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Tools of the Master Dyer
Dye Materials in Seventeenth and Eighteenth Century South Asian Painted Cotton Textiles at the Metropolitan Museum of Art

Sylvia Houghteling and Nobuko Shibayama

About the Authors / Sylvia Houghteling is an assistant professor in the Department of History of Art at Bryn Mawr College. After receiving her PhD from Yale University in 2015, she held the Sylvan C. Coleman and Pam Coleman Memorial Fund fellowship in the Department of Islamic Art at the Metropolitan Museum of Art. Her research and teaching examine intercultural exchange, the decorative arts, and sensory experience in the early modern period. Her first book project, The Art of Cloth in Mughal India, focuses on the history of seventeenth-century textiles in South Asia. Nobuko Shibayama, research scientist, joined the Metropolitan Museum of Art in 1999. She received her PhD in Applied Science for Functionality from the Postgraduate School, Kyoto Institute of Technology, Kyoto, Japan in 1992 and a Diploma in Textile Conservation from the Postgraduate Course, Textile Conservation Centre, Courtauld Institute of Art, University of London in 1995. The focus of her work involves the use of liquid chromatography and mass spectrometry techniques to identify dyes and organic pigments of art objects.

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Abstract | This article reports on an analysis of the dyes used in painted cotton textiles from seventeenth- and eighteenth-century India in the collections of the Metropolitan Museum of Art. The purpose of our study was to identify which red dyes were used to produce the textiles, and to determine whether dyers used cheaper substitutes for indigo as dyestuffs. Our findings preliminarily suggest that chay root (*Oldenlandia umbellata* L.) was not only a dye material used along the Coromandel Coast, but also traveled through overland trade networks for textile dyeing in central India. The results of this analysis contribute to understandings of regional specializations in dyestuffs. More broadly, this study may provide evidence for the mobility of dye materials and the agency that South Asian dyers had to choose their dye materials.

In the period before the development of synthetic dyes, South Asian dyers had perfected some of the most complicated dyeing processes and had become, in Mattiebelle Gittinger’s words, “master dyers to the world.” Gittinger explored the uniqueness of India’s blue dyes, forged from indigo, and the potency of its red dyes, which came from a variety of roots and insects. India’s diverse ecology and cultural communities meant that dyers in different regions of the subcontinent specialized in distinctive dye materials, which often yielded textiles of differing hues. This regional specialization seems to have been a particular characteristic of the red dyes used to color cotton cloth, although there has been little scientific evidence to suggest that textile dyers in fact relied exclusively upon local materials, rather than using dyestuffs traded throughout South Asia. After analyzing the dye materials used on a small sample of textiles that have been attributed to different regions of India, this study has found surprising evidence for the pervasiveness of chay root dyes (*Oldenlandia umbellata* L.) across our textile samples. This finding may indicate that the use of this dye material, which is associated with specific regions in southeastern India, was more widespread than previously believed.

Historical texts from the seventeenth century praise the chay root dye, a colorant that was an essential part of the dyer’s palette in the textile producing regions of the Coromandel Coast (fig. 1).

A seventeenth-century observer noted that the potency of chay root varied greatly depending upon where it had been grown, and also upon factors such as water quality and dye bath components: “Chay, a small thin root, a span or a span and a half long, is used for dyeing red, but the quality varies greatly; in one place it may be half as good again as in another...It does not fade, but the more it is washed, the better it becomes.” It is believed that the high concentration of decomposing seashells in the riverbeds of the Krishna (also

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Notes

2 Cecil 2013, pp. 68–73.
3 Moreland, Methold, and Schorer 1931, p. 77.
known as the Kistna) River and the Kaveri River in the northern Coromandel Coast region increased the calcium content in the soil, improving the red hue of the chay root dyes. Gittinger also cites Dutch sources that suggest that chay root was cultivated in northern Sri Lanka and the Madurai region of South India, and chay root grew wild in the Puri region of Orissa and in Bengal, but was exported and not used as a dye material.\(^4\) The southern Coromandel Coast (the site of production for many of the textiles for European export) was said to grow an inferior form of chay root, and dyers in the southern port of Madras (Chennai) imported chay root from the northern Coromandel Coast for dyeing.\(^5\) Beyond the specialized chay root, the most common and widespread red dyes were madder (Rubia tinctorum L.) and its related species, manjīsthā (Rubia cordifolia L.). Both dyes were used throughout India, although madder grew best in the temperate, mountainous regions of northern India.\(^6\) The third well-known and widely-used red dye was āl (Morinda citrifolia L.), whose root bark produces a red color.

In terms of usage, researchers have assumed that dyers making textiles along the Coromandel Coast utilized chay root, while dyers situated in western India in Gujarat or in the central Indian city of Burhanpur deployed manjīsthā or āl due to economics and availability. G.W. Taylor notes that besides the unique chay root dyes, there did not seem to be a clear pattern in the selection of madder-type dyes as opposed to āl, suggesting that selection was a matter of simple economic calculation. He writes: “both dyes were widely available, give similar shades of colour and presumably whichever was used was based on simple economics—a reasonable conclusion for these mass market textiles.”\(^7\) Yet as late as the 1850s, distinct regions were nonetheless known to specialize in the production of different dyestuffs. When South Asian dye materials were displayed at the 1851 Great Exhibition in London, the dye materials for āl came from present-day Madhya Pradesh in Central India, the manjīsthā came from throughout India (Assam, Nepal, and Bombay), while the chay root came directly from the town of Masulipatnam, the central historical trading center of the northern Coromandel Coast.\(^8\)

Historians have demonstrated that regional specializations in dyestuffs gave economic and political importance to the entire textile industries of various dye producing regions.\(^9\) Ian Wendt has pointed out, however, that not only indigo, but also chay root dyes became “commercial commodities” that were “used in dyeing centers throughout South Asia.”\(^10\) It has been difficult to confirm from extant textiles how widely chay root actually circulated. Art historians often use stylistic analysis of decorative motifs to identify the region where a cloth was made, and then employ that visual information to narrow down the possibilities for dye materials to the dyestuffs characteristic of that region. A study of the textile dyes used in South Asian cotton textiles contributes to an understanding of the actual dyes used in the dyers’ palettes, but can also potentially help in identifying where textiles with lesser-known stylistic patterns may have been made.

Finally, the literature has assumed the central role of indigo (Indigofera tinctoria L.) in the production of not only blue dyes, but as a combination color in green dyes as well. However, historical texts suggest that green dyes were produced not only from indigo, but also from ingredients such as dried pomegranate rinds, turmeric, henna, and the tannin produced from halīla, or myrobalan fruit (Terminalia chebula, Retz.).\(^11\) In her analysis of archival sources relating to dyes, Hamida Khatooon Naqvi has hypothesized that dyers substituted these local, more easily obtainable dyes for the more expensive indigo dyes in order to save on costs.\(^12\) Our study has sought to identify whether all of the green and blue dyes on the samples derive from indigo, or whether they might have been made from lesser-known, local dyestuffs.

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\(^4\) Gittinger 1982, p. 21; Cecil 2013, p. 69.  
\(^5\) Irwin 1956, p. 33.  
\(^6\) Taylor 1993, p. 23.  
\(^7\) Taylor 1993, p. 24.  
\(^8\) Bhardwaj and Jain 1982, p. 71.  
\(^10\) Wendt 2005, p. 79.  
\(^12\) Naqvi 1980, p. 160.
Literature Review

Historical studies and investigations of current dyeing practices have provided a great deal of insight into the techniques used to produce Indian painted cotton textiles. Technical studies that identify the dye materials responsible for India’s brilliantly colored cloths can aid in deepening our knowledge of cloth production techniques.

A comprehensive dye analysis study from 1988 tested seventy samples from thirty-nine South Asian textiles held in the Calico Museum of Ahmedabad. The study was informative for the range of dyes used in India. Although it did not specify the fibers tested, the textile objects listed as samples primarily included woven silks and wool carpets and shawls; there seem to have been only two cotton textiles tested. Important studies also exist for the dyes used in Mughal carpets.

Recent years have brought further, comparative studies of the dye materials used for silk cloth. Other recent projects at the Metropolitan Museum of Art that tested the dye materials in another sample group of medieval and early modern textiles imported from India to Egypt had findings that were consistent with Barnes’s study. Our project has sought to identify the dyes for a small, later group of textiles, most of which were likely made in the eighteenth century.

Samples for Study

Our study examined samples from six textiles from the collections of the Metropolitan Museum of Art. The textiles were all cotton cloths that had been painted and dyed, as opposed to block printed. In seventeenth- and eighteenth-century Europe, these textiles were known as “chintz.” In contemporary India, the cloths are called kalamkārī, a word that refers to the pen (kalam) with which the mordants and resists are painted onto the cotton. Kalamkārī means “pen-work.”

Of the textiles under examination, three were likely produced for export to Europe (figs. 3, 4, and 5); in their loose arrangement of the floral motifs, and the large scale of the blooms, they resemble the exported “chintz” textiles sent to Europe in large numbers starting in the second half of the seventeenth century.
fig. 3 (top)
Hanging (detail), attributed to India, late 17th century. Cotton; printed, 203 × 155 cm (80 × 61 in). The Metropolitan Museum of Art (28.78.3), gift of Harry Wearne, 1928.

fig. 4 (left)

fig. 5 (right)
Methods of Analysis

Although it would have been ideal to conduct analysis using non-destructive techniques, it is currently not possible to analyze organic pigments accurately and comprehensively without taking samples. We therefore took small thread samples (of approximately 5 mm–1 cm) of each cloth to conduct this research. After the colorant was extracted from the thread sample, the analysis of these samples was conducted using high-performance liquid chromatography-photo diode array detection (HPLC-PDA). Using the technique of HPLC-PDA, color components in a dye, which have been extracted from a thread sample, are separated and each component is eluted in a specific time (a retention time) according to its chemical properties. Then, the ultraviolet-visible (UV-Vis.) spectra of each separated color component is measured, and the UV-Vis. spectra and the retention time of the compounds are compared with the UV-Vis. spectra and the retention time of standard color compounds, allowing identification of the separated color components in the dye. The result suggests a type of dye that contains the color components identified through HPLC-PDA. The details of this method and the summary of the results are provided in appendix A.

Results

Dyes used for each color were suggested based on the current color and detected colorants from the sample, although there may have been dyes which were not detected because of degradation. A result in which detected color components did not appear relevant was considered to have emerged from cross-contamination. For example, indigotin on a beige sample was not recognized as having resulted from an effort to dye the cloth blue; rather, such a result was regarded as cross-contamination. There were samples in which overlapping colored parts were difficult to separate, and as a result, it was not unequivocal to determine the dye for each color. The difference of colors on the samples on which the same colorants were detected may have also been due to different mordants.
Among the red, pink, and purple samples of the textiles, alizarin was found to be a major colorant. In *chay* root (*Oldenlandia umbellata* L.), the main colorant to the exclusion of other colorants is alizarin.\(^21\) Alizarin also appears in madder (*Rubia tinctorum* L.) as one of the main colorants, along with other colorants such as purpurin, pseudopurpurin, or munjistin.\(^22\) Sometimes purpurin was detected with alizarin in our samples; however, the amount of purpurin was minute. The ratios of alizarin to purpurin in our textile samples, determined through a comparison of their chromatographic peak areas, was 98-99/1-2, while the ratio of alizarin to purpurin from several reference samples dyed with madder was approximately 90-50/10-50, in addition to the presence of other colorants such as pseudopurpurin and munjistin (see table in appendix A).\(^23\) The variation of the ratios seen in the madder samples may come from differences in dyeing methods, the processing method of the plant, or the location where the plant was cultivated. However, the differences in ratio of alizarin to purpurin between *chay* root and madder dyes are much more pronounced.

The main colorants in *manjistha* (*Rubia cordifolia* L.) are purpurin, munjistin, and pseudopurpurin, and alizarin is not found in a significant amount.\(^24\) Alizarin is not found in *ál* (*Morinda citrifolia* L.) as a major colorant.\(^25\) The main colorants of *ál* are morindone and soranjidiol.\(^26\) The overall absence in our samples of the component purpurin, found in madder and *manjistha* makes it unlikely, though not impossible, that either of these other dyes were used to create the red color. This finding cannot fully exclude the possibility of madder because color components in a dye are subject to change due to ageing or the dyeing process.\(^27\) With these possibilities in mind, the results strongly suggest that *chay* root was the colorant used for all of the red areas on the textiles.
Among the dark colored samples, ellagic acid was detected. Ellagic acid is produced from ellagitannins under hydrolytic conditions. Ellagitannins represent one of two subdivisions of hydrolysable tannins (the other is gallotannins). Because ellagic acid was detected, a substance containing abundant hydrolysable tannins appears to have been used. Myrobalan (Terminalia chebula, Retz.), a plant rich with hydrolysable tannins and often used for South Asian painted and printed textiles, was likely used on our textile samples.

Indigotin was detected in the blue and green-colored thread samples, indicating that an indigotin-containing dye such as indigo (Indigofera tinctoria L.), was used. Indurbin, also found in indigo dye along with indigotin, was also detected on some samples.

Thread samples from figure 6 appeared to show a smaller amount of ellagic acid in contrast to alizarin among the six textiles indicating that much less tannin was used on the textile. The red sample of figure 8 also suggested that a more limited amount of tannins was used in the preparation of that textile. One textile (fig. 3) showed a slight difference in the components of tannins as compared to the other textiles.

Interpretation of Results and Preliminary Conclusions

Our analysis confirmed the use of indigo for both blue and green colors, which is not unusual due to the ubiquity and known superiority of indigo dyes for the coloring of cotton cloth. We did not find evidence for unusual dye combinations in the formation of green dyes, nor did we find cheaper substitutes for blue dyes. This suggests that for both export and domestic cotton cloths of this high level, indigo was used consistently.

The omnipresence of ellagic acid from the tannins in myrobalan fruits (Terminalia chebula, Retz.) indicates that this substance, derived from a dried local tree fruit, was widely used in seventeenth- and eighteenth-century India. In our samples, myrobalan seems to have been used for a range of colors, from light beige to black. Eighteenth-century dye recipes also list myrobalan (called halila) as a component added to achieve purple and deep red dyes. In contemporary practices, the cotton fabric used for qalamkārī is also soaked in a mixture of ground myrobalan fruit and buffalo milk before it is painted; after it is dried, the tannins in the myrobalan fruit work as a ground for the application of an iron acetate mordant that reacts with the tannins to create the black outlines seen on qalamkārī textiles. According to Mohanty, Chandramouli, and Naik, the buffalo milk in the myrobalan mixture helps to “brighten the colour when printed and prevents its spreading to the other side.”

It seems possible, then, that the evidence of tannins from myrobalan fruit may have occurred both because of the fruit’s use as a dye colorant and because of its role in the preparatory stages of painting.

We found that there were smaller amounts of ellagic acid in the samples whose style suggests central Indian origin (figs. 6 and 8) than in those from the Coromandel Coast, perhaps suggesting different approaches to the use of myrobalan fruit in regional dyeing techniques. This could either indicate alternative ways that dyers prepared their cloths, or more limited use of myrobalan as an addition to the dyebath in central India. The distinction in the amounts of ellagic acid provides evidence for material differences between the textiles whose style indicates production in central India and those produced on the Coromandel Coast, even though their primary dyes appear to be the same.

The most surprising finding of our analysis is the prevalence of chay root red dyes, in contrast to the relative absence of manjīsta or āl among the red dyes used to color the cloths. This is unexpected because the use of chay root is typically thought to have been localized and largely confined to the eastern Coromandel Coast of India. The red dyes found on two of the samples whose style most clearly suggests their production in central India, perhaps

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28 Halslam 1966.
29 Mohanty, Chandramouli, and Naik 1987, p. 5.
30 Naqvi 1980, p. 61.
31 Mohanty, Chandramouli, and Naik 1987, p. 103.
Burhanpur (figs. 6 and 8) also seem to have been produced using chay root dye, as the thread samples showed strong results only for alizarin, the colorant in chay root, and not for purpurin, which is found in madder-type dyes (the ratio for the red and purple threads was 99/1).

Visually, the textiles made in central India are characterized by a more symmetrical and regular arrangement of the floral motifs. They almost resemble textiles woven on a loom in the geometric layout of their patterns. This style is more similar to the floral ornament on carpets and textiles made...
for the Mughal court. It can be contrasted to the more irregular dispersal of patterns in textiles made along the Coromandel Coast that can be seen on textiles such as figure 9, although the dyes on this textile were not analyzed for this study. The Mughal imperial style was more prevalent in art objects made in Burhanpur and other regions of central India because of the presence of the Mughal emperors and their noblemen in this region in the seventeenth century. Furthermore, as scholars have recently noted, architectural and wall decorations from Burhanpur bear a striking similarity to the symmetrical, poppy-patterned textile that we analyzed (fig. 8), further supporting the Burhanpur attribution of this textile.

The appearance of chay root dyes on textiles that have been stylistically attributed to the Burhanpur region therefore suggests that the use of chay root may not have been limited to the Coromandel Coast, as studies of earlier textiles have suggested, but, by the seventeenth century, chay may have traveled through overland trade networks for use by dyers in central India.

The best quality chay root was a highly localized product due to the unique ecology of the northern Coromandel Coast described above. Ian Wendt notes that the finest quality dyestuffs were harvested in the wild and grew in sandy soil; chay root that was commercially cultivated was of lower quality. Within the British East India Company records, evidence of the trade along the Coromandel Coast in high-quality chay root appears in letters written from Madras (Chennai). Dyers in this southern Coromandel Coast city imported the far superior chay root dyes from their northern neighbors. The British East India Company officials wrote in 1700 of trying to prevent dyers “from mixing the Southern Chay with the Northern, the latter being the best and costs much more.” Beyond accounts of importing chay root in the regions surrounding Madras (Chennai), there has not been substantial archival evidence that chay root also traveled as a commodity to inland sites such as Burhanpur in central India, or to western India. The findings of chay root on the textiles associated with Burhanpur in our study, therefore, serve as inspiration to investigate the lesser-known aspects of the history of the chay root dye trade.

Finally, the use of chay root dyes on the textiles intended for European export provides yet another reason that Europeans were determined to import painted cotton textiles from India on such a grand scale in the seventeenth and eighteenth centuries. Past studies have emphasized the novelty of lightweight and easily washed cotton as one major inspiration; others have demonstrated that European dyers would not learn how to bind red dyes to cotton until Armenian dyers first introduced the techniques of “Turkey red” dyeing in Marseilles in the eighteenth century. The relative ubiquity of madder dyes in Europe has been taken to suggest that European dyers were only missing the proper techniques in order to be able to fully replicate the vibrant colors of South Asian cloth. However, dyers were also missing a crucial dye material. While European colonies in the Americas and West Indies were, by the eighteenth century, producing large quantities of Indian varietals of indigo, chay root has only been found very rarely on European-made textiles. Although the French imported quantities of chay root dyes in the eighteenth century, and the English experimented with the dye material, chay root was never cultivated on a large scale in Europe. It was also never imported from India in great amounts because, as George Watt warned, “chay-root rapidly deteriorates when kept in a dark place, such as the hold of a ship.” By the twentieth century, dyeing with chay root declined in South Asia, and the plant-based dye had been replaced by synthetic alizarin. These textiles, therefore, are a testament not only to a unique moment in the manufacturing history of South Asia, but also to a moment in botanical history that was never replicated again.

35 Quoted in Irwin 1956, p. 33.
36 Wendt mentions that chay root was traded commercially, but on what scale and to where is unclear. Wendt 2005, p. 78.
38 Phipps 2013, pp. 128 and 134.
40 Quoted in Cecil 2013, pp. 68–73.
Acknowledgements

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Appendix A

Methods:
Small cotton yarn samples were taken from the textile, and each sample (a few threads of approx. 5 mm–1 cm) was extracted using 40μl of a mixture of 0.01 M aqueous oxalic acid, pyridine, and methanol (3/3/4, v/v/v) in a small test tube.41 The thread sample was left for half an hour at room temperature (RT), subsequently heated at 55–60°C for 20 minutes. The extract was then removed to an insert and 80 μl of the new mixture mentioned above was added to the test tube and heated at 90–100°C for 10 minutes; this extract was then moved to the same insert. The tube was rinsed with 20 μl of methanol twice, and the rinsing solution was also added to the insert. The extract in the insert was dried in a vacuum desiccator using an aspirator. The residue was mixed with 8 μl of methanol and 8 μl of 1 percent aqueous formic acid (v/v). The solution was centrifuged for 10 minutes at 3500 g; the supernatant was injected into the HPLC system.

The analytical system used consisted of a 1525μ binary HPLC pump, 2996 PDA detector, 1500 series column heater, in-line degasser and a Rheodyne 7725i manual injector with 20 μl loop (Waters Corporation, Milford MA), an XBridge BEH Shield RP18 (3.5 μm-particle, 2.1 mm I.D. x 150.0 mm, Waters Corporation, Milford MA) reverse-phase column was used with a guard column (Xterra RP18 3.5 μm-particle, 2.0 mm I.D. x 10.0 mm, Waters Corporation, Milford MA) with a flow rate of 0.2 ml/min. The column pre-filter (Upchurch ultra-low Volume pre-column filter with 0.5 μm stainless steel frit, Sigma-Aldrich, St. Louis MO) was attached in front of the guard column. Column temperature was 40°C. The mobile phase was eluted in a gradient mode of 1 percent formic acid in high purity water (v/v)(A) and a mixture of methanol and acetonitrile (v/v, v/v) (B). The gradient system was 90 percent (A) for 3 minutes to 60 percent (A) in 7 minutes in a linear slope to 0 percent (A) in 24 minutes in a linear slope, and then to 90 percent (A) in 1 minute and held at 90 percent (A) for 10 minutes. A summary of the result appears in the table below.

### Summary of the Result

<table>
<thead>
<tr>
<th>Accession number</th>
<th>Main color or overlapped different colors of a sample</th>
<th>Main dye compounds which were detected</th>
<th>Alizarin/Purpurin</th>
<th>Ellagic acid/Alizarin</th>
<th>Suggested dyes</th>
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<td>28.78.3</td>
<td>Figure 3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Pink—brown</td>
<td>alizarin, ellagic acid</td>
<td>98/2</td>
<td>84/16</td>
<td>Brown: tannin dye, chay root dye (Oldenlandia umbellata L.)</td>
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<tr>
<td>2</td>
<td>Blue 1</td>
<td>indigotin, alizarin, ellagic acid</td>
<td>NP</td>
<td>67/33</td>
<td>Red, pink: chay root dye (Oldenlandia umbellata L.)</td>
</tr>
<tr>
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<td>Blue—black (blue 2)</td>
<td>indigotin, alizarin, ellagic acid</td>
<td>NP</td>
<td>34/63</td>
<td>Blue: indigotin-containing dye</td>
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<tr>
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<td>alizarin, ellagic acid</td>
<td>99/1</td>
<td>64/36</td>
<td>Black: tannin dye</td>
</tr>
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<td>72/28</td>
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<td>NP</td>
<td>35/65</td>
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<tr>
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<td>Brown part of a pink-brown sample</td>
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<td>NP</td>
<td>39/61</td>
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<td>NP</td>
<td>37/63</td>
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<td>28.265.112</td>
<td>Figure 4</td>
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<td></td>
<td></td>
<td></td>
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<td>98/2</td>
<td>64/36</td>
<td>Black: tannin dye</td>
</tr>
<tr>
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<td>NP</td>
<td>76/24</td>
<td>Brown: tannin dye</td>
</tr>
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<td>99/1</td>
<td>31/69</td>
<td>Purple: chay root dye (Oldenlandia umbellata L.)</td>
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<td>alizarin, ellagic acid</td>
<td>98/2</td>
<td>48/52</td>
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<td>99/1</td>
<td>63/37</td>
<td>Blue: indigotin-containing dye</td>
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<td>alizarin, ellagic acid, indigotin</td>
<td>98/2</td>
<td>69/31</td>
<td>Blue: indigotin-containing dye</td>
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<tr>
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<td>Purple—black</td>
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<td>25/75</td>
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<td>alizarin, ellagic acid</td>
<td>98/2</td>
<td>64/36</td>
<td>Beige: tannin dye Black: tannin dye</td>
</tr>
</tbody>
</table>

**Note**  
Alizarin/Purpurin: the ratio of the peak areas of alizarin and purpurin in the chromatogram at 450 nm; Ellagic acid/Alizarin: the ratio of the peak areas of ellagic acid and alizarin in the chromatogram at 370 nm; NP: purpurin was not detectable in the chromatogram at 450 nm.
<table>
<thead>
<tr>
<th>Accession number</th>
<th>Main color or overlapped different colors of a sample</th>
<th>Main dye compounds which were detected</th>
<th>Alizarin/Purpurin</th>
<th>Ellagic acid/Alizarin</th>
<th>Suggested dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purple</td>
<td>alizarin, indigotin, ellagic acid</td>
<td>99/1</td>
<td>5/95</td>
<td>Purple : chay root dye (Oldenlandia umbellata L.) + indigotin-containing dye</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pink – the sample was not taken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>alizarin, ellagic acid</td>
<td>NP</td>
<td>7/93</td>
<td>Red : chay root dye (Oldenlandia umbellata L.)</td>
</tr>
<tr>
<td>4</td>
<td>Yellow (purple and red stains were on the sample)</td>
<td>alizarin, ellagic acid</td>
<td>NP</td>
<td>17/83</td>
<td>Yellow : tannin dye (?)</td>
</tr>
<tr>
<td>5</td>
<td>Green</td>
<td>alizarin, indigotin, indirubin, ellagic acid</td>
<td>NP</td>
<td>17/83</td>
<td>Green : indigotin-containing dye, yellow dye (?) or chay root dye (Oldenlandia umbellata L.) (?)</td>
</tr>
<tr>
<td>6</td>
<td>Blue</td>
<td>alizarin, ellagic acid, indigotin</td>
<td>NP</td>
<td>20/80</td>
<td>Blue : indigotin-containing dye</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Yellow</td>
<td>alizarin, ellagic acid</td>
<td>NP</td>
<td>75/25</td>
<td>Yellow : chay root dye (Oldenlandia umbellata L.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Purple – the sample was not taken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red – the sample was not taken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Blue</td>
<td>indigotin, indirubin, ellagic acid</td>
<td>NP</td>
<td>76/24</td>
<td>Blue : indigotin-containing dye</td>
</tr>
<tr>
<td>4</td>
<td>Green</td>
<td>alizarin, ellagic acid, indigotin</td>
<td>NP</td>
<td>79/31</td>
<td>Green : indigotin-containing dye, yellow dye (?) or chay root dye (Oldenlandia umbellata L.) (?)</td>
</tr>
<tr>
<td>5</td>
<td>Black (deteriorated)</td>
<td>alizarin, ellagic acid, indigotin</td>
<td>99/1</td>
<td>71/29</td>
<td>Black : tannin dye</td>
</tr>
<tr>
<td>6</td>
<td>Red</td>
<td>alizarin, ellagic acid, indigotin</td>
<td>99/1</td>
<td>39/61</td>
<td>Red : chay root dye (Oldenlandia umbellata L.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Medium green (dyed part)</td>
<td>ellagic acid, alizarin, indigotin</td>
<td>NP</td>
<td>100/0</td>
<td>Green (dyed) : tannin dye + indigotin-containing dye</td>
</tr>
<tr>
<td>2</td>
<td>Brown (dyed part)</td>
<td>ellagic acid, alizarin, indigotin</td>
<td>NP</td>
<td>93/7</td>
<td>Brown (dyed) : tannin dye</td>
</tr>
<tr>
<td>3</td>
<td>Red (painted part)</td>
<td>alizarin, ellagic acid</td>
<td>99/1</td>
<td>2/98</td>
<td>Red : chay root dye (Oldenlandia umbellata L.)</td>
</tr>
<tr>
<td>4</td>
<td>Blue sample on the medium green and the brown outline</td>
<td>alizarin, indigotin, indirubin, ellagic acid</td>
<td>NP</td>
<td>91/9</td>
<td>Blue : indigotin-containing dye</td>
</tr>
<tr>
<td>5</td>
<td>Dark red (the sample was not taken)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Alizarin/Purpurin: the ratio of the peak areas of alizarin and purpurin in the chromatogram at 450 nm, Ellagic acid/Alizarin: the ratio of the peak areas of ellagic acid and alizarin in the chromatogram at 370 nm, NP: purpurin was not detectable in the chromatogram at 450 nm.
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