environments it rapidly breaks down. It can survive in dry conditions, albeit damaged, in low amounts for a few thousand years.

Qasr Ibrim, in southern Egypt, has one of the lowest rainfalls in the world, and sorghum remains are spectacularly well preserved here. There is a continuous series from the oldest wild plants (grown approximately 3,000 years ago), through several types of domesticated sorghum, until the ruin of the site in AD 1811.

We have isolated DNA from all ages of sorghum found at Qasr Ibrim, and have compared the gene sequences with those of modern sorghum.

We found that all Qasr Ibrim sorghum (including the wild varieties) share a common DNA sequence found in all modern cultivated sorghums. This is consistent with the current hypothesis - based on archaeological evidence - that sorghum was domesticated in the Nile Valley around 2,000 years ago.





Grains of sorghum from Qasr Ibrim. (a) wild arudinaceum, 600-800 BC, (b) bicolor 1200 AD, (c) intermediate 400-600 AD, (d) durra 1500 AD.

The Ancient Biomolecules Initiative is a five-year programme to understand the fate of biological molecules in archaeological and fossil materials, and to explore the applications of this new knowledge.
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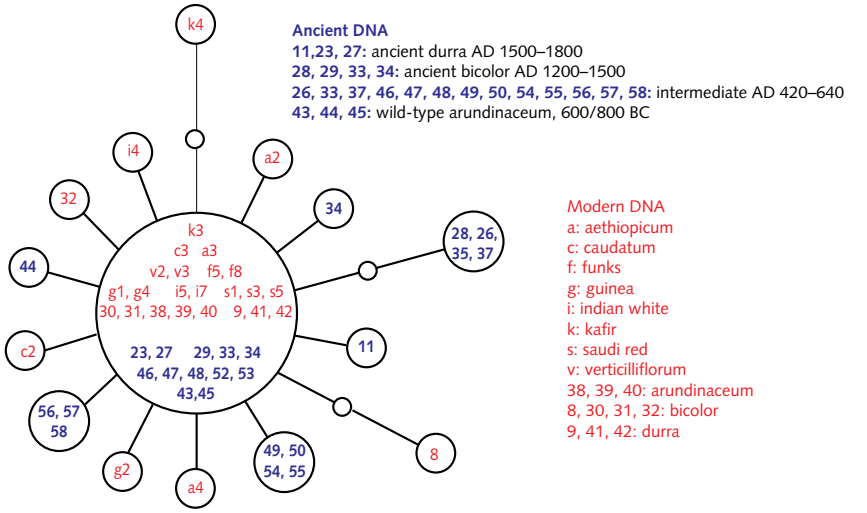
Natural Environment Research Council

Who tamed sorghum: the science in detail

Median Network of Sorghum from Qasr Ibrim based on PEPC Intron 8



Median Network of sorghum from Qasr Ibrim, based on PEPC Intron 8 DNA sequences. Identical sequences are grouped together in nodes. Each line connecting circles represents a single base divergence, empty nodes are virtual sequences with no representative in the dataset. Modern DNA sequences are in red text, and ancient ones in blue.

We have been investigating samples of sorghum from Qasr Ibrim in Egyptian Nubia, a site occupied for nearly three millennia (from around 1000 BC until AD 1811) with virtually no rainfall. Plant remains survive there in a superlative state of preservation.

Four forms of sorghum are found at Qasr Ibrim:

1. From the earliest settlement until AD 100, wild sorghum, race arundinaceum, is the only form found.

2. From AD 100 the primitive cultivated race, bicolor appears, decreasing in frequency after AD 1500.

3. From AD 1200 the advanced cultivated form, race durra, appears.

4. A form apparently transitional between races bicolor and durra has been dated to the 5th - 7th centuries AD.

Methods

Extracting long pieces of good quality DNA from single seeds of modern sorghum has proved to be easy. We have developed this method so that we can now routinely obtain good yields of DNA from individual preserved seeds of up to 2,800 years old. The presence of nucleotides in these seeds has been confirmed by accurate analytical methods (Gas Chromatography-Mass Spectrometry and Liquid Chromatography-Mass Spectrometry) at Bristol.

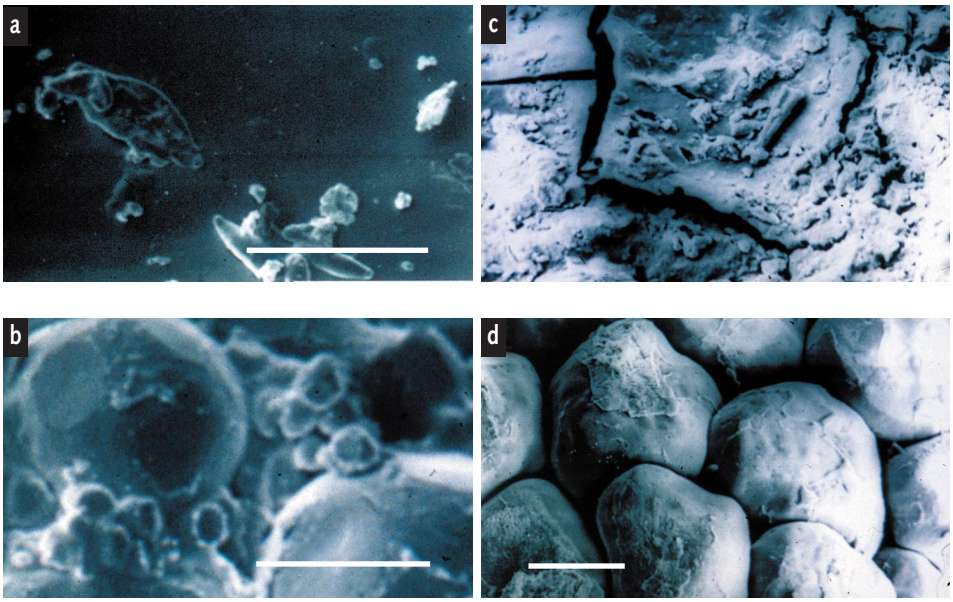
Most of the DNA in older seeds is in the form of short fragments of approximately 200-300 base pairs long. We amplified isolated DNA using the polymerase chain reaction, with defined primers from the ribosomal RNA, the phosphoenolpyruvate carboxylase, and glutathione-S-transferase genes. Sequences of the amplified DNA were compared with reference sequences.

Methods

DNA is extracted from 1-2 seeds, producing samples which can be immediately amplified. The Polymerase Chain Reaction (PCR) amplifies vanishingly small amounts of DNA, using as primers two short pieces of DNA which bind on either side of the target DNA. Through repeated cycles of heating and cooling, the target DNA is enzymatically amplified from as little as 1-10 copies to many billions. We use DNA primers synthesised to be complementary to part of the phosphoenolpyruvate carboxylase (PEPC) gene. In the Polymerase Chain Reaction these produce an amplification product approximately 150 base pairs long. The PCR products are cloned and the resulting DNA sequences aligned against the reference type, modern durra. When all positions of divergence have been aligned, a network of similarity can be drawn.

We found that wild sorghum from the earliest remains at Qasr Ibrim shares conserved DNA sequences with ancient durra and bicolor and the modern races arundinaceum, bicolor, caudatum, durra, guinea and kafir. This is consistent with the hypothesis that modern races of sorghum are descendants of plants domesticated in the Nile valley approximately 2,000 - 3,000 years ago.

Scanning Electron Microscopy of Qasr Ibrim sorghum
(a) modern durra external; (b) modern durra transverse section; (c) ancient durra external; (d) ancient durra transverse section. Bars represent 10μm



Future work

To confirm our hypothesis, we have obtained sorghum remains from other sites of similar antiquity and are analysing their DNA for the presence of the conserved DNA sequences. This information will give vital clues to the development of agriculture, trading practices, and civilisation in the Middle East. It will also help us to understand the agronomic practices which have led to the development of modern sorghum.

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