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Rope from the Christmas Cave: In search of the Talmudic hemp

Introduction and Background

The "Christmas Cave" (later in this paper - CC), located in the Judean Desert on the west bank of the Dead Sea, in the Qidron Valley, 1 km south of Qumran, has no connection to the life of Jesus Christ. Its name simply commemorates the day on which it was discovered by John Allegro in 1960 (Allegro 1965, 6-15 *passim*). In 2007, the cave was surveyed again by Ro'i Porat and Hanan Eshel (Porat R. *et al*. 2007). They confirmed that the finds have no connection to the Qumran Caves. Human activity in the cave began in the Chalcolithic Period, and continued as a hiding place for refugees at the end of the Great Revolt in 73 CE and again in the Bar Kokhba Revolt in 135 CE. Among the archaeological finds from this cave are wool and linen textiles from various periods. This assortment of textiles, in contrast to those found in Qumran, is similar to those found in Masada (Belis 2003, 211, 219). According to Orit Shamir, comparison to the textiles found in The Cave of Letters is more exact, those being generally coarser than the Masada textiles (personal correspondence).

This site is not considered part of, nor related to the Qumran complex of caves. Therefore some of the nomenclature used in Humpert and Gunneweg (2003) under the title "Qumran textiles", is misleading. Gunneweg, in his introduction (p. XIX) under the subheading "textiles", does not mention the Christmas Cave at all, notwithstanding its textile finds being included in the chapters he subsequently describes. The CC finds all appear numbered as category "QCC" (= "Qumran Christmas Cave"), and some have been given a parallel "QUM" number (Belis 2003, 221; Muller *et al*. 2003, 277). In the above volume, Penelope Walton Rogers reports her analysis of some of these fibres, referring to them simply as coming from "a site in the Dead Sea region", which is correct under any circumstances.

These ropes and fabrics were stored since their discovery at the Rockefeller Museum in Jerusalem, examined at École Biblique et Archéologique Française de Jérusalem (EBAF), and only recently relocated to the Israel Antiquities Authority. The articles had been bundled in batches from the various loci within the CC. It is likely that most or all of the articles investigated in this research paper are from the Roman period. Indeed, the sizes of the DNA templates of all the samples are about the same, in that they were under 1000 base pairs and over 180 base pairs, suggesting similar periods of decay. Nevertheless, certain characteristics present in a number of these items give the possible impression that they are from an earlier time period. These suppositions of periodisation should be confirmed in the future by radiocarbon dating.

It is generally accepted, based on both literary sources and archaeological finds, that the primary fibers in use at that time (1st-4th centuries CE) in the Land of Israel were lamb's wool, goat and camel hair, and flax-linen (1). Cotton had not yet appeared. Silk is mentioned in contemporary literary sources but has not been corroborated by archaeological finds of the period.

This research project focuses on the genetic identification of vegetable fibers constituting Roman period ropes and fabrics found in the CC. It has always been assumed that the fiber used in articles of this type is flax, which is well known as being widespread in the Land of Israel in this period, and is mentioned numerous times in the contemporary Rabbinic literature (Mishnah, Toseftah and the Jerusalem Talmud) (2). This assumption has been validated in the past by optical microscopy (Walton Rogers 2003) (3) and X-ray testing (Muller *et al*. 2003) . Nevertheless, it is extremely difficult to discern between quite similar cellulosic bast fibers, such as flax and hemp, by these means, and all the more so when they are ancient, having suffered the damaging and deteriorating effects of time. The genetic fingerprint on the other hand should enable one to determine what is really

in there (Dunbar and Murphy 2009). Samples of these ropes from CC, in addition to selected "linen-look" fabrics have been tested by genetic means in order to correctly determine the fibers of which they are made.

Hemp (cannabis) is mentioned in the Talmudic literature as an existing, albeit marginal, textile product in the Land of Israel, similar - albeit inferior - to flax. Both flax-hemp blend and wool-camel's hair blend (possibly central Asian Bactrian camel hair - which is soft and suitable for garments - and could have been imported - as opposed to the local coarse haired Dromedary, as suggested by Michael Ryder in personal correspondence), are mentioned in Mishnah Tractate Kil'ayim 9, 1 and Tractate Nega'im 11, 2. The indication is that the two fibers blended together are quite similar. Hemp as an inferior, and therefore invalid, substitute for linen is mentioned in Toseftah Tractate Menahot 9, 17. The adulteration of flax with hemp is a possible means of deceit, as flax is more expensive (Oakley 1928, 167-169). Blending flax with hemp may be practiced to obtain rope which is both soft and strong (Weindling1947, 286).

Although linen cordage (rope or twine) (4) is mentioned (Jerusalem Talmud Tractate Sukkah, ch. 1 and Tractate 'Eruvin, ch. 5), it is possible that hemp was also used in these products as well as in other coarse textiles (Weindling 1947, 286; Barber 1991, 15; McKenna 2004, 4-5). Up until now, no archaeological textile finds in the Land of Israel have been identified as hemp.

As opposed to the fabric and nets found in the Land of Israel which have typically been the focus of extensive research, the cordage finds have not yet been thoroughly examined. An additional aspect of this research will look into the cordage found in the Judean Desert and its possible uses, as reflected in the Talmudic literature.

Where were the ropes and fabrics manufactured, and where did the raw materials come from? A probable candidate is Beth Shean (which is mentioned in the Deocletian´s Edict by merit of its superior linen products, but referred to by its Roman name "Scythopolis"), 77 km further north, and was 'the' famous center in this period for flax growing and manufacture of fine linen garments, and is frequently mentioned as such in Talmudic sources. Flax is mentioned in the Biblical period in nearby Yeriho (Joshua 2, 6) from *c.* 1200 BCE. In adjacent Hesban, Yeriho, 'En Gedi and Masada textile, manufacturing implements have been unearthed from the relevant time periods. The distance from the Dead Sea to Jerusalem is 38 km. Rope-making does not require special implements, and could have been done at the location in which they were found, in this case the Christmas Cave. Talmudic literature mentions rope-making in several contexts, one of which is the halakhic injunction against using (even) a derelict synagogue (which

Fig. 1. Photographs of selected rope and fabric samples used in this analysis. © Authors.

is particularly suitable, being a long building) as a rope walk (Mishnah Tractate Megillah 3, 3) due to the site's holiness. Others include rope making done by two halakhically impure individuals (Mishnah Tractate Zavim 3, 2), and the injunction against making rope in a city of refuge, in order to deter the avenger of blood from going there (Toseftah Tractate Makot 3, 10). Apparently, rope is an essential commodity, made only in certain locales (see also Herzberg 1924, 140-146).

Hemp in an agricultural context is mentioned only once in the Mishnah (Tractate Kil'ayim 2, 5). According to Felix (1967, 220-222) the text is corrupt (5) and should be read "caraway". Amar (2000, 336, and personal correspondence) believes that the printed text can be accepted as is, but in any case hemp was definitely a very marginal crop. The Jerusalem Talmud (Tractate Kil'ayim 9, 7) mentions that garments made of hemp (possibly mixed with wool) were imported from "overseas" (perhaps from the Aegean and Asia Minor regions) (6) through the ports of Caesaria and Tyre and their respective vicinities. Perhaps fibers and/or yarn for weaving and rope manufacture were also imported, not locally grown.

Rope (both laid and braided) was certainly used in antiquity for a multitude of purposes. Indeed many rope finds have been retrieved from CC and other sites in the Land of Israel. The vast majority of these ropes are made from palm frond fiber; additional ropes are of goat and camel hair; and the distinct minority is of bast fiber, which has always been assumed to be flax.

Following are the various uses for rope mentioned in Talmudic literature, any or all of which may very well have existed at CC.

Mishnah

To cordon off an area (Pe'ah 4, 5 *passim*)
A leash for an animal (Shabbat 5, 3 *passim*)
A handle for a basket (Shabbat 8, 2 *passim*)
A sailor's knot (Shabbat 15, 1)
A cameleer's knot (*ibid*.)
Tied to a bucket for drawing water from a cistern (Shabbat 15, 2 *passim*)
To secure a burden to an animal's back (Shabbat 24, 1)
To measure the "*t'hum*", the distance permitted to walk on the Sabbath ('Eruvin 1, 9)
Rope bed or stool (Pesahim 4, 9 *passim*)
To measure a parcel of land (Baba Batrah 7, 2-3)
To bind an animal's legs (Parah 3, 9)

Toseftah

To secure a person who is going to immerse in water - *a "lifeline"* (Shabbat 1, 18)
To bind bundles of branches (Betzah 3, 10)
Used for shade, placed on the roof of a booth (Sukkah 1, 4)
To climb up to the roof (Makot 2, 6)
To check the water level in a cistern - *a "dipstick"* (Makhsirin 9, 6)

With that introduction in mind, we have applied DNA technology to identify the fibers of samples of rope and cloth found as the archeological site of CC. We expected the use of DNA sequence information to confirm the identity of the major component (as flax), but also to indicate whether fibers from hemp or another plant species form a detectable fraction of one or more samples. Our data do indicate that flax-linen dominates in every sample tested, and that there is a small amount of hemp DNA in many samples.

Methods and Results

Samples of rope and fabric from CC, part of the Israel National Treasures Collection, were obtained from the Israel Antiquities Authority. Rope samples were numbered I.A.A. 582928 (herein abbreviated 928), 582931 (931), 585795 (795), 585796 (796), and 637538 (538), and 582955 (955) [thread?]. Fabric samples were numbered 582812 (812), 583019 (019), 585440 (440), and 585786 (786) (Fig. 1). Two samples of modern rope were included: one stated to be of linen from Japan, and another from the United Kingdom. A positive control sample of flax, *Linum usitatissimum L.*, was obtained from the garden of the Plant Sciences Department, University of California at Davis, USA. Positive control samples of hemp, *Cannabis sativum L.*, (as drug quality marijuana) were obtained from the police department of Bakersfield, California, USA. DNA was extracted from the samples of rope, fabric and control plant samples and purified by adsorption on and elution from glass filters.

Identification of the plant species that contributed fibers to the rope and fabric samples began with the polymerase chain reaction (PCR)-amplification of the ribulose bisphosphate carboxylase-oxygenase large subunit (*rbcL*) gene (GeneBank accessions: flax: FJ169596.1; hemp: GQ436331.1). This gene is specific for photosynthetic organisms and thus its use avoids confusion from the presence of animal or fungal DNAs. We used two primers designed to generate a 184 bp DNA fragment of the *rbcL* gene. The fragment of flax could be distinguished from that of hemp, because the amplified hemp fragment contained a *BamH* restriction site that allowed its cleavage into two specific fragments.

The PCR products obtained using the template DNA extracted from the ancient rope and fabric samples all contained strong bands of approximately the cor-

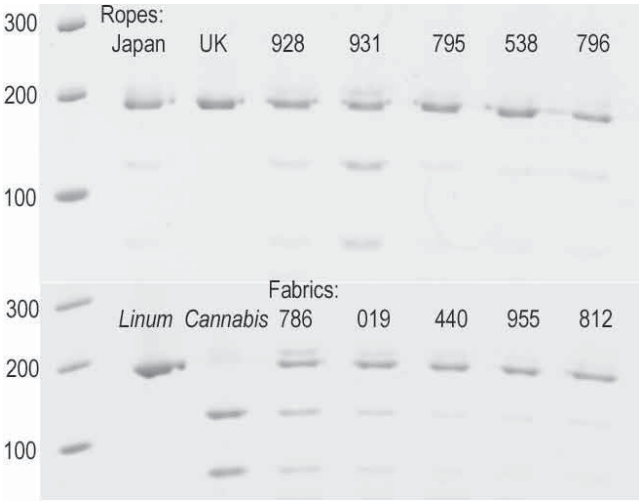

Fig. 2. Restriction analysis of DNA from rope and fabric samples. PCR amplifications were conducted in 20 µl of solution containing 12.1 µL of water, 4 µL of 5x Green Go Taq Buffer (Promega Corporation, Madison, WI, USA), 1.6 µL dNTPs (2.5 mM of each dNTP), 0.125 µL Taq DNA Polymerase (Go Taq, 5u/µL, Promega), 0.6 µL of each primer (forward and reverse, 20 µM), and 1 µL of template DNA. PCR conditions were 96ºC for 1min; 35 cycles of 94ºC for 45 sec, 60ºC for 45 sec, and 72ºC for 1 min; 72ºC for 5 min; 4ºC hold. Following PCR amplification, DNA was subjected to cleavage by BamH1 restriction enzyme. As shown in the lower frame, control DNA from hemp was completely cleaved, whereas DNA from flax was not. DNAs from modern linen (Japan) and (UK) ropes were not cleaved. Rope 931 and fabrics 786 and 019 showed significant cleavage. Numbers at the left show the size of DNA fragments in base pairs.

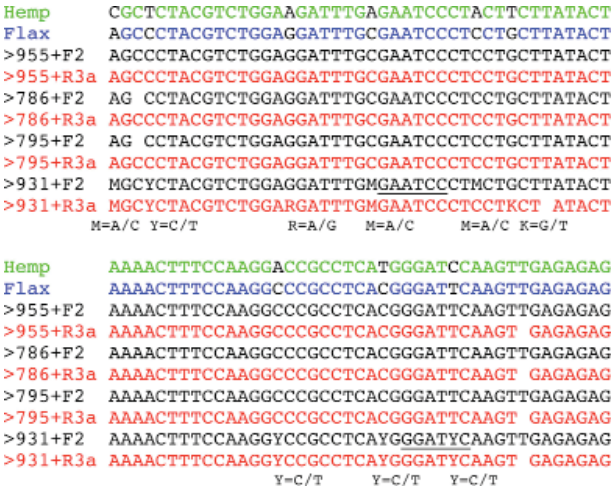

Fig. 3. Base sequences of PCR-amplified rbcL DNA from representative samples of rope and fabric, with corresponding flax and hemp sequences for comparison.
Sequences 795 and 931 are from rope samples; sequences 786 and 955 are from fabric samples. All samples were amplified using forward (F2) and reverse (R3a) primers.
The sequencing procedure was performed with each primer; the results from both primers are shown. Base differences in the hemp and flax DNA are shown in boldface black and the corresponding superpositions in sample 931 are indicated by code letters (M,Y,R,K).

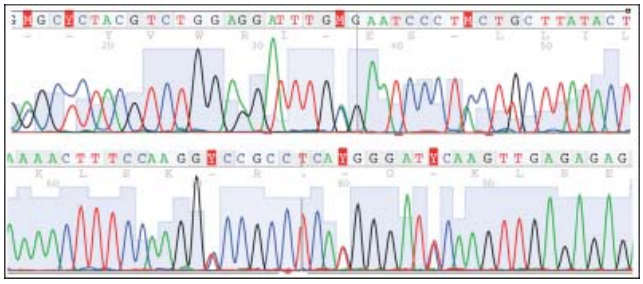

Fig. 4. Chromatogram showing superpositions in the DNA base sequence of sample 931. Bases marked M indicate superpositions of A (green) and C (blue); bases marked Y indicate superpositions of T (red) and C. This chromatogram shows the sequence read using the forward primer (F2); the chromatogram produced by the reverse primer (R3a) showed additional superpositions.

rect size, 184 base pairs (Fig. 2). The band produced using authentic hemp DNA template was cut over 90% by *BamH1*, yielding fragments of 115 and 69 base pairs. In contrast, the bands from most of the ancient samples were not cut significantly by *BamH1*, indicating that they contained little if any hemp DNA. Rope sample 931 and fabric sample 786 were the most notable exceptions, both showing substantial amounts of cutting. However, repetitions of the PCR reaction and restriction digestion, particularly of sample 786, did not consistently show the smaller bands produced by *BamH1*.

A second set of primers, specific for chloroplast gene *trnL* (leucine transfer RNA), was used to confirm the presence of hemp in the ancient samples. Using these primers, amplification of the flax gene gives a 311-base pair fragment; the hemp gene, a 180-base pair fragment. Using these primers, all rope samples

except 538 and all fabric samples except 955 showed a hemp band. Interestingly, although the template DNAs from modern rope samples showed a flax band, those from the ancient samples (assayed approximately five months after DNA extraction) did not, suggesting that the *trnL* gene of flax was more unstable to cleavage than that of hemp. DNA templates from a second set of samples (assayed soon after extraction) gave both hemp and flax bands.
The base sequences of most of the ancient samples confirmed their identity as flax DNA fragments (Fig. 3). Within the 184-base pair amplified DNA of the *rbcL* gene, there was a stretch of 86 base pairs in which accurate sequence determinations could be obtained by sequencing in both directions, giving double assurance of the results. Within that region were nine sites at which the sequences of the flax and hemp genes differed. The sequence of rope sample 931 showed two bases at all nine sites (from at least one reading direction; Figs. 3-4), confirming that this sample contained a significant amount of hemp DNA. Other samples lacked those indications. Fabric sample 786 did not show indication of hemp sequence (Fig. 3), indicating that there was much less hemp DNA in this sample than in sample 931.
A few other indications of two bases at one site, e.g. K (=G/T), or a present/deleted base (=T/-), occurred near the ends of the 86-base pair stretch, but probably represented sequencing errors rather than the inclusion of a variant flax or another species, since in each case these indications were found with only one primer. However, one of the indications in sample 931 indicated C/T, whereas the sequences of flax and hemp at that position were C and A, respectively. It is possible that the ancient hemp differed from the modern control species.

Conclusions and Questions Remaining Open
DNA sequences of the 184-base-pair bands confirmed their identities as flax *rbcL* and in the case of sample 955 confirmed the presence of hemp *rbcL* also. The PCR data using *trnL* primers indicated the presence of hemp DNA in that sample and most other samples, and the sequences of *trnL* bands also confirmed their identities. The sequence information would have indicated the presence of other fibers, such as palm or cotton, but none was detected. We note that the lack of linearity inherent in standard PCR makes it impossible to estimate accurately the relative amounts of template components. This is particularly true for the amplified sequences from trnL, the flax and hemp representatives of which differ greatly in size and composition. This also explains why replications of PCR using 931 and 786 DNA templates showed different amounts of hemp *rbcL* product. With the amplified sequences from *rbcL*, which are identical in size and very similar in composition in flax and hemp, semi-quantitative PCR, combined with restriction analysis, should give reasonable estimates of their relative amounts, and we anticipate performing these experiments soon. The quantification is important, since if the amount of hemp is very small, it may not have been incorporated intentionally into the item, but acquired, perhaps as dust, during fabrication, use, storage, or archeological discovery and investigation.

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(1) See: ASTM D 6798-02 *Standard Terminology Relating to Flax and Linen* (2003) West Conshohoken, PA. "Flax" refers to the plant and its fiber. "Linen" refers to the products produced from spinning onwards in the production process. Both the Hebrew and Aramaic languages do not discern between these two designations, often causing ambiguity.
(2) The Mishnah, Toseftah and Jerusalem Talmud are all works redacted in the Land of Israel. Documentation of material culture appearing in all of them should be relevant to our research. The Mishnah (and probably Toseftah) represents 225 CE *terminus ante quem* and probably long before 70 CE *terminus post quem*. The Jerusalem Talmud, which is a work expounding on the Mishnah, is 350 CE *terminus ante quem*.
(3) Pioneer research in the field is in Catling 1982, 12-17, 65-69. Chemical identification is outlined in: Oakley 1928, 166-169.
(4) See Denton and Daniels 2002: "Rope" is an article of cordage more than approximately 4 mm in diameter", and "twine" is twisted cordage less than 4 mm in diameter. The Talmudic term for rope is "*hevel*", and for twine is "*meshiha*". Our examples are border line in their diameters. Toseftah Tractate 'Eruvin 2, 2 mentions rope of 8 cm in diameter, for measuring the *t'hum*. In Tractate Zavim 1, 11 a rope 50 m long is mentioned.
(5) The printed text reads "*knbs*", while variants including the Jerusalem Talmud read "*krbs*". A perennial plant is necessary for the Mishnaic textual context. This designation fits caraway ("*krbs*"), not cannabis.

(6) See: Fleming and Clarke 1998 (map of Europe - "Type of Physical Evidence and Estimated Age"), and Herzberg 1924, 95-97.

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