Folium in Persian and Islamic Manuscripts (15th–19th Centuries): Historical Significance and Analytical Study

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Folium in Persian and Islamic Manuscripts (15th–19th Centuries): Historical Significance and Analytical Study

Folium in persischen und islamischen Manuskripten (15. – 19. Jahrhundert): Historische Bedeutung und analytische Untersuchung

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Abstract: Medieval manuscripts are an essential part of Persian cultural heritage and a rich source of the country's material culture. Their study sheds light on shared materials across the Mediterranean and Near East. The practice of using blue and purple in manuscripts was popular during the Middle Ages in both Europe and Persia. Persian historical treatises describe a blue dye plant used for paper, in addition to blue indigo, although its specific terminology was previously unknown. The plant is identified as *Chrozophora tinctoria* (L.) A. Juss., also known as turnsole;

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the dye extracted from it is commonly known as folium. This study is divided into three phases: First, dye extraction techniques from *C. tinctoria* fruits were studied based on historical Persian recipes. Second, methods for reconstructing blue-purple paper dyes from turnsole fruits were explored, with local plants harvested in Iran during August and September, and the dyes analysed using spectroscopy, finding a good agreement to folium spectra obtained from European (central Italy) fruits of *C. tinctoria*. Third, folium was identified on manuscripts produced under Islamic rule in the Middle Ages. The findings suggest discussion as to whether this dye was used in Persian manuscripts too, given the notable corpus of citations in Persian historical treatises.

Keywords: folium; Persian and Islamic manuscripts; historical recipes; dye extraction; FORS (fibre optic reflectance spectrophotometry); SERS (Surface enhanced Raman spectroscopy)

Zusammenfassung: Mittelalterliche Handschriften sind ein wesentlicher Bestandteil des persischen Kulturerbes und eine reiche Quelle für die Erforschung des materiellen Kulturerbes des Landes. Das Studium mittelalterlicher Handschriften wirft ein Licht auf gemeinsame Materialien im Mittelmeerraum und im Nahen Osten. Die Verwendung von Blau und Purpur in Manuskripten war im Mittelalter sowohl in Europa als auch in Persien beliebt. Persische historische Abhandlungen beschreiben eine blaue Färbepflanze, die zusätzlich zu blauem Indigo für Papier verwendet wurde, obwohl ihre spezifische Terminologie bisher unbekannt war. Die Pflanze wird als *Chrozophora tinctoria* (L.) A. Juss. identifiziert, die auch als Lackmuskraut bekannt ist; der aus ihr gewonnene Farbstoff wird gemeinhin als Tournesol oder Folium bezeichnet. Diese Studie gliedert sich in drei Phasen: Zunächst wurden die Verfahren zur Extraktion von Farbstoffen aus *Chrozophora tinctoria* Früchten auf der Grundlage historischer persischer Rezepte untersucht. Zweitens wurden Methoden zur Rekonstruktion von blau-violetten Papierfarbstoffen aus den Früchten des Lackmuskrauts untersucht, wobei lokale Pflanzen, die im August und September im Iran geerntet wurden, verwendet wurden. Die Spektren der daraus gewonnenen Extrakte zeigen eine gute Übereinstimmung mit den Foliumspektren, die aus europäischen (mittelitalienischen) Früchten von *Chrozophora tinctoria* gewonnen wurden. Drittens wurde Folium auf Manuskripten identifiziert, die unter islamischer Herrschaft im Mittelalter hergestellt wurden. Die Ergebnisse regen zu einer Diskussion darüber an, ob dieser Farbstoff auch in persischen Handschriften verwendet wurde, da es in persischen historischen Abhandlungen eine beachtliche Anzahl von Verweisen darauf gibt.

Schlüsselwörter: Folium; persische und islamische Manuskripte; historische Rezepte; Farbstoffextraktion; FORS; SERS

1 Introduction

The exploration of historical dye usage in manuscript production reveals a rich interplay of culture, material technology, and artistic expression across various regions. This study specifically investigates the history and application of *Chrozophora tinctoria* (L.) A. Juss. (thereafter *C. tinctoria*), a plant of the Euphorbiaceae family also known as turnsole, and the dye extracted from it, commonly known as folium, in manuscripts produced under Islamic rule. By presenting original Persian recipes, preparing reconstructions of historical recipes, and utilising analytical techniques, we aim to provide a comprehensive understanding of folium's role and significance in Islamic manuscripts, while also considering its connections to both Persian and European traditions.

Traditionally, folium was believed to have been primarily used in Western European manuscripts. However, recent research, including our investigations, has identified its presence in manuscripts produced under Islamic rule. These findings suggest that folium played a role in Islamic manuscript traditions, albeit in a limited number of cases. While Persian recipes predominantly focus on the use of folium as a dye for paper, the identification of this dye within Islamic manuscripts opens new avenues for investigation, particularly regarding its potential use as a colourant in manuscript illumination and painting. This research will focus on three key areas to explore the role of folium within Islamic and Persian contexts:

- **Review of historical records:** We will examine historical records, including Persian recipes, to document traditional methods of folium dye extraction and its documented applications.
- **Reconstructions:** Based on Persian historical recipes, we will recreate the processes used to prepare and apply folium as a dye and explore its properties in practical applications.
- **Instrumental Analysis:** Advanced techniques such as Fiber Optic Reflectance Spectroscopy (FORS) and Surface-Enhanced Raman Spectroscopy (SERS) will be employed to analyse the chemical composition of the folium dye and its occurrence in Islamic manuscripts.

This interdisciplinary approach will allow us to bridge the gap between textual records and scientific evidence, offering new insights into the role of folium in Islamic manuscripts. While the current identification of folium is limited to a few Islamic manuscripts, further research may reveal broader applications, including the potential discovery of folium in Persian manuscript traditions.

2 Review of Historical Records

In the first stage of our investigation, we focus on a brief review of the European context, followed by a more detailed analysis of the Persian tradition. This approach was adopted because the European use of *C. tinctoria* and of its dye folium is relatively well-documented, while the Persian focus has been overlooked by scholars, warranting a deeper investigation in this area.

2.1 European Focus: The Craft and Trade of *C. tinctoria* Dye in Early Modern Europe

Medieval European sources provide detailed documentation on the collection of the plant and the processing techniques used to produce the colourant for illuminated manuscripts. Notable examples include the 12th century CE treatise *On Divers Arts* by Theophilus (Hawthorne and Smith 1979, 38–40), the 14th century CE Montpellier *Liber Diversarum Artium* (Clark 2011, 110–111), the 14th–15th century CE *De Arte Illuminandi* (Brunello 1992, 63–67), and the 13th-15th century CE *The Book on How to Make All the Colour Paints for Illuminating Books* (Melo et al. 2018). These texts provide thorough descriptions of the plant's collection and processing methods for manufacturing the colourants used. Furthermore, this knowledge was meticulously preserved in *Ms. Parma* 1959, a Portuguese text written in Hebrew characters, which likely aimed to assist in the production of Hebrew Bibles illuminated with the colourants described in these sources (Melo et al. 2018). The most recent edition of this treatise was published by Strolovitch (2010).

It is noteworthy that across numerous medieval and early modern treatises and descriptions, a wide array of terms has been used to refer to both the plant and the dye, creating significant challenges in precisely identifying the species involved (Wallert 1990, 141–155). Typically, *C. tinctoria* was known as "turnsole," derived from the Latin *torna-ad-soleum* (meaning "turns towards the sun"). However, it was also referred to as *folium*, *solanum*, *solsequium*, *morella*, *morelle*, *Heliotropium tricoccum* ("heliotrope with three small balls"), *dyer's croton* (*Croton tinctorium*), *katasol*, *maurelle* (in French), *litmus* (UK), *lakmus* (Germany), and *Lakmoes* (Netherlands) (Guinot 1996, 30). These terms have historically been applied to a broad range of plants from diverse botanical families, all of which produce hues varying from blue to violet to red, depending on the pH of the solution in which they are processed. The blue-violet dye is derived from the fruits of *C. tinctoria* (family Euphorbiaceae), an annual herbaceous plant thriving in the Mediterranean basin, North Africa, and Central and Southwest Asia, including Iran (Cardon 2007, 40, 577). This plant

commonly grows in dry, disturbed habitats such as fallow lands and edges of cultivated fields, particularly in limestone-rich soils (Figure 1). *C. tinctoria* typically reaches a height of 10–40 cm, with grey-green, tomentose foliage; erect, branching stems, and rhombic to ovate leaves with sinuate margins (Nabais et al. 2020, 3). Fruiting occurs from late August through September, aligning with the summer season.

During the Middle Ages, blue and purple dyes were extracted from *C. tinctoria* and absorbed onto small pieces of cloth known as clothlets, which were then dried. These clothlets, preserved as watercolour-like materials, were utilised later by miniaturists for manuscript illustrations and illuminations. To do so, artists would cut a section of the clothlet and dissolve the colour with a suitable binding agent. The

Figure 1: Distribution map of *C. tinctoria* (turnsole) in Iran and worldwide. Source: Hoseini, S. S., Najafi, G., Moazzez, A. F., Hazrati, S., Ebadi, M.-T., & Yusaf, T. (2020). "Potential of *Chrozophora tinctoria* Seed Oil as a Biodiesel Resource." Applied Sciences.

colour obtained was commonly called folium, a term referring to the dye-saturated cloth rather than the plant itself; the clothlets were typically stored between book leaves, or *folia*, to retain their colour longer. Consequently, folium designated the prepared cloth. In *Schedula Diversarum Artium*, Theophilus described three hues achievable with folium: a brownish-red colour or *folium rubeum*, a purple to violet colour or *folium purpureum,* and *folium saphireum*, a blue hue; each depending on the environment (acid or alkaline) in which it has been tempered (Hendrie 1847, 43–45). Clarke (2016) notes that "katasol" likely refers to turnsole, particularly in Middle English technical treatises, where it generally refers to cloth used to capture dyes, often but not exclusively from *C. tinctoria*. However, Melo et al. (2018) argue that, in the chapter 24 of *Book of All Colour Paints*, "katasol" specifically refers to the dye derived from *C. tinctoria* fruits.

De Arte Illuminandi provides a detailed recipe for preparing blue folium noting that it lasts up to a year before gradually turning purple (Brunello 1992, 63–67). The author advises preparing the dye protected from sunlight and keeping the cloth in a dry place within books. In contrast, the *Book of All Colour Paints* instructs exposing the coloured cloth to urine vapours, drying it in sunlight until it achieves a "blackberry" hue. The clothlets should then be stored away from winter air until needed. The recipe also specifies that once tempered with gum Arabic, the dye must be applied immediately to prevent fading (Melo et al. 2018). From the 16th century CE onward, recipes for folium began to gradually disappear from artists' manuals. Painters increasingly turned to alternative colourants that were both easier to handle and more readily available, either locally or through expanding global trade networks. These colourants included madder, kermes, indigo, and brazilwood, often mixed with lead white.

During this period, however, the folium plant found renewed use in the production of textiles dyed with *C. tinctoria* in southern France, specifically by the Gallarguois, or inhabitants of Grand Gallargues in the Languedoc region. It was not until the 19th century CE, however, that scientists and botanists were able to travel to this region to examine the plant first-hand, observe the extraction process, and thus correct earlier errors and inconsistencies. Galmiche (2013) comprehensively summarizes the field studies and historical surveys that have sought to identify the precise characteristics of this dye. In his opinion, the most reliable descriptions are those of Montet in 1754 and Père Hugues in 1835. Being pastor in Gallargues from 1838 to 1845, he was in the best position to accurately record the entire manufacturing process (Galmiche 2013, 143, 150–158; Montet 1754, 687–698; Hugues 1996, 160–71).

Hugues notes that this craft has been practiced in the region since at least 1600, and the process was restricted to hot and windy days. In brief, the process was as follows: The fruit was first crushed under a millstone, forming a paste which was then placed in woven baskets and pressed in a press to extract all the juice. Once the

juice was collected, human urine was added. Then, the dyer had to proceed rapidly to dye the cloth before the colourant lost its potency. The washed rags were then soaked and kneaded with the hands in the mixture of juice and urine, before being quickly spread on drying racks positioned above layers of horse manure, known as *aluminadou*. To prepare an effective *aluminadou*, the craftsman selected manure rich in horse excrement that had undergone substantial fermentation. A layer of manure was covered with fresh straw, and then layered with the rags. The rags were stacked and covered with straw, followed by an additional layer of manure. The rags remained on the *aluminadou* for only 1 h, as the manure was highly potent; the manufacturer monitored the process closely to avoid overexposure. If the rags were left in the manure's vapour for too long, they would develop an undesirable yellow hue, rendering the operation unsuccessful. Thus, the dyer removed the rags as soon as they acquired a deep blue tint. The dyed rags were then allowed to dry, with care taken to avoid prolonged exposure to the sun, which could degrade the dye. Under the intense sunlight and strong northern wind, the rags would dry thoroughly. However, if the weather turned wet during the drying process, the dyeing would become ineffective, as the juice, without the heat needed to crystallize it, would fail to become embedded in the cloth fibres.

Alongside the aluminadou process, Montet documented another method in 1754 which involved the use of quicklime. In this method, the rags were first dyed and then left to dry in the sun. Once dried, they were placed in a vat and immersed in urine collected by the village's women, with contributions from the entire community. Quicklime was then added to the vat, and the mixture was covered with reeds and a large blanket to retain heat. The rags were left to ferment in the urine's warmth for approximately one day or more. This fermentation allowed the rags to develop the desired blue colour, after which they were removed from the vat (Montet 1754, 692–94).

The dyed cloths, often made from recycled rags of various materials and known as *drapeaux* in French, were primarily exported to the Netherlands. There, they were employed to colour the outer rind of Edam cheeses in a distinctive red hue, commonly referred to as fool's heads or cannonballs. The rags were transported from Grand Gallargues to the ports of Sète and Marseille from where Dutch merchants shipped them to the Netherlands. Although no direct records survive in French or Dutch detailing the exact cheese-colouring method, it seems that Dutch farmers applied the dye by rubbing the cheese rinds directly with the rags. This allowed the dye to adhere to the crust, gradually turning reddish-purple due to the acidity of the cheese surface (Galmiche 2013, 378–380). This coloured coating helped preserve the cheese during export, especially to the Dutch colonies. However, the use of *C. tinctoria* juice for this purpose began to decline in the 1850s, eventually ceasing around 1875 with the advent of synthetic colourants (Galmiche 2013, 380–381).

What distinguishes this enigmatic plant from other medieval European sources of blue-violet dye is its elusive chromatic structure, which has not been understood until recent years, despite extensive research into the plant over the last few decades. (Aceto et al. 2015, 159–168; Degano 2018; Guineau 1996, 23–44; Gettens and Stout 1966; Krekel 1996; Melo et al. 2018; Pozzi and Leona 2015, 67–77; Wallert 1990, 141–155). Finally, recent investigations by Nabais et al. (2020) have revealed the molecular structure of the medieval blue derived from *C. tinctoria*, composed of the blue dye chrozophoridin, a derivative of the alkaloid hermidin, represented by two isomers, and by several anthocyanins.

Unlike in Iran, where *C. tinctoria* was used to dye paper for luxury manuscripts and albums, the plant did not enjoy this status in Europe, where its application was primarily limited to paint materials until the late 15th century CE. In France, *C. tinctoria*, or turnsole, was classified by royal edicts as a "teinture de petit-teint" – a non-permanent dye – unlike more durable colourants such as indigo, madder, woad, and kermes, which were classified as "teinture de grand-teint." Consequently, the use of turnsole by master dyers for textiles was prohibited in France, confining it to lower-quality, utilitarian materials. While French records contain mentions of maurelle and turnsole for colouring utilitarian paper, these references are often brief and lack detailed descriptions of the processes involved (Diderot et D'Alembert 1751-65, 480; Payen and Richard 1851, 556; Valmont de Bomare 1775, 86). For instance, many sources refer to sugar loaves wrapped in purple or blue paper, intended to enhance the sugar's white colour and reflect its quality. Although some references cite turnsole as a source of blue dye, most sources indicate that various lichens, widely available in French regions such as Normandy, Auvergne, and Lyonnais, as well as in England and the Netherlands, were the primary materials. Other plants commonly mentioned for blue dyes include woad, indigo, India wood, and Brazilwood wood (Brückle 1993; De Lalande 1761, 79–80 and 86; Robiquet 1829, 236).

2.2 Persian Focus: Traditional Dyeing Practices in Persian Manuscripts

Building upon our previous investigation, the colourants designated for paper dyeing in medieval Persian historical treatises are categorised into two groups: primary colours (*mofradāt*) and secondary colours (*morakkabāt*) (Barkeshli 2016, 49–89; Barkeshli, Ataie, and Alimohammadi 2008). Within the primary colours, various shades of blue (*kabud*) are mentioned, using terms similar to the Latin designation for turnsole used in European sources, such as *toḵm-e-ʿalaf-e aftāb gardeš* (seed of a sun-turning weedy plant), *toḵm-e-ʿalaf-e ḵor gardesh* (seed of a

sun-revolving weedy plant), and *toḵm-e-ʿalaf-e āftāb gardān* (seed of a weedy plant that turns towards the sun). These are referenced alongside the use of indigo dye. Within the secondary colours, references to shades of green (*sabz*) and another type of green (*fariseh*) are made, with the term *kabudak* (blue). However, the recipes for green hues, which could refer to either indigo or turnsole, merit separate exploration and presentation in future articles.

The absence of terms like *toḵm-e-ʿalaf-e aftāb gardeš*, *toḵm-e-ʿalaf-e ḵor gardesh*, *toḵm-e-ʿalaf-e āftāb gardān*, and *kabudak* from contemporary Persian language posed a mystery to conservation scientists and historians regarding the natural local plant being referenced, until our present investigation. Through botanical studies in the region (Mozaffarian 2018; Labbafi 2024), interviews with botanical scholars such as Valiollah Mozaffarian in 2019, and analysis of the recipes, we have determined that these terms correspond to folium derived from the fruits of the *C. tinctoria* plant. Despite the terms "folium" and "turnsole" are frequently (but incorrectly) used as synonyms in the ancient literature, it is appropriate to clarify that "folium" should be referred exclusively to the dye extracted from *C. tinctoria*, while "turnsole" must be considered as a popular term for the *C. tinctoria* plant, also known as dyer's croton. In the following, the term "turnsole", instead of *C. tinctoria*, will be used in the realm of the text of ancient treatises.

The term *kabudak* likely derives from the ancient Persian word *Kabud*, meaning blue, while the other three terms stem from "sun-follower," owing to the flowers' rotation towards the sun, akin to the behaviour from which turnsole derives its name. In other Persian sources, including botanical encyclopaedias, the plant is referred to by various names such as *azraq* ازرق (Labbafi 2024) *ranginak* رنگینک (Labbafi 2024), *goosh-barreh* گوش برّه (Hammami, Azadi, and Sadrabadi 2018, 157–161), *gul-e aqrabi* گل عقربی (Noori, Zare Mayvan, and Mazaheri 2012, 118–126), and *kabudak* کبودک (Mayel Heravi 1993, 59).

There are numerous Persian historical recipes from 15th–19th centuries where material technology of turnsole or *C. tinctoria* are introduced for obtaining blue dye. The Persian terms that are used for the name of the plant under one of the primary colours (blue), are either *Toḵm-e-ʿalaf-e aftāb gardeš*, *tokhm-e-ḵor gardesh* and *tokhm-e ʿalaf-e āftāb gardān*. Two techniques are described to obtain blue dye from turnsole. The first technique involves processing in moist soil, while the second technique makes use of an earthen pot. In both methods, cloth is soaked in the extract of turnsole fruits exposed to sal-ammoniac (salammoniac, salmiac, ammonium chloride) in Persian called *naushādur*.

2.2.1 Blue (*Kabud*) – First Technique

In four treatises, the first technique is described: *Resaleh-ye Joharīyeh* (treatise on essential materials) by Sīmī Neyšapuri (15th century CE; published 1994), *Resāleh Dar Bayān-e Kāğaḏ, Morakkab va Ḥall-e Alvān* (treatise on paper, ink, and colour solutions) by an anonymous author (15th century CE; published 1993), *Golzār-e Ṣafā* (rose garden of purity) by Ali Seyrafi (16th century CE; published 1993) and *Ḵaṭṭ va Morakkab* (script and ink) by Hossein Aqili Rostamdari (16th century CE; published 1993). These sources explain the process of making blue dye. In the first two sources, the recipe is identical, and the term *Toḵm-e-ʿalaf-e aftāb gardeš* is used (Sīmī Neyšapuri 837 AH/1433, published 1994, 281; anonymous 9th AH/15th century CE; published 1993, 58–59):

> رنگ کبود – به نیلِ سرابی صاف کرده کنند و به آب گلهای کبود، امّا آن نیز پسندیده نیست. بهتر از همه آن است که در فصل تابستان قدری تخم علفِ آفتابْ گردش بگیرد، و رکویی پاک را به شیرهٔ آن بیالاید و در سایه خشک کند، باز بیالاید تا سه بار، بعد از آن پاره ای خاک را به آبِ نوشادر نمْگین کند و آن رکوی رنگین یک ساعت در زیرِ آن خاک نمناک کند تا رنگ لاجورد گیرد و خشک کند، هر گاه که خواهد قدری از آن کبودک در آب سرد بیفشارد و صاف سازد و کاغذ بدان رنگ کند. امّا این نیز پایدار نباشد و از رنگ اصل بگردد و بنفش شود.

> *For the blue colour, they first attempt dyeing with the extract of blue flowers (golhā-ye kabud) and filtered Sarābi indigo (nil-e Sarābi), but these dyes are not recommended. The best method is to gather turnsole seeds (fruits) during the summer season and extract their essence. Dip a clean piece of muslin cloth into the extract and allow it to dry in the shade. Repeat this process three times. Next, mix some soil with sal-ammoniac solution (nušador) and place the cloth inside the soil for 1 h until it becomes blue like lapis lazuli (lājevard). Then, let it dry. To dye paper, squeeze a small amount of dye from the cloth into cold water and filter it until the clear blue colour is obtained, then use it to dye the paper. However, this dye is not permanent and will eventually turn purple from its original colour.*

According to the recipes that are mentioned above, the sources have stated in the beginning that the blue dye made from blue flowers (*golhā-ye kabud*) is not stable and changes to purple and it is better to make blue dye with turnsole. But in the end of the recipes, contrary to other sources that are mentioned below, it is stated that this dye also is not recommended since it is not permanent, and it converts to a purplish colour after some time. The other sources that are described below refer to turnsole as the best dye for blue.

The two other 16th century CE sources, *Golzār-e Ṣafā* by Seyrafi (950 AH/1543; published 1993, 244) and *Ḵaṭṭ va Morakkab* by Hossein Aqili Rostamdari (930–984 AH/1523–1577; published 1993, 337) contain recipes to obtain blue dye from turnsole and are similar to those above; however, they use the term *tokhm-e-ḵor gardesh* and do not make any comments on its instability.

In his recipe, Hossein Aqili Rostamdari in *Ḵaṭṭ va Morakkab* writes (930–984 AH/1523–1577; published 1993, 337):

چون خواهد که رنگ کبود کند تخم خورْگردش بگیرد و شیرهٔ آن را بگیرد و لته پاک را به آن بیالاید و در سایه بگذارد تا آن لته خشک گردد. باز نوبت دیگر آن لته را به آن آب تر کند و در سایه خشک کند. همچنین تا به سه نوبت، و بعد از آن آب نوشادر که از او خاک را نم کند و آن لته را در آن خاک نهد و چندان بگذارد که آن لته لاجوردی شود. بعد از آن، آن را بیرون بیاورد و در چینی نهد و آب سرد اندَکْ اندَکْ بر او ریزد چندان که رنگ او تمام بیاید، بعد از آن هر چه خواهد در آن رنگ کند.

If one desires blue dye, collect some turnsole seeds (fruits) and extract their syrup. Immerse a clean piece of muslin cloth in the extract and let it dry in the shade. Repeat the soaking process with the turnsole extract and drying the cloth. This process can be repeated up to three times. Afterwards, moisten soil with sal-ammoniac solution (nušador) and place the cloth inside the moistened soil until it turns blue like lapis lazuli (lajevard). Then, remove it from the soil and place the cloth in a china bowl. Slowly pour cold water drop by drop onto the cloth to extract the dye until its colour saturates the water. Then, dye whatever is desired with it.

The recipe from *Golzār-e Ṣafā* by Seyrafi (950 AH/1543; published 1993, 244) is presented in poetic form and has been translated both textually and in rhyme as follows:

به کبودي اگر آهنگ کني	که ورق نيز باين رنگ کني
شرط اينست که در تابستان	تخم خور گردش گيري پس از آن
شيرة وي بفشاري و دگر	لَتة پاك بآن سازي تر
خشك در سايه کني اي دلدار	دگرش رنگ کني تا به سه بار
آبِ نوشادر آري و به آن	خاك را نَم کني اي جان جهان
لته در خاك گذاري يکدم	که برآيد وي از آن بوي بهم
لاجوردي چو شود بيرون آر	تا دم کار نگاهش ميدار
پس به چيني نه و بروي هم تيز	آبِ سرد اندك اندك مي‌ريز
کاغذ آنگاه بکن رنگ بآن	خشك در سايه کن اي سروِ روان

Textual translation:
If you desire blue dye for paper, the process involves collecting turnsole fruits in summer and extracting it. Dip a clean piece of muslin cloth into the extract and allow the moist cloth to dry in the shade, repeating this process three times. Moisten some soil with a sal-ammoniac solution (nušador) and place the cloth inside the dampened soil for a while to allow penetration. When the cloth turns blue like lapis lazuli (lājevard), remove it and let it dry. Subsequently, place the cloth in a china bowl and add cold water drip by drip to extract the dye. Finally, dye the paper with it and let it dry in the shade.

Poetic translation in rhyme:
If you wish to dye with blue, make it a tune, So that even the paper shall mirror its boon.
The condition is this, as summer you greet, Take the turnsole fruits, let them turn in your feat.
Press the juice from those turnsole fruits, Soak it in pure cloth, with skilful deeds.
Let it dry in the shade, my dear, Then dye it thrice, with colours clear.
Bring the juice of sal-ammoniac, do not abstain, Tinge the soil to enhance the stain.
Place the cloth in the moistened earth, Let it absorb fragrance and colours of worth.
When it turns blue outside the soil's domain, Take it out, let it dry in the open terrain.
In a China bowl, pour cold water with grace, Dye the paper in that colourful space.
Dry it in the shade, oh elegant one, Follow this process until it's done.

2.2.2 Blue (*Kabud*) – Second Technique

The second technique is described in *Resāleh Dar Bayān-e Ṭarīqeh-ye Sāḵtan-e Morakkab va Kāğaḏ-e Alvān* (treatise on the method of preparing ink and coloured paper) dated to the Safawid period (16th century CE), and in *Resāleh Dar Maʿrefat-e Kāğaḏ-e Alvān* (treatise on the knowledge of coloured paper), dated to the19th century CE, both by anonymous authors. These texts discuss the method for obtaining blue dye for exposing the clothlets to sal-ammoniac; an earthen pot should be used to place the cloth in to absorb the turnsole extract.

The first source, *Resāleh Dar Bayān-e Ṭarīqeh-ye Sāḵtan-e Morakkab va Kāğaḏ-e Alvān* (16th century CE; published 1993, 510) mentions the disadvantages of using blue flowers for dyeing as we have seen also in the 15th century CE recipes (Sīmī Neyšapuri 837 AH/1433; published 1994, 281). Both *Resāleh Dar Bayān-e Ṭarīqeh-ye Sāḵtan-e Morakkab va Kāğaḏ-e Alvān* (16th century CE; published 1993, 510) and *Resāleh Dar Maʿrefat-e Kāğaḏ-e Alvān* (19th century CE; published 1993, 524), suggest that turnsole is the best material to be used for dyeing blue. The technique described in both sources is in the same; however, the first source, *Resāleh Dar Bayān-e Ṭarīqeh-ye Sāḵtan-e Morakkab va Kāğaḏ-e Alvān* (16th century CE; published 1993, 510) specifies the process in more details using the term *tokhm-e ʿalaf-e āftāb gardān*, meaning folium.

> رنگ کبود – این رنگ را بعضی به لکّه های کبود می کنند، امّا آن پسندیده نیست؛ زیرا کاغذ را درشت و شکننده می کند. امّا طریق احسن آن است که در فصلِ تابستان قدری تخم علف آفتاب گردان بگیرد و در رکوی پاک شیرهٔ آن را بیالاید سه چهار نوبت؛ بعد از آن قدری نوشادر را نرم بسایند و در کوزه کنند و آب گرم در وی کند و بسیار حرکت دهند تا آب کف کند و در آفتاب نهند چند روز بدین منوال. چون کوزه باز از آب خالی ماند، رکوی را که به رنگ آلوده است در آن کوزه نهند و سرش را محکم ببندند و یک روز در آفتاب نهند و آن رکو که رنگ گرفته باشد بنهند، و هر گاه خواهند که کاغذ را رنگ کند همان طریق رنگ کنند و خشک کنند. و اگر خواهند که رنگ کاغذ روشنتر باشد بسیار کنند.
>
> *For blue, some people dye with the extract of blue dyes from flowers, but it is not recommended because it makes the paper brittle and fragile. The best method is to take fruits of turnsole in summer and soak a clean cloth in its extract three to four times. Take some sal-ammoniac, grind it in a mortar until it becomes fine, and place it in an earthen pot (kuzeh). Add warm water and shake it to froth. Keep it in the sun for a few days. When the earthen pot is totally dry and free of water, place the cloth soaked in the extract of turnsole dye into it to obtain a blue clothlet. Tighten the lid and keep it in the sun for one day. To dye paper, add water to the clothlet and extract the blue dye for colouring paper. For each use, the process is the same. If a lighter colour is required, add more water.*

The other source *Resāleh Dar Maʿrefat-e Kāğaḏ-e Alvān* by an anonymous author probably 13th A.H./19th CE based on Taimurid and Safawid information, describes the same recipe in brief manner using the term *Toḵm-e-ʿalaf-e aftāb gardeš* as follows: (19th century CE; published 1993, 524).

در فصل تابستان قدری تخم علف آفتاب گردش را آب بگیرد و رکوی بدان تر کند چند نوبت. و بعد از آن قدری نوشادر نرم ساید و در کوزه کند و آب گرم در وی ریزد و بسیار حرکت دهد تا آب کف برآرد و در آفتاب نهد بر این منوال. چون کوزهٔ آب خالی باشد، آن رکو را که به رنگ آلوده است در آن کوزه نهد و سرش محکم کند و در آفتاب نهد یک روزه آن رکو رنگ گرفته باشد، هر گاه که خواهد که کاغذ رنگ کند، به همان طریق رنگ کند و اگر خواهد که کاغذ روشنتر باشد، آب بیشتر کند.

The best way to make blue dye is to obtain some turnsole fruits in summer and moisten a piece of muslin cloth with its extract three times. Take some sal-ammoniac, grind it in a mortar until it becomes soft, and place it in an earthen pot (kuzeh). Add warm water and shake it to froth. Keep it in the sun for a few days. When the earthen pot is totally dry and free of water, place the cloth soaked in turnsole dye in it, tighten the lid, and keep it in the sun for one day to obtain a blue clothlet. To dye paper, add water to the clothlet and extract blue dye for colouring paper. For each use, the process is the same. If a lighter colour is required, add more water.

As mentioned above, according to Persian historical recipes, the blue and purple solutions extracted from turnsole were stored, after being adsorbed onto cloth and dried, and they were utilised as paper dye. It remains uncertain whether, like the European practice (Nabais et al. 2020, 1) they were also used as paint by cutting off a piece of clothlet and extracting its colour with the appropriate binding medium, as this is not mentioned in the Persian historical treatises (Barkeshli 2013, 101–133; Barkeshli 2016, 49–89).

3 Reconstructions

In the second phase of the project, we created reconstructions of the colourant based on Persian recipes. The colourant is derived from the fresh fruits of the *C. tinctoria* plant. These fruits were harvested in 2022 and 2023 in the Telo area, approximately 30 km from the centre of Tehran, Iran, between the second half of August and the end of September (Figure 2). Fresh fruits can vary in colour from light green to dark green depending on when they are picked during harvesting period. The purple fruits represent the final stage of ripening, while the dark green fruits are in an intermediate stage, rich in dye (although they will ultimately turn purple as the blue extract turns to purple). The light green fruits are unripe and therefore unsuitable for dye-making purposes. Thus, efforts should be made to collect the fruits as dark as possible before they are fully mature on the plant.

3.1 Collection of Fruits

For the experiment, we collected fruits from early August to the end of September, spanning 2022–2023, covering stages from light green to dark green, and finally to purple. The fruits displayed various colour shades: light to dark green in June–

Figure 2: *C. tinctoria* fruits (left) and plants (right) in the Telo-Tehran area.

August 2022, and purple in August–September 2023, corresponding to different stages of ripening (Figures 3 and 4). When soaked in water, the unripe light green fruits did not produce any colourant. However, the dark green semi-ripe fruits yielded a rich blue dye that eventually turned purple. The fully ripe purple fruits consistently produced a stable purple dye. We believe these variations were due to the different stages of fruit maturity – raw fruits from the first pick in June 2022, semi-ripe, slightly

Figure 3: Fresh *C. tinctoria* plant from the Telo-Tehran area.

Figure 4: Unripe and semi-ripe fresh fruits harvested from *C. tinctoria* plants in the Telo-Tehran area.

Figure 5: Folium extracted from fresh *C. tinctoria* plants in different stages of ripening, after soaking in water for 2 h. From left to right: sample of three picked fruits from different stages of fresh *C. tinctoria* plants before soaking, unripe light green, semi-ripe dark green, and fully ripe purple fruits after soaking in water.

more developed fruits from July–August 2022, and fully ripe fruits from August–September, which gave a stable purple extract. This observation aligns with findings by Aceto et al. (2015). We also noted that when fresh fruits were soaked in water, the mature purple fruits turned the water purple within 2 h, while the dark green fruits turned the water blue. In contrast, soaking light green fruits did not result in any colour change (Figure 5).

3.2 Preparation of Clothlets

The fruits from intermediate and final stages of *C. tinctoria* were individually collected for experimentation in August and September 2022–2023, including both dark green and purple fruits. Since Persian recipes do not specify how to extract the dye, we chose to crush a pound of the fruits in a stone mortar and to obtain the extract. Small square pieces of cotton cloth, each measuring 7.5 cm^2 and weighing 1.4–1.8 g were prepared, soaked in the aqueous extract, and dried in the shade following the Persian historical recipes (Table 1).

The impregnation process could be repeated up to 4 or 5 times. After each drying cycle, the cloth pieces were re-soaked in the extract until fully penetrated, then left to dry in the shade (Figure 6).

Table 1: Size and weight of cloths before and after soaking in folium extract.

	Folium Clothlet	
Size of the cloth	Weight before soaked in the *kabudak* extract	Weight after soaked in the *kabudak* extract
7.5 cm	1.4 – 1.8 g	2.8 – 3 g

Figure 6: Cloth pieces soaked in the extract of *C. tinctoria* fruit before being fumigated with sal-ammoniac (naushādur).

Following the extracting, impregnating, and drying process of the cloth pieces, an earthen jar that had not been exposed to water and remained unglazed was selected. Next, 20 g of ammonium chloride (*naushādur*) powder was poured and mixed with warm water in the jar until it foamed. The jar was then placed in the sun until all dissolved water completely evaporated. All the cloth pieces previously soaked in the extract were placed in the jar and left in the sun for a day until the fabric colourants converted to a deep blue-purple hue (Figure 7).

In the final stage, the fabrics dyed deep blue were removed from the jar, after which they could be stored and used to create dyes in different shades of blue whenever needed (Figure 8).

3.3 Reconstruction of Paper Dyes Based on Persian Historical Recipes

The dye was extracted from folium clothlets to obtain shades ranging from the primary colour blue to purple (*Kabud*) following the Persian historical recipes

Figure 7: The process of making folium clothlets. From left to right: unglazed earthen pot, foamed ammonia chloride, and placing soaked folium cloths in the dried jar impregnated with ammonia chloride.

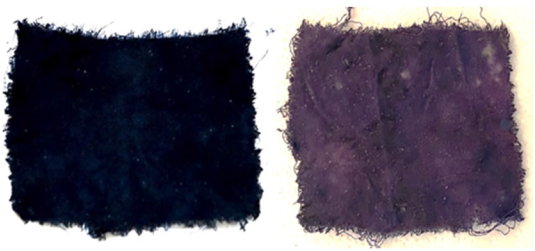


Figure 8: Cloths impregnated with the extract of *C. tinctoria* from different stages of maturity of the fruits after fumigation with ammonium chloride.

outlined in Hossein Aqili Rostamdari's *Ḵaṭṭ va Morakkab* (930–984 AH/1523–1577, 337). The dried folium clothlets were placed in a China bowl, and cold water was added drop by drop to extract the dye. To achieve different shades of colour, as described in *Resāleh Dar Bayān-e Ṭarīqeh-ye Sāḵtan-e Morakkab va Kāğaḏ-e Alvān,* varying amounts of water were used (Figures 9 and 10).

In our experiments, we also explored the time factor by soaking the papers at concentrations of 1:10 for 1, 5, and 60 min to achieve light to dark blue shades of colour (Table 2).

3.4 Storage and Preparation of *C. tinctoria* Fruits for Future Use

Since the period for harvesting *C. tinctoria* fruits is limited, it is advisable to store them for future use. Alongside preparing folium extract clothlets during the season, fresh fruits can be picked and naturally dried or dried in an oven to expedite ripening. To minimise seed popping, the fruits can be dried at lower temperatures (e.g., 50 °C) for longer durations. Ideally, the fruits should be dried in a well-ventilated oven. Once dried, they can be safely stored for years and used as needed for dye extraction.

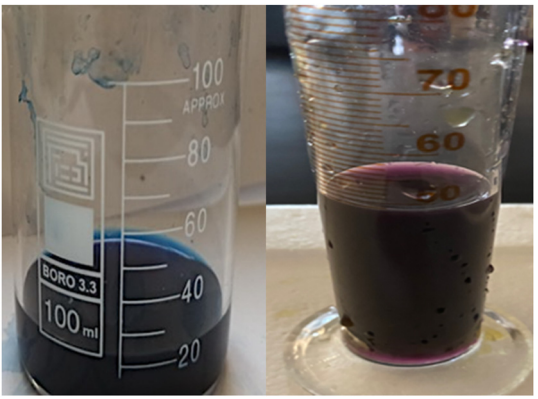


Figure 9: Blue (left) and purple (right) dyes extracted from the blue and purple folium clothlets obtained from different stages of maturity of the fruits.

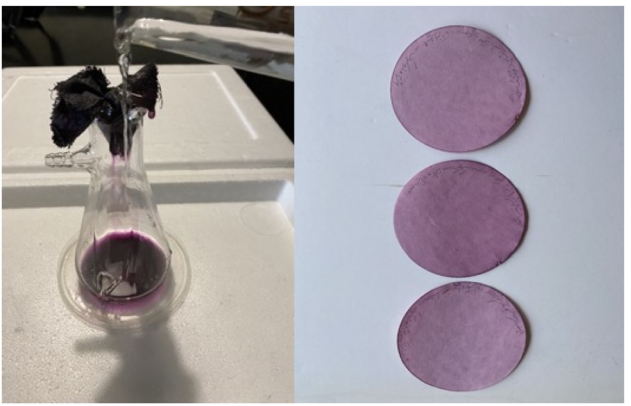


Figure 10: Left: Extraction of purple folium clothlets. Right: Papers dyed from extracted purple folium clothlets according to Persian historical recipes.

In our experiments, as shown in the Figure 4, most of the fruits were still green, indicating they were unripe, while some were darker, suggesting a higher potential for developing blue or purple colours. We placed the *C. tinctoria* fruits in an oven at 80 °C for drying, observing the changes in colour and texture as they dried over 10–11 h, checking on them every 2 h. Interestingly, during the last hour, some fruits began to pop up like popcorn, prompting us to remove them from the oven. While some did pop, the majority remained intact (see Figures 11 and 12). This preparation step is used for the dye extraction process in the next phase of our scientific analysis and lays the groundwork for potential future studies.

Table 2: Different shades of dyed paper with blue folium from extracted clothlets in different durations of time.

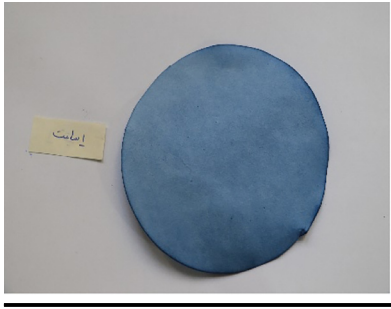
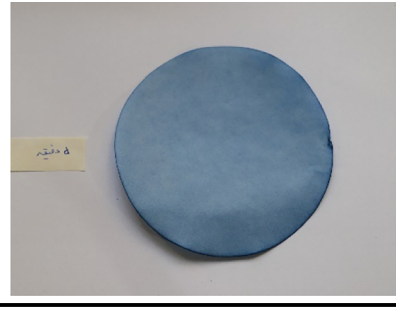
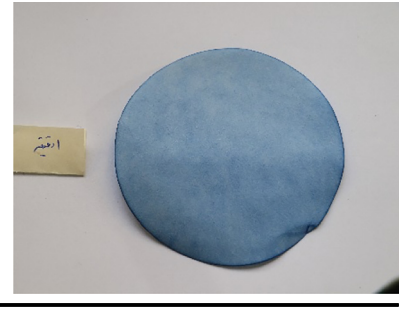
Blue (*Kabud*)		
60 min	5 min	I min
		

Figure 11: Drying fresh fruits from the *C. tinctoria* plant in an oven at 80 °C for about 10–11 h to expedite ripening and storage for future use.

Figure 12: Fruits popping up like popcorn in the last hour of drying in the oven, indicating they should be promptly removed.

4 Instrumental Analyses – Comparing Persian and European Folium

In the third phase, instrumental analyses were carried out employing FORS (Fibre Optic Reflectance Spectrophotometry) and SERS (Surface Enhanced Raman Spectroscopy).

4.1 Sample Preparation for Instrumental Analytics

Samples were prepared by extracting the dye from the external cuticles of *C. tinctoria* fruits. The fruits were collected in Umbria (Central Italy) during August 2023

and allowed to dry in an oven at 80 °C for 10 h; then the external cuticles were taken and subjected to extraction in cold water for 1 h upon stirring. After filtration on paper, the resulting extract was used to paint on parchment.

The samples from Iranian fruits were prepared the same way, after the fruits had been dried as mentioned above locally and sent to the Italian laboratory. In this way, the spectral responses were totally comparable.

4.2 Fibre Optic Reflectance Spectrophotometry (FORS)

FORS measurements were carried out with an Avantes (Apeldoorn, The Netherlands) AvaSpec-ULS2048XL-USB2 model spectrophotometer and an AvaLight-HAL-S-IND tungsten halogen light source; the detector and light source were connected with fibre optic cables to an FCR-7UV200-2-1,5 × 100 probe positioned at 45° with respect to the surface normal. The spectral range of the detector was 200–1160 nm; spectra were collected in the range 350–1100 nm. The spectral resolution was 2.4 nm calculated as FWHM (Full Width at Half Maximum), according to the features of the monochromator (slit width 50 µm, grating of UA type with 300 lines/mm) and of the detector (2048 pixels). Diffuse reflectance spectra of the samples were referenced against the WS-2 reference tile (Avantes), guaranteed reflective at 98 % within the spectral range of interest. The spot size of the investigated area on the sample was 1 mm. The sample-to-probe distance was 2 mm, corresponding to the focal length of the probe. Instrumental parameters were 10 ms integration time, 100 scans for a total acquisition time of 1.0 s for each spectrum. The system was managed by means of AvaSoft v. 8™ dedicated software, running under Windows 10™.

4.3 Surface Enhanced Raman Spectroscopy (SERS)

SERS analysis was performed by means of Ag nanoparticles colloidal pastes (AgNP). AgNP (1 µL) was poured on the sample and allowed to dry before exposing it to the laser beam. SER spectra were collected with a high-resolution dispersive Horiba (Villeneuve d'Ascq, France) LabRAM HR Evolution model spectrometer coupled with a confocal microscope. The instrument was equipped with 532 and 633 nm excitation lasers, a 1,800 lines/mm dispersive grating, a 800 mm focal length achromatic flat field monochromator, and a multichannel air-cooled CCD detector. The spectral resolution is 2 cm^{-1}. Spectra were taken with long working distance 50× and 80× objectives. Laser power at the sample was < 1 mW. Exposure time was 1–10 s according to needs (3 accumulations). The system was managed with LabSpec 6

software running under Windows 10™. For reference, both FORS and SERS spectra were recorded on parchment with aqueous extracts from *C. tinctoria* violet fruits.

4.4 Comparing Persian and European Folium

Figure 13 shows the FORS spectra (in apparent absorbance coordinates, using the Log (1/reflectance) transform) of folium from violet fruits of *C. tinctoria* from Italy (green spectrum) and from Iran (blue spectrum). The absorption bands characteristic of folium occur at ca. 549 and 584 nm and allow to selectively identify this dye with respect to other purple dyes such as orchil, madder, scale insect dyes, Tyrian purple, and alkanna (Aceto et al. 2014, 1488–1500).

Figure 14 shows the SERS spectra of folium obtained from *C. tinctoria* from Italy (bottom line) compared to folium obtained from *C. tinctoria* from Iran (top line). Both spectra align with the spectral features reported in the literature (Aceto et al. 2017b, 48, 530–537).

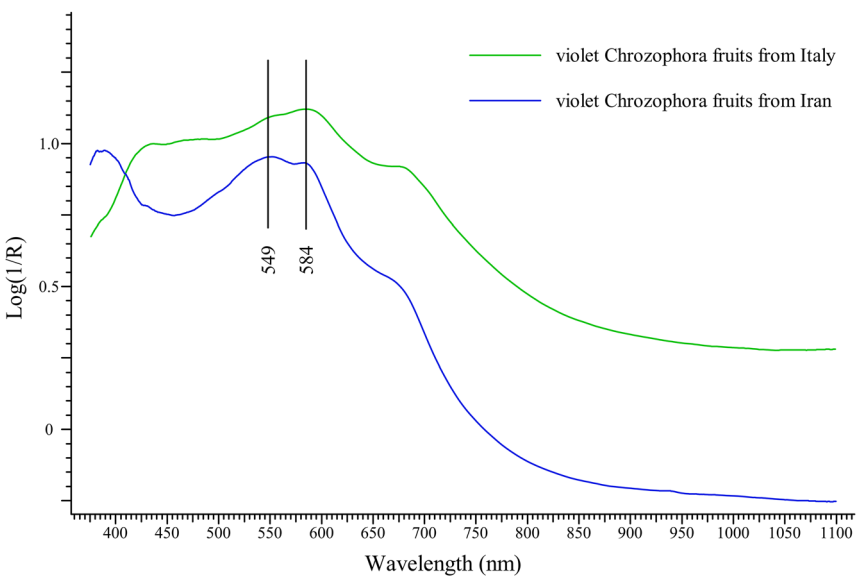


Figure 13: FORS spectra of violet cuticles of *C. tinctoria* extracts from Iran and Italy.

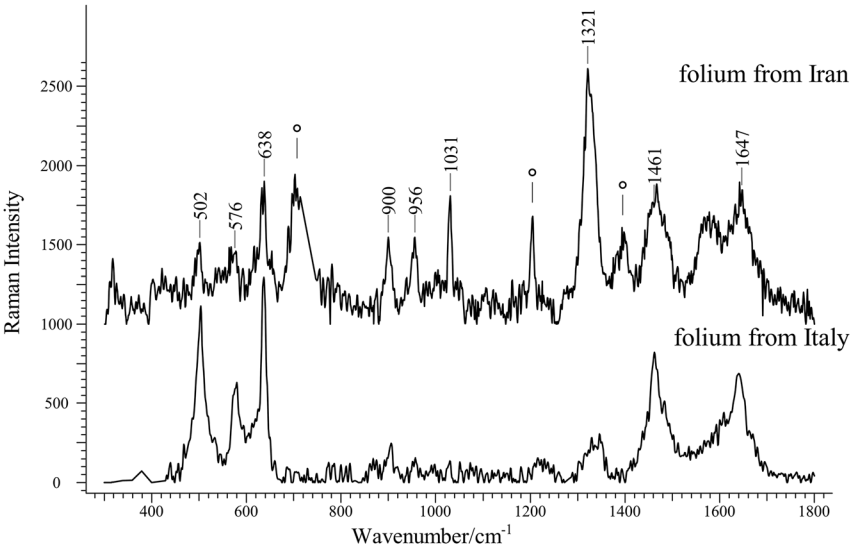


Figure 14: SERS spectra of folium obtained from *C. tinctoria* collected in Iran (top) and Italy (bottom). The bands belonging to AgNP have been pin-pointed.

4.5 Identification of Folium in Manuscripts Produced Under Islamic Rule

The findings suggest discussion as to whether this dye was used in Persian manuscripts, too. It has been already pointed out that folium was widely used in manuscripts produced in Europe, particularly in the Late Middle Ages and the Renaissance (Aceto et al. 2017a, 461–469). However, given the notable corpus of citations of folium in Persian historical treatises, described in the previous sections, it is expected that this dye was also used in manuscripts produced under Islamic rule, which at present, to the authors' knowledge, has not yet been verified. Recently, the authors of this study were able to find a small, but meaningful number of identifications of folium in manuscript produced outside Europe (Table 3).

4.5.1 Identification of Folium in ms. Copte-Arabe 1

In addition to the experiments carried out in laboratory, recent observations by the authors of this work have shed further light on the use of folium in manuscripts. Our identification of this dye in the palette of ms. Copte-Arabe 1 at the Institut Catholique de Paris (ICP), underscores the significance of our findings (Figure 15). The

Table 3: List of manuscripts analysed in this study.

List of Manuscripts			
Signature	**Provenance**	**Period**	**Library**
Copte-Arabe 1	Egypt	1249–1250 CE	Institut Catholique de Paris
Copte 129(11)	Egypt	10th century CE	Bibliothèque nationale de France, Paris
Arabe 5847	Northern Iraq	1236–1237 CE	Bibliothèque nationale de France, Paris

Figure 15: Location of the measurement spot to identify folium in ms. Copte-Arabe 1 (f. 65v, white spot) dated 1249–1250 CE, produced in Egypt, kept at the Institut Catholique de Paris, Bibliothèque de Fels.

identification was based on the typical spectral features previously described and on the overall characteristic shape of the FORS spectra.

The manuscript Copte-Arabe 1 is a Four Gospels book written in Bohairic Coptic with a parallel Arabic translation (Baumstark 1915). This manuscript is composed of paper, ink, and pigments, and its dimensions are 255 × 175 × 60 mm. It is believed to originate from Northern Egypt, possibly Cairo, and dates back to 1249/50. The manuscript was acquired in Egypt in 1885 by Émile Amélineau (1850–1915) and was subsequently given to the library of the ICP by Maurice Le Sage d'Hauteroche d'Hulst (1841–1896). It once belonged to a bilingual New Testament codex which now consists in two separate volumes: the first part (Paris, ICP, ms. Copte-Arabe 1) gathers the Gospels of Matthew, Mark, Luke, and John, while the second one (Cairo, Coptic Museum, ms. Bibl. 94) contains the Pauline Epistles and the Acts of the Apostles. The colophon preserved at the end of the second volume (Farag 2023) (Cairo, Coptic Museum, ms. Bibl. 94, f. 216r.) states that the book "was written by the hieromonk Gabriel for the archdeacon and sheikh al-Našū Abū Šakir ibn al-Sami al-Rahib ibn al-Muḥadhab (…) and was achieved the 10th Kyhakh in the year of the Martyrs 966, that is, 1249/50 of the Christian era". The scribe's name also appears in ms. Copte-Arabe 1 at the end of each Gospel book, which confirms the dating and attribution of both parts of the original manuscript. See, for example, ms. Copte-Arabe 1, f. 225r: "For God's sake, remember me, the poor Gabriel, unworthy to be called a monk and a priest, and may God forgive me. Time of the Martyrs 966 (1249/50 CE)". Traces of the scribe Gabriel are found in a small group of Coptic manuscripts that attest to his activity during the first half of the 13th century CE. Horner (1898–1905, I, 91–92) suggested identifying the scribe Gabriel with the future patriarch Gabriel III of Alexandria, head of the Coptic Church 1268–1271. Whatever one may think of such a hypothesis, the fact that Gabriel III was himself a Syrian appears significant in the context of book production in Egypt during the late Ayyubid period (1171–1250). Ms. Copte-Arabe 1 is indeed considered as a witness of the highest state of painting in Egypt and the allied territory of Syria during the last years of the Ayyubid rule (1218–1250). He also wrote a Copte-Arabic Four Gospels book in 1205 (Vatican City, Biblioteca Apostolica Vaticana, Cod. Vat. Copt. 9) and another one in 1257 (Cairo, Coptic Museum, ms. Bibl. 93). The latter was undertaken in the household of Sheikh al-Amjad, son of al-'Assāl, to which Gabriel had been attached in Syria and Old Cairo for the preceding 10 years. Therefore, it is very likely that ms. Copte-Arabe 1 was written in Cairo rather than in a monastic workshop.

The text of ms. Copte-Arabe 1 has been written before the illustration was executed (Leroy 1974 and Hunt 1985, 127). However, even if the same scribe wrote the two parts of the original manuscript, the miniatures do not seem to be the work of a single painter (Leroy 1974, 177). According to Leroy (1974), it seems that one major artist undertook the greater part of the illustration of ms. Copte-Arabe 1, while

another, less expert hand can be detected in parts of the Luke portrait (f. 105v). This second hand can be compared with the one who painted the frontispieces of ms. Bibl. 94. Further analysis could determine whether these various artists had similar dyes at their disposal, and whether it is possible to distinguish them from the mixtures they produced.

4.5.2 Identification of Folium in ms. BnF Copte 129(11)

The making of ms. Copte-Arabe 1 must be examined within its context of origin, which shows many technical features common to other Coptic and Arabic manuscripts. As such, the use of folium is attested in Egypt as early as the late 10th century CE. Four occurrences of folium were identified by the authors, again according to the typical FORS spectral features, in ms. Copte 129(11) kept at Bibliothèque nationale de France in Paris (BnF), produced in Lower Egypt. This volume of the New Testament that contains Acts, Epistles, and Apocalypse, was written in the monastic workshop of Tūtun, in the Fayyum region, in the last quarter of the 10th century CE. Folium was used in this manuscript at ff. 113r and 113v to obtain different shades of bluish grey, mainly in the zoomorphic decoration of the margins; it was sometimes mixed with indigo for pale grey tones (see e.g. f. 113v, Figure 16). The early date of ms. Copte 129(11) suggests that the use of folium was known in Egypt long before the first Crusade (1096–1099 CE).

4.5.3 Identification of Folium in ms. Arabe 5847

Another, later example of folium use can be found in an illustrated copy of the *Maqāmat* by Al-Ḥariri produced in Djazirah (northern Iraq) in the early 13th century CE. The luxurious ms. Arabe 5847 (Paris, BnF) was written and painted in 634 A.H. (1236–37 CE) by Yahyā ibn Mahmūd al-Wāsiti, active in Baghdad in the late Abbasid era. The two occurrences of folium in ms. Arabe 5847, identified by the authors by the typical absorption bands in the FORS spectrum, concern a small detail of vegetal decoration, in a light violet tone, and the pale blue robe of a character (see e.g. f. 156r, Figure 17). This identification was based on the typical spectral features previously described and on the overall characteristic shape of the FORS spectra.

4.5.4 Summary Comments on the Identification of Folium

In Figure 18, the FORS spectra taken from mss. Copte-Arabe 1, Copte 129(11), and Arabe 5847 are compared with the spectra of standard folium obtained from Italian and Iranian fruits of *C. tinctoria*. Both the spectral features and the overall shape of the spectra are similar, suggesting the use of folium in all cases.

Figure 16: Location of the measurement spots to identify folium in ms. Copte 129(11) (f. 113v, white spots) dated 10th CE, produced in Lower Egypt, kept at the Bibliothèque nationale de France (BnF) in Paris.

5 Discussion

The comparison between European and Persian dye recipes reveals notable differences in complexity and detail of description. European sources, particularly from medieval manuscripts, tend to offer more detailed descriptions of dye production processes, involving multiple steps for extraction, modification, and application. These recipes often utilise additives such as vinegar, urine, and salts to alter the colour and stabilise the dye, reflecting a highly developed understanding of dye chemistry and a need for consistency in manuscript illumination, textile dyeing, and food colouring.

In contrast, Persian sources for *C. tinctoria* (turnsole) feature simpler extraction techniques. The most common Persian method involves squeezing the plant's fruits

Figure 17: Location of the measurement spot to identify folium in ms. Arabe 5847 (f. 156r, white spot) dated 1236/37 CE, produced in Baghdad, kept at the Bibliothèque nationale de France (BnF) in Paris.

and adding sal-ammoniac (*noshādar*) to shift the dye's colour from purple to blue. This simplicity may suggest a more practical use of the dye in Persian contexts or imply that much knowledge was transmitted orally rather than documented in detailed recipes.

Despite the relative simplicity of Persian recipes, notable similarities in the uses of *C. tinctoria* across Europe and the Islamic world persist. Our scientific analysis identified traces of the folium dye in manuscripts produced under Islamic rule, raising the possibility of cultural and material exchanges across regions. For instance, manuscripts like ms. Copte-Arabe 1 contain recipes with similarities to those found in Coptic and Arabic sources, suggesting knowledge circulation between Egypt, the Levant, and Mesopotamia. This cultural exchange may explain the

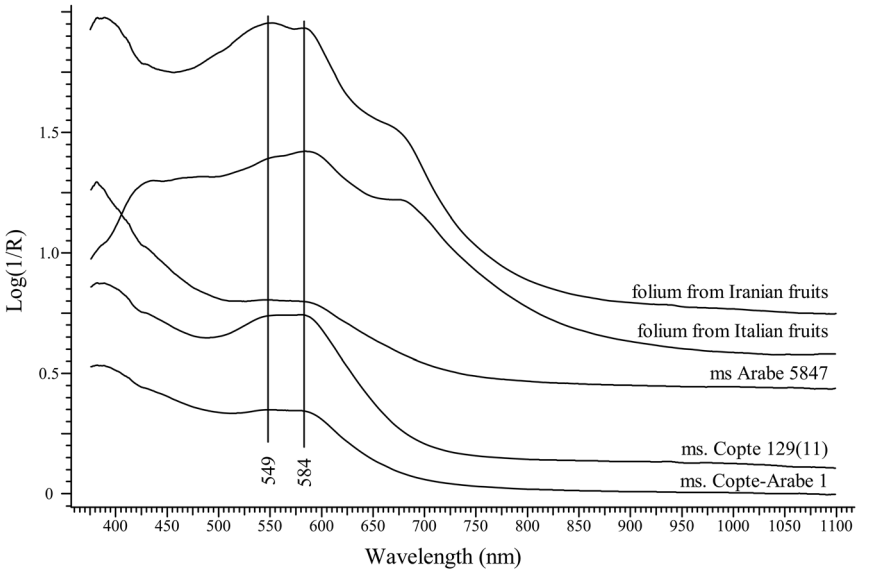


Figure 18: FORS spectra from the Islamic manuscripts analysed in this study, compared with spectra of folium reference spectra prepared according to historical recipes.

presence of *C. tinctoria* and folium in both European and Islamic traditions, despite differences in recipe complexity.

While folium was identified in manuscripts under Islamic rule, its application as a colourant in Persian manuscripts remains unverified. This study's analysis of folium reconstructed from Persian recipes revealed similarities to European samples, suggesting possible shared practices. However, the absence of direct evidence of its use in Persian manuscripts calls for further investigation. Continued research in collaboration with art historians and conservation scientists will be crucial in clarifying the extent to which this dye played a role in Persian manuscript production.

The findings of this study, including the identification of the dye in Persian manuscripts for the first time, open new avenues for research. They raise important questions about the transmission of knowledge across the Mediterranean and Near East and the role of local plants in regional manuscript traditions. The simplicity of Persian recipes may point to a more localised, perhaps less commercial, approach to dye-making, contrasting with the broader trade networks that supported more complex European dye recipes. As more Persian manuscripts undergo scientific analysis, further evidence of these connections may emerge, enhancing our understanding of the regional dynamics of dye production and manuscript illumination.

6 Conclusions

This research into *C. tinctoria* and its dye folium in Persian manuscripts provides new insights into the broader traditions of manuscript production under Islamic rule. Historically, folium was thought to be primarily a Western dye; however, its identification in Islamic manuscripts challenges this perspective, highlighting the cross-cultural diffusion of materials and techniques.

Our findings confirm that folium was used as a colourant in Islamic manuscripts, particularly in specific examples such as ms. Arabe 5847, an illustrated copy of the Maqāmat by Al-Ḥariri produced in Djazirah (northern Iraq) in the early 13th century CE. This raises intriguing questions about the potential application of folium in Persian manuscripts. The simplicity of Persian recipes suggests a localised, practical approach to dye-making, distinct from the more complex European recipes. Nevertheless, the identification of folium in Islamic manuscripts broadens our understanding of shared materials across the Mediterranean and Near East.

This study underscores the importance of integrating research into art-technological resources with instrumental analysis. The identification of folium in both Islamic and European contexts emphasises the role of *C. tinctoria* in shaping manuscript traditions. As more Persian manuscripts undergo scientific analysis – particularly focusing on paper dyes and the specific techniques used for dye extraction and application – examining works like the *Shahnameh* or the *Khamsa* of Nizami may yield further insights into the use of local plants and dyes. We may uncover additional evidence of these regional and cross-cultural connections, thereby enriching our understanding of manuscript illumination across different traditions. Ultimately, this research not only contributes to the field of manuscript studies but also emphasises the importance of preserving and appreciating the intricate cultural legacies that inform artistic practices today.

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