The Colors and Dyes on Ancient Textiles in Israel

Zvi C. Koren (Kornblum)*

INTRODUCTION

We may never know where the art of dyeing originated or which peoples were the first to dye their textiles. It is most probable, though, that this craft was discovered in each geographical region independently. Historical evidence indicates that in antiquity, China, India, and Persia had established skills for decorating or coloring textiles. Chinese silk-dyeing, Indian cotton-dyeing, Egyptian linen-dyeing, and dyeing of wool in Mesopotamia, were all well practiced in antiquity. Traders and merchants, especially the Phoenicians, had undoubtedly helped spread local dyeing techniques, dyestuffs, and dyed cloths from one area to another. Wars and conquests in ancient times, which forced craftsmen to move from one country to another, had also helped disseminate dyeing techniques.

Historical records and archaeological findings have noted the existence of dyed or colored textiles more than five thousand years ago. Various historians state that the Babylonians, Assyrians, and the Chaldeans wore rich multicolored clothing. The Accadian word for color (bir-mu) also means colored textiles or goods, which is analogous to the Hebrew b’rommim of Ezekiel 27:24.

Before beginning a discussion of textile dyeing it is worth mentioning two important historical notes regarding the oldest ancient textiles discovered. The earliest definite evidence of textile weaving dates from about 7000 B.C.E. at Jarmo in northern Iraq and consists of clear weaving impressions formed on clay fragments that were in contact with these textiles. The oldest textiles discovered consisted of linen, which were found in a small cave at Nahal Hemar in the Judean desert, Israel, and they date from the pre-pottery Neolithic period (about 6500 B.C.E.).

The earliest possible indication of colored thread is probably from Çatal Hüyük in Turkey at the beginning of the 6th millennium. At this Early Neolithic Anatolian site a group of beads was found with traces of red inside the string holes. It may be that the now-missing thread was originally colored red.

What may be one of the most ancient colored or dyed textiles ever found consists of woolen fragments from the Cave of the Treasure at Nahal Mishmar in the Judean desert (Israel). These small cloths date from the Chalcolithic period (4th millennium) and are reported to include red, green (possibly intrusive), black, and tan or yellow (probably natural colors).

In Egypt, one of the earliest colored textiles found was beside a mummified body in an unidentified tomb at el-Gebelein (central Egypt). This linen cloth mural dates from the first half of the 4th millennium and had been painted in red, black, and white: it depicts scenes of boating, hunting, fishing, and funeral rites. Another predynastic Egyptian textile found was a piece of red-edged matting. Red and brown linen mummy wrappings beginning with the First Egyptian Dynasty (about 3000 B.C.E.) have been found. By 2000 B.C.E., the dyeing of linen and leather was practiced by individual craftsmen as well as by temple industries. Balls of red and blue wool from

* Prof. Zvi Koren is the Director of the Edelstein Center for the Analysis of Ancient Textiles and Related Artifacts, Shenkar College of Textile Technology and Fashion, Ramat Gan.
about 2000 B.C.E. were found in Egyptian graves. A four-thousand-year-old bright red-stained piece of leather was found in the burial chamber of a pyramid. Red, yellow, and green cloth were displayed in Early Egyptian pictures and by 1500 B.C.E. striped red, deep blue, and yellow cloth became fashionable. Woolens had been imported from about that time from Babylonia and later brown, salmon, and bright blue also appeared.

In Mesopotamia, traces of a woven fabric dating from the middle of the 3rd millennium were found in the Great Death Pit at the Royal Tombs of Ur and they seem to have been colored a brilliant ochreous red.

In Anatolia, some of the oldest colored textiles found originated from Tsarskaja (Novosvobodnaja), Kuban, and date from the middle to late 3rd millennium. These consisted of an undergarment (probably linen) belonging to a buried tribal chief, which was brightly decorated with purple color and covered with tassel-like red threads. The chief’s overgarment consisted of a fluffy yellow cloth ornamented with narrow black stripes to form a plaid pattern.

The coloring or dyeing of textiles may have originated from body painting. This latter practice was performed for beautification as well as for conferring magical powers or sexual attraction. Prehistoric man and woman may have subsequently realized that clothes, too, could be colored. In addition, the earliest dyes or coloring substances were undoubtedly discovered by accident through serendipitous staining by berries, fruits, nuts, blossoms, leaves, stems, roots, bark, twigs, etc.

From various ancient writers, it has been estimated that almost a thousand different natural colorants have been utilized since the practice of coloring or dyeing began. However, as trade in each district’s superior dyestuff began between various communities, a much smaller number of primitive coloring substances were still being used during ancient and medieval times. Primitive man primarily used dyestuffs of vegetable origin from nearby available sources. The primitive coloring process must have simply consisted of boiling the dyestuffs in water and then introducing the textile sample to be dyed or colored.

Only some direct knowledge about the dyeing tools and techniques used by the ancients has survived to the present time. These old techniques were a closely guarded trade secret as they were passed down from father to son over the centuries. It is clear that “books” of dyeing recipes did exist, as mentioned in the Hellenistic “chemical” papyri, but none have survived to the present time (Fig. 1).

Modern scientific research of ancient textile dyes is helping decipher the secrets associated with ancient dyeing practices and thus to regain the lost art related to this technology. The results of such an investigation would open a historical window to the understanding of the development of culture and technology in antiquity.

The art of dyeing has a very prominent Jewish connection. Robinson has conjectured, though without proof, that it may be quite possible that the Jews learned the art of dyeing during their time in Egypt. The dyer was a well-respected craftsman in ancient Palestine. He knew how to control the matching of the colors by immersing small samples of the cloth as he protected his hands with special gloves. Many Hebrew words associated with his craft have been used in Jewish writings. In the Jerusalem Talmud (Tractate Shabbat) it is stated that the dyer wore a badge of dyed wool behind the ear. Jewish and Syrian dyers always had a good reputation so that in Imperial Rome and even in the Middle Ages dyeing was more or less their monopoly.

The Jewish writings mention the red insect dye (or wool dyed with this insect), *Tola‘at ha-Shani*, as well as the colors or woolen dyeings produced from molluskan dyes, *Tekhelet* (blue-purple) and *Argaman* (red-purple).

These three Biblical colors or dyeings, which are usually mentioned together, are known as the “sacramental colors” as they are associated with the priestly clothes of Aaron and with the textiles used in the Temple. The mystery of the sources of
these dyes has still not been unambiguously deciphered. However, science is helping narrow the list of possible sources for these rare purple and red dyes. Later Jewish writings discuss the dyes that can be produced from various plants. Thus, the Jerusalem Talmud, Tractate Shevi‘it, contains a “botanical” section (Chapter 7) that describes the plants that were used for dyeing textiles – as well as for the coloring of man and beast. Though not all of the dyestuffs mentioned in these sources have been actually discovered on antique textiles, the mere mention of them in historical sources makes it somewhat probable that some of them may yet be found in future archaeological digs.

The earliest picture of a Semitic dress, which might have also been used by Hebrews, is depicted in an Egyptian painting at Beni-Hasan (about 1900 B.C.E.) in the tomb of Khnemhotep, a high-ranking Egyptian official. In this colored painting, the Egyptians are portrayed with skirts of white linen, whereas the Asians are wearing colored striped skirts and colorful embroidered clothing (Fig. 2).

Brunello has assumed that the Hebrews practiced dyeing on a vast scale based on the the number of purported dyeworks that have been discovered throughout Israel. However, on none of these sites, except for the molluscan Royal Purple dyeing installations at Tel Dor and at some other coastal sites in Israel, have any remains of dyestuffs been found. Hence, these installations have not yet been scientifically proven to be dyeworks.

ADDING COLOR TO A TEXTILE

The following sections discuss adding colors to textiles by various methods: utilizing the natural color of the fibers; coloring; and dyeing.

Natural Colors of the Fibres

The different natural colors of wool were used to add “color” to a textile. The ancients preferred to select natural brown, reddish, white, or black wool for such colors. Accadian texts mention that grays were obtained by spinning black and white wool together into a double thread; various shades of beige or brown were easily obtainable from the natural coloration of the fibers. Thus, creamy, beige, or yellowish colors can be obtained from the natural shades of wool and linen fibers. Dark brown or black fibers were introduced into a textile by the inclusion of coarse goat hairs. Soft brown hues were also obtained by the introduction of camel hair. With these hues, various designs can be incorporated into the fabric with these naturally colored (or undyed) fibers.

Archaeological evidence of these practices include a First Dynasty (about 3000 B.C.E.) Egyptian pleated tunic found in a tomb at Tarkhan, which consists of a vertical occasional gray pinstripe on its shirttails. This decorative effect was obtained by using a darker yarn in the warp. Such striped designs have also been found in textiles from later Dynasties.

In the ‘En-Boqeq excavations in Israel, one of the cloths contained a mixture of camel hair and sheep’s wool, which consisted of a mixture of soft-brown and creamy-yellow textures, respectively.

In Kefar Shāhak, southern Aravah of Israel (Early Arabic period – about the 7th century C.E.), a twisted yarn consisting of a mixture of dark goat hairs and yellowish sheep’s wool has been found.9

Coloring the Fabrics

This article will differentiate between coloring or coloration of a fabric and dyeing, each depending on the process of introducing color on or into a fabric or fiber. The difference between these two processes is not always clearly defined. The art of coloring fabrics probably began in antiquity by “coating” the textile rather than dyeing it. “Coloring” refers to applying a color-producing material onto a fabric by physical means, such as by painting, rubbing or pressing it into the fiber. This coating process yielded colors on fabrics that were, in general, not very fast (i.e. stable) to
washing. The process of “dyeing” a textile refers to the fixing of a coloring substance into the textile by chemical means so that a chemical bond is produced between the dye and the fiber.

A colorant can be classified as a dye, pigment, or lake, although the latter two may also be considered as “dyes” if the resulting color is not fugitive. The true dyes were generally of an organic origin with a chemical affinity for the fiber. A pigment is a dry color and, alone or in a binder, may be coated onto the fibers; it may also be transferred into the fibers by immersing them in a water mixture containing this pigment. A lake is a water-insoluble colored substance made by precipitating an organic coloring material by means of a salt, onto or into the fibers.

One of the simplest coloring techniques was to press natural products into the body of the fabric with albumen or clotted blood. These items included leaves, flowers, fruits, sticks, wood, shells, feathers, hair, fur, berries, nuts, etc. Another early coloring technique included physically applying inorganic matter to the textile. It is probable that the first pigments used in coloring by the Egyptians were ocher and lampblack as they were the same colors used to prepare the inks for use on papyri. The painting of red, black, and white colors on a cloth was discovered at el-Gebelein, Egypt, as previously described.

Yellows, reds and browns could have been supplied from iron minerals and earths (“ochers”). These clays contain iron oxides in colors ranging from the red anhydrous form (hematite), through orange, to the most hydrated pale yellow form. The ochers were mixed with either fat or water before applying. A reddish brown-colored Egyptian cloth dating from the second millennium B.C.E. has been scientifically shown to have been colored with “red ocher” – anhydrous iron (III) oxide. In addition, prehistoric and more recent reddish-brown colored cloths excavated in Israel may have also been colored with that mineral.

When iron became a common metal, it was discovered that any soluble salt of iron – usually an acidified water solution such as vinegar – could be made to act as a dyeing agent. Fibers darker than their natural shades were also obtained by placing the textiles in a hot bath of a salt solution of tin. The fastness of the color depended on the type of coloring substance, the binder, and the fiber. Thus, some of these colorations – or actually dyeings – were fortuitously fast due to the formation of a chemical union between the colorants and the fibers.

White or shades of cream could have been obtained from lime, gypsum, or clay. Blacks and grays were produced on textiles from minerals containing manganese, soot (carbon), charcoal, lamplblack, coal, and bitumen from the Dead Sea. These pigments were simply rubbed onto the fabric or bound to it by grinding the pigment into a powder and adding a binder consisting of water, milk, bone marrow, egg albumen, or clotted blood. The binder could also have been a tree resin, gum or other naturally occurring sticky material.

The bleaching action of sunlight can whiten the material, especially linen. Conversely, the blackening action of smoke can “color” a fabric and produce a pattern on it by the use of a stencil.

In Ugarit (Ras Sharma), on the north coast of Syria, the coloring of a textile by means of copper has been found. In some parts of the ancient world, red mineral coloring of textiles by cinnabar (mercury sulfide) and orpiment (arsenic trisulfide) and yellow realgar (arsenic bisulfide) have also been found.

The above-mentioned inorganic and organic techniques of coloring or “printing” on a textile also developed into ancient methods of “resist printing” or “resist dyeing.” This method involves the prior treatment of a portion (or portions) of the fabric in a certain way such that during the coloring or dyeing process, the pretreated portion “resists” the color and remains uncolored. The outline about this portion thus forms a pattern on the fabric.
**Dyeing of Textiles**

The dyeing of textiles may have been practiced at least as far back as the end of the Neolithic period (about the 4th millennium) as remains of colored textiles from that era have been found. The most varied and spectacular colors on textiles were obtained by dyeing the fibers with organic dye sources. Some, but definitely not all, were widely available and the specific shade of a color desired often depended on the skills of the dyer. Organic dyestuff sources belong to the vegetable and animal worlds. In addition to this flora and fauna classification, the dyes can also be categorized according to their dyeing procedures; this will be discussed in a later section.

Of the natural fibers used in antiquity, it was found that wool was the easiest to dye. This dyeability is due to its proteinic structure that contains various "docking points" for the dyes. In contrast, the cellulosic nature of linen makes it less reactive than wool and its relatively dense fibers prevent most dyes from penetrating well into its structure. Thus, while ancient wool dyeings show a wide range of colors, the main fast dye for linen discovered in archaeological excavations is blue indigotin pigment which can penetrate into the fibers in its soluble form (see later).

**SOURCES OF THE DYES**

This section discusses the sources of the dyestuffs from the vegetable and animal kingdoms.

**Vegetable Kingdom**

Plant sources of textile dyes were the most plentiful and widely used of all the natural dyestuffs. Different parts of the plants were used for the various dye sources. In some plants, the flowers are utilized for extracting the dye material. In another it could be the leaves, while in another, it could be just the roots, or perhaps the entire plant may sometimes be used. Each of the primary colors – red, blue, and yellow – can be produced from the appropriate plant.

For each of the three color groups, the main plants used as dyestuffs for this color will be listed in the appropriate table. The common English and Hebrew (transliterated) names and the botanical name of each plant are also indicated, as is the part of the plant used for obtaining the major dyes.  

**Red-Dye Plant Sources**

The plant most used in the antique world to yield red dyeings on textiles was madder (Fig. 3; Table 1). Its roots contain glucosides – sugars – capable of liberating the dyes, especially by

---

**Table 1: Common Red-Dye Plant Sources**

<table>
<thead>
<tr>
<th>Common</th>
<th>Botanical</th>
<th>Hebrew</th>
<th>PART USED</th>
<th>MAJOR DYES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madder</td>
<td><em>Rubia tinctorum</em> L.</td>
<td>poo’ah</td>
<td>roots</td>
<td>alizarin; purpurin</td>
</tr>
<tr>
<td>Safflower</td>
<td><em>Carthamus tinctorius</em> L.</td>
<td>qoortam</td>
<td>flower petals</td>
<td>carthamin (red) “safflower yellow”</td>
</tr>
<tr>
<td>Henna</td>
<td><em>Lawsonia inermis</em> L. <em>Lawsonia alba</em> Lamarck</td>
<td>ḫena</td>
<td>leaves</td>
<td>lawsone; others</td>
</tr>
</tbody>
</table>

19*
fermentation and acid action (Fig. 4). Both in the Middle East and in Europe, the madder species most widely used was *Rubia tinctorum* L.\(^{10}\) (Fig. 5). Madder is said to contain more than 20 different dye components in varying concentrations, though the main components are the closely related chemical species – alizarin and purpurin. In Europe, other species of *Rubiaceae* have also been used to some extent.

In ancient Egypt, madder was used quite frequently, and it was also locally available in Syria and Palestine. This dye may go back some 5,000 years or more, as it has been reportedly found on Egyptian textiles from the 3rd millennium. King Tutankhamon’s belt as well as some other textiles found in his tomb are said to be colored with the madder plant. Though not in the Near East, but nevertheless of historical importance, cotton samples found in Mohenjo-Daro, India, and dating from the late 3rd millennium may have been dyed with madder.

Safflower can yield a beautiful pinkish hue on a textile. The yellow and red petals of the flower can produce either color depending on the dyeing process. Carthamin (the red coloring substance) is not soluble in water but dissolves in an alkaline-aqueous solution, whereas safflower yellow is very soluble in even cold water. Henna, though widely utilized to color hair, was also used for the orange-red dyeing of textiles. The reddish hues on some 21st Dynasty (about 1000 B.C.E.) mummy cloths may have contained henna and safflower.

**Blue-Dye Plant Sources**

More than fifty species of plants are known to exist that can furnish the same blue dye, indigotin. However, in the ancient Middle East, it is believed that only two species were primarily used: *Indigofera tinctoria* L. (“indigo”) of Asian origin and *Isatis tinctoria* L. (“woad”) of the more temperate regions (Fig. 6, Table 2).\(^{11}\) The woad plant was at some point in time grown in Israel after its importation, whereas the indigo plant may have also been locally grown after importation or just imported for dye usage. Though these plants also contain other minor coloring matters, indigotin is dominant in both plants (Fig. 7). However, the indigotin content from the true indigo plant, which is native to India, is higher than that obtainable from woad by perhaps as much as 30 times. Scientists are currently working on methods that will distinguish between these two plant dyestuffs by focusing on their minor dye components.

All the plant blues discovered on ancient textiles in the Near East consisted of the indigotin dye.

Indigotin is considered a “vat dye” (see later section) and the processes involved in producing it from all the appropriate plants are similar. The precursor to indigotin is present in the plant as the colorless indican, which, upon fermentation, decomposes into fructose and indoxyl; the latter is the reduced form of indigotin and forms a yellow water-soluble compound. This yellowish substance turns to the final blue insoluble indigotin form upon air-oxidation.

The indigotin dye is contained primarily in the leaves of the indigotin-producing plant. This dye is relatively expensive as the actual amount of dyestuff obtained from each leaf is small. The dye is extracted in the following way: The leaves are ground and allowed to ferment in water with the subsequent addition of an alkaline substance (Fig. 8). This alkaline substance could have been vegetable ashes, decomposed urine (a source of ammonia) and/or limewater. The impurities contained in the dyebaths as a result of the plants used and the high temperatures of the tropics necessarily imply a rapid and spontaneous fermentation sufficient to reduce the dyestuff to a soluble form (Figure 9). This dye solution is able to penetrate the immersed fibers. Subsequently, the textile is removed from the solution and the air-oxidized insoluble indigotin is formed (Figure 10). The blue dye was also extracted as a powder by striking the surface of the reduced yellow-green solution with sticks to hasten the air-oxidation of the substance and its consequent precipitation. The dried residue is then mostly indigotin powder and it can then be pressed into cakes.

The complexity of the indigotin-dyeing process...
implies that the general technique of dyeing was already highly advanced in the Bronze Age, and therefore other easily applied substances were already in use.

Forbes discusses the history of the woad plant, as follows. Woad was known to both the Egyptians and the inhabitants of Mesopotamia well before Hellenistic times. Its cultivation as a dye plant began seriously during Hellenistic times at which time it came to Palestine and Syria. In the classical world, woad was more popular than the indigo plant.

The history of the indigo plant is described by Brunello and Forbes; however, their use of the word “indigo” may refer to the dye and not to the specific plant. Forbes relates the following items concerning indigo. In ancient Mesopotamia, the indigo plant, known in the seventh century B.C.E. as “lalangu”, does not seem to have been cultivated. It became common and was cultivated during Hellenistic times in Egypt and Syria but not in Palestine. The word “nil” is common to Arabia, Persia, and India, and it means “sky-blue’’. In the Jewish literature, the word “nil” is first mentioned in the Gaonic period, and it might refer to the indigo plant or to the blue dye, which can also be obtained from woad. In the period of the Mishna, indigo (or woad?) was imported as a dye. In Roman Palestine, the indigo plant was cultivated in the second century C.E. and it was called “kalaian”, which might also refer to woad, or “indaco” (“indik” in Arabic). Interestingly, the indigo plant was not used during Roman times as a textile dye, but rather as a pigment for painting objects, whereas woad was used for dyeing cloth. For example, indigo (or, again, perhaps an indigotin-producing plant) was used in decorating a Roman parade shield (about 200 C.E.), which was found at Dura Europos. Indigo is also mentioned for coloring stones in the “chemical” papyri of late Hellenistic date.

Brunello, in discussing the indigo plant, makes the following points. It may be that the indigotin dye from the indigo plant did not come into common use until about 300 B.C.E. or the Roman era, when it was used only as a coloring extract. It seems that the Romans did not have any exact knowledge concerning the use and extraction of the dye and it is possible that the true indigo was not even used by the dyers as it was too costly. On the other hand, woad was extensively used as the plant was an ordinary item of commerce in that region. As far as the true indigo plant is concerned, it is not yet certain whether it was known to the Greeks of ancient times.

It has been suggested by Forbes that the indigo dye from the indigo plant was found on Early Egyptian cloth dating from the fifth dynasty (about 2500 B.C.E.) as well as on later mummy wrappings. This definitive statement concerning the specific plant origin of the indigo coloring substance seems premature as there has not been

Table 2: Common Blue-Dye Plant Sources

<table>
<thead>
<tr>
<th>PLANT NAME</th>
<th>PART USED</th>
<th>MAJOR DYES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigo</td>
<td><em>Indigofera tinctoria</em> L.</td>
<td>Nil</td>
</tr>
<tr>
<td>Woad</td>
<td><em>Isatis tinctoria</em> L.</td>
<td>Isatis (Nil?)</td>
</tr>
</tbody>
</table>
any test, then or now, that might distinguish between the use of woad or the indigo plant (Fig. 11). Often, only elementary analyses were originally conducted on this artifact and on other ancient Egyptian blue dyeings, which revealed that the coloring substance was a vat dye (see later) or specifically the indigotin dye, and nothing more should be inferred regarding the plant source.

Based on its morphology, the woad plant is believed to be native to southeastern Europe (or even to southeast Asia), whereas indigo is native to India. The oldest indigotin-dyeing (or coloring) found in Egypt, which consists of blue stripes on cloth, dates from the middle of the 3rd millennium. An indigotin-producing plant or the dye itself had to be imported into the Near East at some point in time. On the one hand, woad had less distance to travel to eventually reach the Near East than the indigo plant. However, trade in the blue dye consisted of it being often sold as the already extracted solid form, which would make it possible to be transported from India and its environs. In addition, the blue dye content in the true indigo plant was much higher than in woad, which might have led the indigo plant to displace woad, at least as far as large-scale indigotin-production was concerned.

The woad vs. indigo plant mystery is still with us, and awaits further scientific analyses.

Yellow-Dye Plant Sources

As Table 3 indicates, there were many plant sources for dyeing a textile with a yellow shade. Modern dyeings using ancient recipes have shown that an almost endless number of plants can yield a yellow dyeing. Thus, while very little of these colors in ancient textiles has actually survived to this very day, it is most probable that yellow dyeings, at least on a home scale, must have been prevalent, though seasonal.

Forbes reports on the historical uses of pomegranate rinds as follows: In Mesopotamia, as early as 2000 BCE, pomegranate rinds were ground with water to extract the yellow dye. In Egypt, pomegranate was used from at least 1500 BCE. as finds in tombs have shown, and in Palestine the rinds were used in textile dyes and inks.

Safflower yellow, one of the two coloring substances in safflower, is not a very fast or stable dye as it is soluble in water. Bright yellow linen mummy bindings from the 12th Dynasty Tomb of the Two Brothers (about 2000 BCE) were analysed and reported to have been dyed with safflower.

Saffron, according to Forbes, was not produced in ancient Palestine but was grown in neighboring Syria and Egypt (Fig. 12). A yellow dye used on the textiles from Bar-Kokhba's Cave of Letters was analyzed and identified to be saffron (Fig. 13).

Animal Kingdom

There were a number of important scale-insect (red) and sea molluskan sources (purple) for the most precious of dyes. The high cost of such dyeings resulted from the meager coloring substance extracted from each mollusk or insect and thus substantial dyeings with these dyestuffs were only affordable to the very rich. Although the Phoenicians have been generally credited with the discovery of the purple dye in about 1500 BCE, the use of this dye may actually have begun earlier. The Minoans of Eastern Crete may have discovered the purple dye sometime in the first half of the 2nd millennium BCE. and the Western Semites living along the coast of the Levant may also have predated the Phoenicians in the use of this dye.

Molluskan Sources

The Neogastropoda class of sea snails includes the Muricidae family of mollusks, which was the group that yielded the true purple – Tyrian (or Royal) Purple (see Table 4). The most important members of the genus Purpura and related genera that yielded the “purple” dye were Murex trunculus, Murex brandaris, and Thais haemastoma (Fig. 14). It should be noted, though, that more
Table 3: Common Yellow/Brown-Dye Plant Sources

<table>
<thead>
<tr>
<th>Common</th>
<th>Botanical</th>
<th>Hebrew</th>
<th>PART USED</th>
<th>MAJOR DYES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saffron</td>
<td><em>Crocus sativus</em> L.</td>
<td>karkom</td>
<td>stigmas (pistils)</td>
<td>crocetin</td>
</tr>
<tr>
<td>Safflower</td>
<td><em>Carthamus tinctorius</em> L.</td>
<td>qoortam</td>
<td>petals (florets)</td>
<td>“safflower yellow”; carthamin (red)</td>
</tr>
<tr>
<td>Weld</td>
<td><em>Reseda lutèola</em> L.</td>
<td>richpa</td>
<td>whole plant</td>
<td>luteolin</td>
</tr>
<tr>
<td>Persian (or buckthorn) berries</td>
<td><em>Rhamnus spp.</em></td>
<td>eshhar</td>
<td>unripe berries</td>
<td>rhamnetin; others</td>
</tr>
<tr>
<td>Pomegranate</td>
<td><em>Punica granatum</em> L.</td>
<td>rimon</td>
<td>rinds</td>
<td>granatonine; tannins</td>
</tr>
<tr>
<td>Sumach</td>
<td><em>Rhus coriaria</em> L.</td>
<td>og</td>
<td>leaves/twigs</td>
<td>tannins</td>
</tr>
<tr>
<td>Walnut</td>
<td><em>Juglans regia</em></td>
<td>egoz</td>
<td>green outer shell</td>
<td>juglone</td>
</tr>
<tr>
<td>Turmeric Gall nuts (nutgalls, oak galls)</td>
<td><em>Curcuma longa</em> L.</td>
<td>koorkoom</td>
<td>rhizomes</td>
<td>curcumin</td>
</tr>
<tr>
<td></td>
<td>(on oak)</td>
<td>efetz</td>
<td>cysts</td>
<td>tannins</td>
</tr>
</tbody>
</table>

Table 4: Major Muricidae Species Used for “True” Purple Dyeing

<table>
<thead>
<tr>
<th>Common</th>
<th>MOLLUSK NAME</th>
<th>MAJOR DYES</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>murex trunculus</em></td>
<td><em>Phyllonotus trunculus</em> (1758)</td>
<td>Dibromoindigo (purple); Monobromoindigo: indigotin (blue)</td>
</tr>
<tr>
<td><em>murex brandaris</em></td>
<td><em>Bolinus brandaris</em> (1758)</td>
<td>Dibromoindigo</td>
</tr>
<tr>
<td><em>purpura haemastoma</em></td>
<td><em>Thais haemastoma</em> (1767)</td>
<td>Dibromoindigo</td>
</tr>
</tbody>
</table>

23*
than a dozen purple-producing muricids currently live off the Mediterranean coast of Israel and Lebanon. In antiquity, there could certainly have been more.

The one dye that is common to all of the muricids is dibromoindigo, a dark-purple indigotin derivative with two bromine atoms. This dye, similar to its simpler relative, indigotin, is produced through a complicated reduction-oxidation process. The part of the snail that is used is the yellowish secretion from the hypobranchial gland. The dye precursor to the brominated indigo, under the influence of light and air, becomes green, blue, and finally purple in a few minutes (Fig. 15).

A dyeing with this substance – a vat dye (see later) – can be obtained while the fiber is present in a bath of the extracted gland. Alternatively, the already formed water-insoluble purple dye can then be reduced in the presence of the fibers, and then air-oxidized, as is done with the plant-dye indigotin (Fig. 16).

The Tekhelet and Argaman colors of the Bible were derived from this class. The Argaman (red-purple) color was probably mostly dibromoindigo. The source of the tekhelet may have been Murex trunculus and its color may have been either bluish purple or just blue. Of the various purple-yielding gastropods studied so far, M. trunculus is the only one that contains the blue indigotin in addition to the dibromoindigo and monobromoindigo. However, it may be possible to control the dyeing conditions so that during the reduction stage the dibromoindigo dye is debrominated, at least in part, to yield the blue indigotin. Even if we find ancient tzititz (fringes) that are colored blue, that may still not indicate that the original color was blue because of the possibility of decomposition of the purple. However, if we do find a “true purple” tzititz, then it seems likely that the purple hue was dominant and that this is the color of Tekhelet. It seems that the mystery of the Tekhelet color will still persist until more scientific analyses are conducted.

Scale-Insect Dyes

The wingless female insects and their eggs from which a red dye was produced belong to the order Homoptera and the superfamily Coccoidea (see Table 5). Historically, there were five important families: American, Armenian, and Polish cochineals, kermes, and Indian lac. However, the “American cochineal” family was utilized only in the Americas prior to the discovery of the New World by Europeans. Thus, it is not found on pre-16th century C.E. textiles outside of South and Central America (Fig. 17).

Although the coccid family consists of over a thousand species, only a small number of them yield red dyestuffs in sufficient quantities for dyeing textiles. These coccids can be distinguished by their major dye component. However, differences between various species within a given family are more difficult to discern. Thus the major dye substance of each cochineal species (Dactylopiidae or Margarodidae) is carminic acid. Some Kermes species of coccid insects contain two major dyes: kermesic acid and flavokermesic acid. Other Kermes species may not contain any dye in significant quantities; this includes Kermes biblius and Kermes palestiniensis. The final family – lac – consists of insects that breed on certain trees in Southern and Eastern Asia. These insects secrete a resinous substance (lac), within which they live, which sticks to the branches. The dyestuffs from this insect consist of laccaic acids.

Dyeing of wool mordanted with alum (see later) with a cochineal species yields a crimson (bluish red) – almost violet – color (Figs. 18–20). Kermes dyeings on alum-mordanted wool produce a more subdued scarlet (orangey red) color (Figs. 21–23).

The Biblical Tola‘at ha-Shani was most probably a coccid insect and not a “worm” – but which one? The Tosephtha (the “additional commentaries” that were written in the first few centuries C.E.) on Tractate Menahot of the Babylonian Talmud (Chapter 9, section 6), states that the only Tola that is acceptable for use in the dyeing of the sacred textiles for use in the Temple was one
Table 5: Historically Important Scale-Insect Dyes

<table>
<thead>
<tr>
<th>Entomological Family / Species</th>
<th>Insect Name</th>
<th>Other Names</th>
<th>Geographical Origin and Habitat</th>
<th>Major Dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dactylopiidae</td>
<td>/ Dactylopius coccus (Costa)</td>
<td>American cochineal; Coccus cacti</td>
<td>South/Central America; cacti</td>
<td>Carminic acid</td>
</tr>
<tr>
<td>Margarodidae</td>
<td>/ Porphyrophora hamelii (Brandt)</td>
<td>Armenian cochineal; Ararat cochineal; Kirmiz</td>
<td>Armenia; grass roots</td>
<td>Carminic acid</td>
</tr>
<tr>
<td></td>
<td>/ Porphyrophora polonica (Linne)</td>
<td>Polish cochineal; Polish grains; St. John's Blood</td>
<td>Eastern Europe; plant roots</td>
<td>Carminic acid (some kermesic and flavokermesic acids)</td>
</tr>
<tr>
<td>Kermesidae</td>
<td>/ Kermes vermilio (Planchon)</td>
<td>Kermes; Kermococcus vermilio</td>
<td>circummediterranean; Quercus coccifera (Kermes-oak or shrub oak)</td>
<td>Kermesic and flavokermesic acids</td>
</tr>
<tr>
<td></td>
<td>/ Kermes ballotae (Signoret)</td>
<td></td>
<td>circummediterranean; Quercus coccifera</td>
<td>Flavokermesic and kermesic acids</td>
</tr>
<tr>
<td></td>
<td>/ Kermes ilicis (Linne)</td>
<td>Coccus ilicis</td>
<td>Quercus ilex (Green oak)</td>
<td>Practically none</td>
</tr>
<tr>
<td></td>
<td>/ Kermes biblicus</td>
<td></td>
<td>Levant; oak</td>
<td>Probably none</td>
</tr>
<tr>
<td></td>
<td>/ Kermes palestinensis</td>
<td></td>
<td>Levant; oak</td>
<td>Probably none</td>
</tr>
<tr>
<td>Kerriidae</td>
<td>/ Kerria lacca (Kerr)</td>
<td>Indian lac; Stick-lac</td>
<td>South/East Asia; trees</td>
<td>Laccace acids</td>
</tr>
</tbody>
</table>

25*
obtained “from the mountains.” However, both *Kermes vermilio* and the Armenian cochineal are found in the “mountains.” Kermes feeds on oak trees that grow at relatively high altitudes, and the Armenian cochineal is found on the roots of certain grassy plants at the base of Mount Ararat.

Brunello reports that an insect-red dye was supplied by a variety of Kermes according to its ancient use in Mesopotamia. During the Babylonian captivity, the Hebrews used the Aramaic word “zehori” instead of “Tola”; “carmil” also appears in the Hebrew literature in association with the *Tola*.

Science has helped narrow the field of possible scale-insect dye candidates for the Biblical *Tola’at ha-Shani* to only a few. Analyses of the insect dyes found on ancient textiles in Israel from ‘En-Boqeq and the Cave of Letters indicates that the species at each site was either the *Kermes vermilio* species or the Armenian cochineal variety. Close relatives of these two species, however, can still not be excluded. Unfortunately, analysts of scale-insect dyes have sometimes interchanged the words cochineal with kermes, which also compounds the identification problem. The words “kermes”, “kirmiz”, “carmine”, “carminic”, and “crimson” all originate from the same Eastern root meaning “worm”. Adding to this confusion, some translations of the *Tola’at ha-Shani* render it as the “scarlet worm” whereas others give it as the “crimson worm”.

Forbes reports on the uses of the insect dyes as follows. The Egyptians used an insect dye which they precipitated with alum to form crimson lakes for coloring leather. Kermes was used in the Hellenistic period to dye wool, leather, and silk by applying it as a vat-dye using Egyptian alum and urine to fix the dye to the fiber (Fig. 24). The lac dye appeared in Egypt when the connections with Armenia, Byzantium, and the North were interrupted by the Arab invasions of the seventh century C.E., resulting in the unavailability of kermes and cochineal. Forbes states further that Polish cochineal was definitely unknown in antiquity; however, analyses have shown that this dyestuff may have been used as far back as about two thousand years ago. He and Brunello state that the Ararat valley cochineal from the mountains (i.e., Armenia) was probably the Biblical *Tola’at ha-Shani*. The dyeing ability of the Armenian cochineal was recognized by the Assyrians when Sargon II invaded Urartu (Armenia) in 714 B.C.E. and mentioned “red stuffs from Ararat and Khurkhi” amongst the booty taken.

According to Forbes, the kermes-oak was growing in ancient Palestine though it is not mentioned in ancient Jewish writings. This oak was introduced into Assyria by Tiglath-Pileser I at about 1100 B.C.E. as a breeding place for the kermes insect. However, prior to this time, other kermes species might have also supplied a red dye.

**FUNCTIONAL CLASSIFICATION OF HISTORIC DYES**

The natural dyes that have been identified on historic textiles can be grouped into three functional (or chemical) categories depending on their properties in the dyeing process: substantive and adjective. The substantive or direct dyes can be fixed into the fiber without the assistance of an intermediary or stabilizing agent. Adjective or mordant dyes are those that cannot be directly fixed into the fiber with a high degree of stability.

**Mordant Dyes**

Most of the natural dyes – including the madder family of plants, most yellows, and the scale-insects – belong to this category. These dyestuffs need a “biting agent” – a mordant (French: mordre – to bite) – to fasten the dye to the fiber. The direct affinity of this type of dye to the fibers is very low; thus, a stabilizing agent that has previously impregnated the fibers and has bonded to them can also chemically attach itself to the dye. The mordants typically used in antiquity were inorganic salts of aluminum (“alum”), iron, and tin. These will form insoluble “lakes” with the dyes. Organic substances called tannins,
obtainable from sumac leaves or oak gall "nuts," have also served as mordanting agents.

Various metal mordants used with the same dye can brighten or darken the resultant colors.

It has not yet been clearly established when the practice of mordanting of dyes began in the Near East. Mordanting was very likely being practiced by the Egyptians during Roman times. The Roman historian Pliny the Elder (first century C.E.) relates how the Egyptians would apply different colorless substances onto a plain cloth, immerse it in a dye bath, and it would emerge with different colors on it.

Brunello discusses the availabilities and qualities of the mordants, as follows. According to Pliny, Egyptian alum was the best, though ancient dyers were aware of other mordants. The extraction of alum began at least several centuries before Pliny. One source of alum was various oases to the west of the Nile Valley. Alum was also exported from Tuz Khurmatli, Mesopotamia, or from Hamairan on the Persian Gulf. Another source of alum was from deposits near Kara Hisar, which is near the Lycus River, about ninety kilometers from the south coast of the Black Sea. The poorest quality was found in Palestine in deposits not very far from the Dead Sea and at Machairus in Persia.

**Vat Dyes**

This name is somewhat ambiguous in that all dyes were placed in some form of vat (Fig. 25). The most outstanding examples of these dyes are (blue) indigotin – obtainable from either a plant or sea molluskan source – and (purple) dibromoindigo, which can only be obtained from a mollusk.

The term "vat dye" corresponds to those dyes which undergo the two chemical processes, reduction and oxidation, before being fixed in the fiber. A dye in this category needs to undergo reduction to obtain the water-soluble form, which is a whiter color ("leuco"), usually yellowish to greenish, than the final form. The indigotin dyeing process is performed over a period of time by fermenting the leaves in water containing an alkaline substance. Fermentation is brought about by the micro-organisms present in the leaves of the indigotin-producing plant, and also in the urine which is usually added to the vat. Fermentation in a basic medium reduces the precursor to indigotin, which also dissolves in the basic solution. The alkaline substances used in antiquity were one or more of the following: decomposed or stale urine – producing alkaline ammonia, vegetable ashes, or lime water. Once dissolved in the dye bath, this reduced form of the dye was able to impregnate the fibers. To attain the final blue or purple insoluble dye form ("pigment"), the wet fiber was allowed to become oxidized in the air.

**Direct Dyes**

Some of the yellow dyes and tannins can be used for direct dyeing without the use of a "fixer", although they may be further stabilized by the use of a mordant. Saffron and turmeric belong to this class, though the latter can be better fixed into the fiber by after-treatment with an acidic medium, such as lemon juice or vinegar.

**DYES FOUND ON ARCHAEOLOGICAL TEXTILES IN ISRAEL**

A tentative picture of the dyestuffs used in Israel from almost three thousand years ago emerges from the textiles uncovered at various archaeological sites in Israel.

Table 6 summarizes the findings from those textile dyeings that have already been investigated (Fig. 26). It is to be noted that although the only yellow dyestuff (other than the tannin group) that has been positively indentified on archaeological textiles in Israel is saffron, other yellow dyes were definitely used but have thus far not been identified. However, this class of dyestuffs is not very fast and thus the dyestuff could have easily decomposed over the archaeological time frame.
### Table 6: Dyes Discovered on Textiles at Various Archaeological Sites in Israel

|                  | Kuntillet ‘Ajrud 18  
|                  | (Eastern Sinai)  
|                  | 9th-8th cent. BCE  
|                  | Iron Age II  
|                  | Wadi ed-Daliyeh 17  
|                  | (Eastern Samaria)  
|                  | 4th cent. BCE Persian Period  
|                  | Qumran 18  
|                  | (Judean Desert)  
|                  | 1st cent. CE Roman Period  
|                  | Cave of Letters 19  
|                  | (Judean Desert)  
|                  | 2nd cent. CE Roman Period  
|                  | "Bar-Kokhba"  
|                  | ‘En-Boqeq 20  
|                  | (Western Dead Sea)  
|                  | 7th cent. CE Byzantine Period  
| Madder            | +  
| Indigotin         | + (on linen)  
| Saffron           | +  
| Tannins           | +  
| Insect            | +  
| Molluskan         |  

**RESULTANT COLORS ON ARCHAEOLOGICAL TEXTILES**

A particular color on a textile may come from various sources as Table 7 summarizes. Each of the primary colors – red, blue and yellow – is generally derived from only one dye source. However, green, orange and purple may be obtained by a double dyeing of the appropriate primary colors (see the table).

**Acknowledgments**

The author is deeply grateful to Dr. Sidney M. Edelstein, Chairman of the Dexter Chemical Corp. of New York, for supporting this research in ancient textile dyes. Much source material for this article was obtained from the Sidney M. Edelstein Collection at the Jewish National and University Library at the Hebrew University, Jerusalem. The help, friendship, patience, and professionalism that were given to the author by Chagit Sorek and Etan Ayalon during the course of writing this article have been much appreciated.

28
Table 7: Colors Found on Archaeological Textiles and their Possible Sources

<table>
<thead>
<tr>
<th>COLOR OBSERVED</th>
<th>TYPICAL SOURCES</th>
<th>MORDANT NEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red (various shades)</td>
<td>Madder-family plants</td>
<td>Alum</td>
</tr>
<tr>
<td></td>
<td>Scale Insects</td>
<td>Alum</td>
</tr>
<tr>
<td>Blue</td>
<td>Indigotin (from Indigofera or Woad)</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>Molluskan</td>
<td>(None)</td>
</tr>
<tr>
<td>Yellow</td>
<td>Natural color of wool, linen, camel hair</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>Yellow dye source (See Table 3)</td>
<td>Alum (or none)</td>
</tr>
<tr>
<td>Green</td>
<td>Top-dyeing of blue+yellow</td>
<td>(As needed)</td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td>Alum and/or Iron</td>
</tr>
<tr>
<td>Orange</td>
<td>Madder-family</td>
<td>Alum</td>
</tr>
<tr>
<td></td>
<td>Top-dyeing of red+yellow</td>
<td>Alum</td>
</tr>
<tr>
<td>Purple</td>
<td>Madder</td>
<td>Iron</td>
</tr>
<tr>
<td></td>
<td>Top dyeing of red+blue</td>
<td>Alum and/or Iron</td>
</tr>
<tr>
<td></td>
<td>Molluskan [&quot;Tyrian (or Royal) Purple&quot;]</td>
<td>(None)</td>
</tr>
<tr>
<td>Beige-Brown</td>
<td>Natural camel hair</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>Decomposed natural wool color</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>(Inorganic) salts/minerals</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>Yellow dye source</td>
<td>Iron</td>
</tr>
<tr>
<td></td>
<td>Tannins</td>
<td>(None)</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>Natural coarse goat hair</td>
<td>(None)</td>
</tr>
<tr>
<td></td>
<td>Tannins</td>
<td>(None)</td>
</tr>
<tr>
<td>Black</td>
<td>Tannins</td>
<td>Iron</td>
</tr>
<tr>
<td></td>
<td>Top-dyeing of red+blue+yellow</td>
<td>Iron</td>
</tr>
<tr>
<td>White</td>
<td>Bleached linen</td>
<td>(None)</td>
</tr>
</tbody>
</table>
NOTES AND REFERENCES

1. The general references upon which this article is based include the following:
Bayer Farben Revue. 1964-. Notes on the History of Dyeing (Series). Leverkusen;
Levey, M. 1959. Chemistry and Chemical Technology in Ancient Mesopotamia. Amsterdam;
The following references are in Hebrew:
Czyzyk, B. 1951. Treasury of Plants. Herzliya;
Feliks, J. 1957. Plant World of the Bible. Ramat Gan;
7. The iron that established itself on the fibers could also have served as a fixative (or mordant) for organic colorants (see later).
9. The information contained in these three tables and in the discussion that follows has been extracted from the references mentioned in notes 1–3 and from: *The Society of Dyers and Colourists. Colour Index*. Bradfors.
10. The “L.” designation after the plant species name is for Linnaeus, the 18th century botanist who named this and many other species.
11. To avoid confusing the dye substance with the plant, the name “indigotin” will be used for the blue dye. “Indigo” will be used to designate the plant itself. For references on indigo and woad see the following: Sandberg, G. 1989. *Indigo Textiles: Technique and History*. London; Balfour-Paul, J. 1992. Indigo in the Arab World. *HALI* 61: pp. 98–105, 140.