



**International Journal of Recent Development in Engineering and Technology**

Website: [www.ijrdet.com](http://www.ijrdet.com) (ISSN 2347 -6435 (Online)), Volume 15, Issue 3, March 2026)

# A Comparative Study on Natural Dyes on Cotton Fabric

Yuvanigha K R<sup>1</sup>, Arunkumar K V<sup>2</sup>

<sup>1</sup>M.Sc Student, <sup>2</sup>Assistant Professor, Department of Costume Design & Fashion, PSG College of Arts & Science, Coimbatore

**Abstract-** Natural dyes create a remarkable range of products and intricate hues that work well together. High levels of environmental pollution are caused by straight-off-a-day synthetic. Researchers focus on using natural colors in the food, cosmetics, and textile industries has shifted in the past year. Natural dyes are sustainable and long-lasting in textiles. A thorough analysis of a few plant-based natural dyes used to color cotton fabric is included in this review study. These dyes include cutch, pomegranate, myrobalan, madder, marigold, onion, and sappan. The sources of dyes, dyeing behaviour, color characteristics, fastness properties are the topics of this review. The resulting dyes are processed without the use of mordants like vinegar, sodium chloride, and potassium dichromate and provide a range of hues. Globally, more natural colors should be used to protect us from pollution and other negative effects. The study emphasizes the potential of natural dyes as environmentally friendly solutions for cotton dyeing.

Keywords : *Cotton fabric, Sustainable textiles, Colour fastness, Natural dyes, Eco-friendly dyeing*

## I. INTRODUCTION

Dyes are colourful elements that are used to add color to a variety of substrates, including polymers, textiles, and cosmetics. Furthermore, they find use in sectors like pharmaceuticals, paints, food, and medicine. Chemical structure, nuclear structure, industrial classification, and material source can all be used to categorize dyes. They fall into two categories: natural and synthetic. The majority of colours are synthetic and come from petrochemicals. Triarylmethane, anthraquinone, and azo dyes are among the various kinds of synthetic dyes. Industrial use of synthetic dyes has major adverse effects on human health and the environment. These dyes are persistent contaminants that have the potential to infect water bodies, lowering the aesthetic value of aquatic ecosystems.

Because of their accumulation and bio magnification in the food chain, they may also have toxicological impacts on aquatic flora, animals, and human health. The complicated structures of synthetic dyes make it difficult to remove them from wastewater using traditional methods. Clinical experiments and animal toxicity studies have also shown that children who consume synthetic food dyes have negative behavioural effects. There is a need for re-evaluation and additional research since the present permissible daily intake of food dyes may not be sufficient to preserve neurobehavioral in vulnerable youngsters. As a result, the adverse effects of synthetic dyes on the environment and human health are becoming more widely recognized, underscoring the necessity of environmental clean-up and green chemical processes.

## II. REVIEW OF LITERATURE

### 2.1 Natural dye

Natural dyes are a mixture of different phytochemicals and their quality and quantity depend on the extraction conditions, such as pH, temperature, time duration of extraction, and the solvent's nature and concentration. A change in the process conditions may have an impact on the final color of the textile material since it is dependent on the phytochemical content of the extracted solution. (Shafiq et al., 2021)

### 2.2 Sources of natural dye

There are various sources of natural dye. Natural dyes have been available since antiquity and can be derived from a variety of plant parts, such as roots, bark, leaves, flowers, and fruit. These dyes are under the category of

- 1) Natural dyes derived from plants, such as pomegranates, myrobalan, catechu, indigofera, flowers, bark, leaves, and seeds.
- ii. Lac and cochineal are natural colors made from insects.
- iii. Natural colors derived from shellfish, cuttlefish, murex snails, and



## International Journal of Recent Development in Engineering and Technology

Website: [www.ijrdet.com](http://www.ijrdet.com) (ISSN 2347 -6435 (Online)), Volume 15, Issue 3, March 2026)

molluscs. iv. Natural dyes made from minerals, such as malachite, ochre, and clay. (Verma & Gupta, n.d.)

### 2.2.1 Vegetable dyes:

The primary source of the dyestuffs used to create color in the past was the plant kingdom. Up to 500 different plant species were found to be dye suppliers. These vegetable sources are biodegradable in addition to being interchangeable. They also have health and pharmacological benefits. They can be extracted from a plant's roots, stems, stalks, leaves, bark, berries, and seeds, among other parts. (Singh & Yadav, 2000)

### 2.2.2 Animal dyes:

Animals are another natural source of dyes. The greatest red dyes available to the ancient people were derived from animals and were used to create a variety of crimson and purple hues. The primary source of natural dyes is insect secretions and dried insect remains (Liu et al., 2003)

### 2.2.3 Mineral dyes:

These dyes are made from natural earth pigments, and the presence of oxides or hydrated oxides of manganese gives them their tinctorial qualities. Manganese brown, chrome yellow, iron buff, Prussian blue, and nankin yellow are a few examples of mineral dyes.

Since they are very insoluble in water and other solvents, a binder must be present in order to attack the fiber surface. The colors that are produced on the fiber are incredibly resistant to light and chemicals, and calcinations change them into richer, deeper hues. Since many mineral colorants have been discovered to be toxic in nature, their uses are restricted.

The term "natural dye," which refers to all dyes made from natural resources, including minerals and vegetable dyes, is more accurate because minerals are utilized to fix or improve the fastness of vegetable dye. Additionally, certain minerals are utilized to provide wherewithal matter. For instance, egg albumin, cow manure, urine, and seru. (Jihad, R. (2014)

### 2.3 Importance of natural dye

Making consumers aware of the environmental problems caused by synthetically dyed textiles and making on alternative widely available are the keys to the success of natural dyes. Developing countries figure prominently in this equation because their lower labour costs will help to offset the higher cost of the natural dyeing process. In addition, many developing countries already have long traditions of natural dyeing and possess the raw materials to extract dyes. Natural-dyed products thus represent a good opportunity for value-added exports from countries that already are world leaders in textile manufacturing. Natural dyes are the safe dyes, because they do not produce any undesired by-products and at the same time they help in regenerating the environment. In spite of these several advantages, natural dyes have over synthesis; their use is still limited due to the non-availability of dyes in the standardized farm, shortage of trained dyers, knowledge gap, higher labour cost associated with collection and preparation of dyes. But many natural resources that are being wasted indiscriminately or go away as waste products contain useful pigments. The eco-friendly nature of natural dyes produces fantastic, attractive, earthy colours. (Chungkrang & Bhuyan, 2020)

### 2.4 Advantages of natural dye

Natural dyes are bio-colours recovered and extracted from natural sources, and their stability is solvent. The demand for natural dyes has been increasing in the current moment due to rising environmental concerns. Many chemicals, such as synthetic dyes, have mutagenic and carcinogenic components used daily in the synthesis formulation and finishing processes. Moreover, synthetic dye effluents are hazardous for water bodies and agri-land as these effluents imbalance the pH, COD, and BOD levels of water. Consequently, environmental organizations raise awareness that eco-labelled and ayurvedic-based products should be used to improve lifestyle. Therefore, green products such as the demand for natural dyes can be used as an alternative to synthetic colourants.

Natural dyes are mostly used for dyeing of the textiles from natural fibers to enhance their eco-friendly characteristics. Apart from indigo, other natural dyes are usually not used for printing directly. As well as synthetic dyes, natural dyes can be used to dye textiles at all stages such as fiber, yarn, or fabric. Natural dyes are biodegradable and do not cause any health hazards and hence they can be easily used without much environment concerns. Recently, there has been revival of the growing interest on the application of natural dyes to overcome the environmental damage caused by synthetic dyes. However, all-natural dyes are not ecofriendly. There may be

presence of heavy metals or some other form of toxicity in natural dye. So, the natural dyes also need to be tested for toxicity before their use.(Jordeva et al., 2020a)

On the other hand, numerous studies have also shown that natural dyes are nontoxic and sustainable and have no disposal issues. Their effluents are nontoxic,

biodegradable, and could be reused as a bio-fertilizer to improve crop growth .Secondary metabolites of the plant extracts are used as tonic and herbal system that transfers their biological activities when employed on matrices such as silk, wool, and cotton .The most vital factor is that the cultural heritage with a broad spectrum of colours is now being revived as state-of-the-art for the colouration of different substrates. Besides the advantages of natural dyes, these have limitations, such as poor colour yield, low fastness rating, reproducibility of shades, etc. To overcome these limitations, mordants such as salts of  $Fe^{2+}$ ,  $Al^{3+}$ ,  $Cr^{1+}$ , and  $Cu^{1+}$  are used, but their applications also create environmental hazards . Nowadays, plant-based functional isolates may be alternatives to toxic mordants have been included, which not only have excellent herbal and biological characteristics, but also have added value to the bio-colouration of fabric dyeing to form a variety of firm and fast shades.(Talib et al., 2023)

## 2.5 Selected natural dyes

Plants	Scientific name	Part used
Cutch	Acacia catechu	Wood
Pomegranate	Punica granatum	Rind
Myrobalan	Terminalia chebula	Fruit
Madder	Rubia tinctorum	Root
Marigold	Tagetes erecta	Flower
Onion	Allium cepa	Skin
Sappan	Biancaea sappan	Wood

### 2.5.1 Cutch (Acacia catechu L.)

Main chemical constituents of Acacia catechu from the heartwood are catechin and epicatechin. The powdered heartwood of A. catechu contains tannin phyto-constituents. Catechin is a type of natural phenol and

an antioxidant. It is a secondary metabolite of the plant that belongs to the chemical family of flavonoids. It is used for dyeing of fabrics with different mordants. It yields brown, reddish brown and black shade. The color obtained exhibit very good fastness properties.

The present study focused on the development of the optimum extraction conditions of coloring component from the natural material *Acacia catechu* (Khair) and its application on silk fabric with chemical mordants. The study also analysed the light, wash, rubbing and perspiration fastness to check the colors stability. (Khatun et al., 2017)

#### 2.5.2 Pomegranate (*Punica granatum* L.)

*Punicagranatumis* from the family *Punicaceae*. It grows in all warm countries of the world and was originally a native of Persia. The rind of pomegranate contains a considerable amount of tannin, about 19% with pelletierin. The main coloring agent in the pomegranate peel is granatonine which is present in the alkaloid form N-methylgranatonine. This compound gives color to the dye. Its study will enable us to understand the structural chemistry of the coloring compound. (Satyanarayana & Chandra, n.d.)

#### 2.5.3 Myrobalan (*Terminalia chebula* Retz.)

The phytochemical profiling of myrobalan reveals the presence of several phenolic compounds, primarily hydrolysable tannins such as chebulic acid, chebulinic acid, chebulagic acid, ellagic acid, and gallic acid. The tannin content can make upto 20-50% of the total phytochemical constituency of myrobalan. In addition to tannins, myrobalan also contains a range of phenolic compounds (like phenol and propenoic acid), terpenoids (like arjunic acid and terminolic acid), flavonoids (like quercetin and rutin), and sterols. These compounds contribute to its ability to act as a mordant and dye, providing a range of colour tones from golden yellow to deep brown, depending on the dyeing process and the use of other mordants. (Agrawal, 2025)

#### 2.5.4 Madder (*Rubia tinctorum* L.)

Madder dye is extracted from the roots of *Rubia tinctorum* L. or *Rubia cordifolia*, plants belonging to the *Rubiaceae* family. The roots contain natural colorants such as alizarin, purpurin, and munjistin, responsible for red hues. Madder exhibits antioxidant, antimicrobial, anti-inflammatory, and anti-cancer properties.

It produces pink, red, orange, and maroon shades on cotton fabrics. Madder is valued for its excellent color fastness, non-toxicity, and historical importance in natural dyeing. (Derksen et al., 2021)

#### 2.5.5 Marigold (*Tagetes erecta* L.)

Many varieties of Marigolds have been cultivated all over the world but two of them are *Tagetes erecta* and *Tagetes patula* are most important. Marigold plants are chubby and branching and can grow up to 60 cm tall.. Lutein and its isomer zeaxanthin are also known as oxycarotenoids or xanthophylls. These xanthophylls are the basic element in the marigold flowers and present in high concentration than other plants. The xanthophylls because of their yellow to orange red coloration and natural occurrence in human foods can be used as a food colorant. Therefore there exist a high demand for the significantly pure xanthophylls that can be used as a food colorant and a nutrient supplement. Marigold extract also finds application in coloring foods like edible oils, mustard and other salad dressings, cakes, ice cream, yogurt and dairy products. (Farooq et al., 2013)

#### 2.5.6 Onion (*Allium cepa* L.)

Onion dye is primarily derived from the outer dry skins of *Allium cepa* L., a bulbous plant belonging to the *Amaryllidaceae* family. Onion skins are rich in flavonoids, quercetin, phenolic acids, and sulphur compounds. These compounds exhibit antioxidant, antimicrobial, anti-inflammatory, and anti-hyperglycemic properties. Onion skin dye produces yellow, orange, and brown shades on cotton fabrics. The use of onion waste as a dye source supports waste valorization and sustainable textile processing. (Mohan et al., 2020)

#### 2.5.7 Sappan (*Biancaea sappan* L.)

Sappan dye is obtained from the heartwood of *Caesalpinia sappan* L., a small tree belonging to the *Fabaceae* family. The heartwood contains brazilin and brazilin, natural colorants responsible for red hues. Sappan exhibits antioxidant, antimicrobial, anti-inflammatory, and anti-cancer properties.

It produces pink, red, and purplish-red shades on cotton fabrics. Its stability, non-toxicity, and eco-friendly nature make it suitable for natural dyeing and functional textile applications. (Bukhari et al., 2023)

#### 2.6 Colour Characteristics and Fastness Properties:

Natural dyes produce a wide range of soft and earthy shades on cotton. Studies report moderate to good fastness to washing, rubbing, perspiration, and light when appropriate mordants are used. Tannin-rich dyes such as cutch, marigold, and myrobalan generally show superior fastness properties compared to other dyes. (Hassaan & El Nemr, 2017)

#### 2.7 Comparative analysis:

Comparative analysis of fastness properties reported in literature indicates that cutch-dyed cotton fabrics generally show higher resistance to washing and rubbing due to the presence of natural tannins, whereas dyes such as marigold and onion skins primarily contribute to shade brilliance and functional properties rather than fastness performance. (Daberao et al., n.d.)

#### 2.8 Environmental and Sustainability Aspects

Natural dyes are biodegradable and renewable, resulting in minimal environmental impact. The use of plant waste materials such as onion skins supports waste valorization. Natural dyeing processes require lower toxicity levels compared to synthetic dyes, aligning with sustainable textile production goals. (Jordeva et al., 2020b)

#### REFERENCE

[1] Agrawal, A. (2025). Textile Application of Natural Dye Extracted from Myrobalan (*Terminalia chebula*): Process Optimisation using RSM. *Journal of the Textile Association*, 86(02), 221–229. <https://doi.org/10.63665/jta.v86i2.14>

[2] Bukhari, M. N., Wani, M. A., Fatima, M., Bukhari, J. S. S., Shabbir, M., Rather, L. J., & Mohammad, F. (2023). Dyeing of Wool with Sappan Wood Natural Dye Using Metal Salts for Enhancement in Color and Fastness Properties. *Journal of Natural Fibers*, 20(2), 2208890. <https://doi.org/10.1080/15440478.2023.2208890>

[3] Chungkrang, L., & Bhuyan, S. (2020). Natural Dye Sources and its Applications in Textiles: A Brief Review. *International Journal of Current*

*Microbiology and Applied Sciences*, 9(10), 261–269. <https://doi.org/10.20546/ijcmas.2020.910.034>

[4] Daberao, A. M., Kolte, P. P., & Turukmane, R. N. (n.d.). Cotton Dying with Natural Dye.

[5] Derksen, G. C. H., Van Holthoon, F. L., Willemsen, H. M., Krul, C. A. M., Franssen, M. C. R., & Van Beek, T. A. (2021). Development of a process for obtaining non-mutagenic madder root (*Rubia tinctorum*) extract for textile dyeing. *Industrial Crops and Products*, 164, 113344. <https://doi.org/10.1016/j.indcrop.2021.113344>

[6] Farooq, A., Ali, S., Abbas, N., Zahoor, N., & Ashraf, M. A. (2013). Optimization of Extraction and Dyeing Parameters for Natural Dyeing of Cotton Fabric Using Marigold (*Tagetes erecta*). *Asian Journal of Chemistry*, 25(11), 5955–5959. <https://doi.org/10.14233/ajchem.2013.14202>

[7] Hassaan, M., & El Nemr, A. (2017). Health and Environmental Impacts of Dyes: Mini Review. *American Journal of Environmental Science and Engineering*, 1, 64–67. <https://doi.org/10.11648/j.ajese.20170103.11>

[8] Jihad, R. (2014) Dyeing of Silk Using Natural Dyes Extracted from Local Plants. Head of the Textile Engineering Department at Kombolcha, Institute of Technology, Wollo University, Ethiopia. - References—Scientific Research Publishing. (n.d.). Retrieved February 25, 2026, from <https://www.scirp.org/reference/referencespapers?referenceid=2145325>

[9] Jordeva, S., Kertakova, M., Zhezhova, S., Golomeova-Longurova, S., & Mojsov, K. (2020a). Dyeing of textiles with natural dyes. *Tekstilna Industrija*, 68(4), 12–21. <https://doi.org/10.5937/tekstind2004012J>

[10] Jordeva, S., Kertakova, M., Zhezhova, S., Golomeova-Longurova, S., & Mojsov, K. (2020b). Dyeing of textiles with natural dyes. *Tekstilna Industrija*, 68(4), 12–21. <https://doi.org/10.5937/tekstind2004012J>

[11] Khatun, M. H., Akhter, A., Kadri, H. J., & Mostafa, M. G. (2017). OPTIMIZATION OF ALKALINE EXTRACTION OF NATURAL DYE FROM.

[12] Liu, L., Zhao, L., Liang, X., Zheng, Q., Liu, Q., Wang, J., Guo, H., Zhao, S., & Chen, W. (2003). Study on Production of Transgenic Wheat with a Stress-inducible Transcription Factor Gene DREB1A by Microprojectile Bombardment. *Zhongguo sheng wu gong cheng za zhi = Journal of Chinese biotechnology*, 23(11), 53–56.



**International Journal of Recent Development in Engineering and Technology**

**Website: [www.ijrdet.com](http://www.ijrdet.com) (ISSN 2347 -6435 (Online)), Volume 15, Issue 3, March 2026)**

- [13] Mohan, R., N, G., D, H. J., & Sivakumar, V. (2020). Studies on Natural Dye (Pelargonidin) Extraction from Onion Peel and Application in Dyeing of Leather. *International Journal of Recent Engineering Science*, 7(1), 12–16. <https://doi.org/10.14445/23497157/IJRES-V7I1P103>
- [14] Satyanarayana, D. N. V., & Chandra, K. R. (n.d.). Dyeing Of Cotton Cloth with Natural Dye Extracted From Pomegranate Peel and its Fastness.
- [15] Shafiq, F., Siddique, A., Pervez, Md. N., Hassan, M. M., Naddeo, V., Cai, Y., Hou, A., Xie, K., Khan, M. Q., & Kim, I.-S. (2021). Extraction of Natural Dye from Aerial Parts of Argy Wormwood Based on Optimized Taguchi Approach and Functional Finishing of Cotton Fabric. *Materials*, 14(19), 5850. <https://doi.org/10.3390/ma14195850>
- [16] Singh, S. S., & Yadav, S. (2000). Optimization of dyeing conditions for wool using barberry bark. 43, 39–40.
- [17] Talib, A., Fazal-ur-Rehman, Adeel, S., Ali, A., Ahmad, T., Hussaan, M., & Qayyum, M. A. (2023). Sustainable Isolation and Application of Plant Extract-Based Natural Dye for Bio-Dyeing of Silk Fabric. *Coatings*, 13(1), 112. <https://doi.org/10.3390/coatings13010112>
- [18] Verma, S., & Gupta, G. (n.d.). Natural dyes and its applications: A brief review. 4(4).