EXTRACTION OF NATURAL DYE FROM THE LEAVES OF *PHYTOLACCA OCTANDRA* (L.) AND IT'S APPLICATION ON TEXTILE SUBSTRATES

DISSERTATION SUBMITTED TO THE MAHATMA GANDHI UNIVERSITY, KOTTAYAM, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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DECLARATION

I, hereby declare that work which being presented in the dissertation, entitled "**Extraction of natural dye from the leaves of *Phytolacca octandra* (L.) and it's application on textile substrates**" in fulfilment of requirements for the award of the degree of Master of Science in Botany and submitted to St. Teresa's College (Autonomous), Ernakulam is an authentic record of my work carried out during M.Sc. period under the supervision of Dr. Tintu Jose Manicketh.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other University or Institute.

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Stephy Johnson

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CHAPTER -1

INTRODUCTION

Dyes are colored compounds that are widely used in textiles, printing, rubber, cosmetics, plastics, and leather industries to color their products. Among all the dyes used in industries, textile industries are placed in the first position in the use of dyes for the coloration of fiber (Reisch, 1996). Dyeing is an ancient art which predates written records and it was practiced since Bronze Age (Satyanarayana et al., 2013). In textile processing dyeing is an integral part where textile coloration is done to make the fabric lively (Nusrat et al., 2015). Dyes can be classified into natural and synthetic based on their origin.

Synthetic dyes are produced from cheap petroleum sources, vastly used commercially to impart color to textiles because they have simple dyeing process with good fastness properties (Haji et al., 2010). Although synthetic dyes have been used mostly in the process of dyeing textiles due to its excellent color fastness since 1856, they usually contain harmful substances, and bring great harm to the surrounding environment (Cai et al., 2012). Synthetic dyes are suspected to release harmful chemicals that are allergic, carcinogenic, and detrimental to our environment and human body (Neha et al., 2011). The serious environmental problems of public health concern related to colored waste waters containing synthetic dyes have diverted researchers promptly to look for eco-friendly products. So to recover our living condition we need to introduce environment friendly materials to use in textile processing that can accomplish the consumer's requirement as well as economy of country (Nusrat et al., 2015).

Natural dyes are found from natural sources such as plants, animals, insects, or minerals (Samanta et al., 2009). The use of natural organic dyes obtained from renewable resources such as plants and trees has the potential for not only preserving the precious petrochemicals but also the endangered environment for our coming generations (Asif et al., 2010). Natural dyes are mostly used for dyeing textiles from natural fibers to enhance their eco-friendly characteristics. Natural dyes have wide application in the dying of most of the natural fibers, e.g. cotton, linen, wool, and silk fibers, and to some extent for nylon and polyester synthetic fiber (Sonja Jordeva et al., 2020). While the direct dyeing of natural dyestuffs has poor dyeing reproducibility and low color fastness on cotton fabric due to the lack of active groups in the molecule of cotton (Ding & Freeman, 2017). Natural dyes are mostly used on silk and wool (Dayioglu et al., 2015). However, the major issues for natural dyed textiles are reproducibility of shade, non-availability of a well-defined standard procedure for application, and poor lasting performance of shade under water and light exposure (Sonja Jordeva et al., 2020). For successful commercial use of natural dyes, the appropriate and standardized dyeing techniques need to be adopted without scarifying the required quality of dyed textile materials (Samanta et al., 2009).

In addition to chromophores, most dyes also contain groups known as auxochromes (colour helpers), examples of which are carboxylic acid, sulfonic acid, amino, and hydroxyl groups. While these are not responsible for colour, their presence can shift the colour of a colourant, and they are most often used to influence dye solubility (IARC, 2010). A covalently saturated group which, when attached to a chromophore, changes both the wavelength and the intensity of the absorption maximum is known as auxochrome, e.g., NH2, OH, SH, halogens etc. Auxochromes generally increase the value of λmax as well as εmax by extending the conjugation through resonance. These are also called colour enhancing groups. An auxochrome itself does not show absorption above 200 nm (Gürses et al., 2016). A chromophore is usually an electron-withdrawing group, while an auxochrome is commonly an electron-donating group and the two are linked through a conjugated system (Burkinshaw 2016).

The organic dye molecules contained three main components such as chromogen, chromophore and auxochrome. The chromogen is a chemical compound that is either colored or could be made colored by the attachment of suitable substituent (Gürses et al., 2016). The chromophore and the auxochrome(s) are also part of the chromogen (Carmen and Daniela 2012). The chromophore is a chemical group that is responsible for the appearance of color in compounds (the chromogen) where it is located. The colorants are sometimes also classified according to their main chromophore (e.g., azo dyes contain the chromophore –N=N–) (Iqbal 2008). The auxochrome is a substituent group found in a chromogen that influences its color. The chromophore or chromophoric group is responsible for chromogen which will be colored. The chromophore itself is not capable of determine a particular color and hue (Marsden 1982).

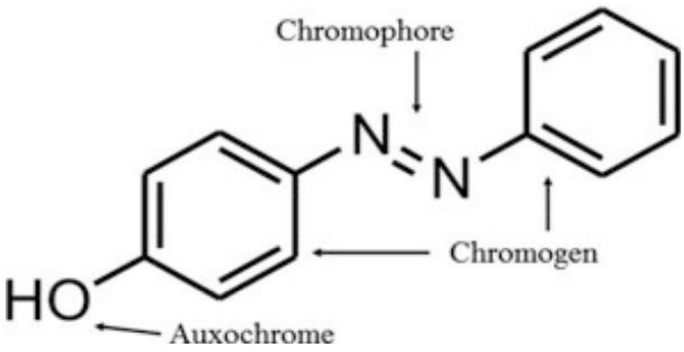

Fig. 1: The components of 4-Hydroxyazobenzene (Gürses et al., 2016)

Weeds are unwanted plants that deplete the environment, so using weeds as a source of natural dye has benefits in both the textile industry and maintaining the harmony of the environment. *Phytolacca octandra* (L.) is a fast-growing weed commonly known as ink-weed, found in forests and near rivers, though it also thrives in drier regions with hot climates. It belongs to the family Phytolaccaceae. Its parts can be used to obtain the natural dyes (Zhao et al., 2014).

1.1 BACKGROUND AND SIGNIFICANCE OF THE PRESENT STUDY

Phytolacca octandra (L.) is a common weed that is available in the locality of Tripunithura. In recent years, the use of plant-based products has been increasing. The identification and preparation of useful products from a futile substance and its application in various fields can thrive the economy. So, it is necessary to investigate the hidden potential of the plant *Phytolacca octandra* (L.). Research on *Phytolacca octandra* remains incomplete, particularly in the field of phytochemistry, taxonomy, and anatomy. Further exploration of these aspects could lead to discoveries in medicine, pharmaceuticals, agriculture, etc.

- The study would help to discover the hidden ability of the weed, *Phytolacca octandra* (L.).
- The study helps to find out the different applications of *Phytolacca octandra* (L.) in various fields.

1.3 OBJECTIVES

The objectives of the present study are:

- To extract the natural dye from the leaves of *Phytolacca octandra* (L.).
- To study the various eco-friendly methods of natural dye extraction.
- To assess the potential of the extracted dye and its application on various textile substrates.

CHAPTER-2

REVIEW OF LITERATURE

2.1 Review about the textile substrates used

2.1.1 Cotton

Cotton lint is long (>25 mm) fiber that can be spun into yarn. This product is used in clothing, denim, towels, and dollar bills. The lint fibers can be easily separated from seeds through the ginning process. Cotton has the distinction of being, with only mechanical cleaning, quite pure cellulose, as much as 95%. Cellulose, the sugar of little cells, is a polymer of as many as 20,000 glucose residues linked β-1→4 (Fang et al., 2018).

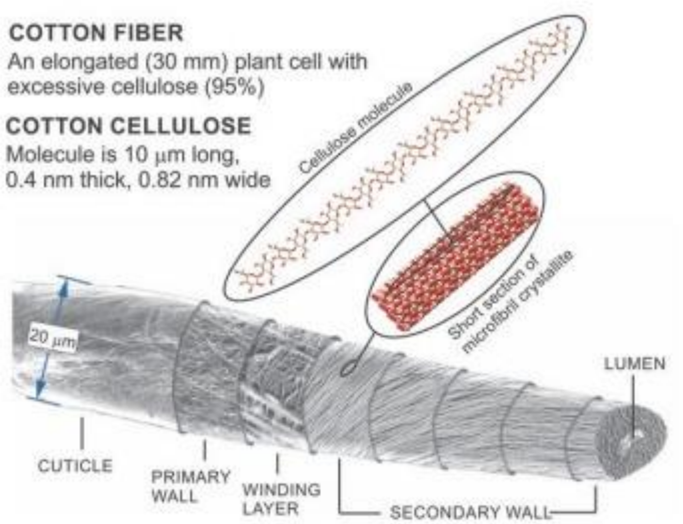

Fig. 2: Montage of electron micrographs, not to scale, selected and placed to resemble the different layers that compose the cotton fiber that is modified from the original figure described in Goynes (2005).

Cotton is a single-celled fiber made of several layers:

Cuticle: Outermost layer composed of waxes and pectins that protect the fiber. Primary Wall: A thin, elastic outer skin containing randomly oriented microfibrils and some cellulose. Secondary Wall: Comprises most of the fiber's mass; contains highly oriented cellulose fibrils in concentric layers or lamellae. Lumen: Central hollow canal containing remnants of cytoplasm. Each secondary wall lamella consists of fibrils—tiny cellulose threads arranged helically. These fibrils are made up of crystallites, which are bundles of cellulose chains, and amorphous regions that allow for flexibility and moisture absorption (Nickerson et al 1940).

Cotton fibers, when freshly picked and not dried, are generally round in cross-section, but as they dry, they flatten and develop convolutions—twists believed to be caused by changes in microfibril orientation. These convolutions, which occur about ten times per millimeter, may create weak points along the fiber, reducing its strength compared to crystalline cellulose. The structure of cotton fiber is highly hierarchical, with cellulose molecules about 10 μm long, forming crystallites composed of roughly 175 glucose units, and a cross-section possibly containing millions of such crystallites. The fiber's secondary wall, composed primarily of cellulose, is believed to develop in layers influenced by daily temperature changes (Fang et al., 2018).

Properties of cotton are:

Tensile Strength: Cotton fibers exhibit good tensile strength, typically around 30,000–60,000 psi, depending on fiber fineness and maturity. Fine fibers tend to be stronger due to better molecular alignment and outer wall elasticity. Elasticity and plasticity: Cotton fibers show moderate elasticity with about 8% elongation at break. They demonstrate elastic aftereffects, particularly under humid conditions, due to their fibrillar network and partial plasticity. Moisture absorption: Cotton is highly hygroscopic, absorbing up to 25% of its weight in water. Moisture improves fiber flexibility and strength, making it useful for textiles that require breathability and comfort. Swelling behavior: Cotton fibers swell laterally in water and certain chemicals (e.g., NaOH), leading to structural changes that improve dyeability (e.g., mercerization). Swelling is limited by the cuticle and crystalline regions unless chemically treated. Thermal and Chemical Resistance: Cotton is relatively stable under heat but degrades under prolonged exposure to acids or UV light, primarily affecting the less dense amorphous regions of the fiber (Nickerson et al 1940).

Chemical composition of cotton:

Cellulose: 88-95%, Waxes and fatty acids: 0.5-1.0%, Proteins: 1-2%, Pectic substances: 0.5-1.5%, Mineral ash: 0.5-1.0%, Water: 6-8% (Nickerson et al 1940).

2.1.2 Rayon

Rayon is a regenerated cellulose fiber derived from natural sources like wood pulp or cotton linters. Its structure includes:

Long Cellulose Chains: Rayon consists of β-D-glucose units linked via β(1→4) glycosidic bonds, similar to natural cellulose. Crystalline and Amorphous Regions: The fiber has alternating regions of high order (crystalline "micelles") and less ordered, amorphous areas. These regions affect the fiber's strength, dye uptake, and flexibility. Orientation from Processing: The crystallinity and orientation are significantly influenced by the coagulation and regeneration processes. Stretching during spinning increases alignment but has limited effect on crystallinity itself (Lovell et al., 1946). Rayon is produced via processes like the viscose method, which involves alkali treatment, xanthation, and extrusion into an acid coagulation bath. Structural parameters like crystallinity, fibril orientation, and chain alignment are strongly affected by stretching, coagulation, and drying conditions (Ingersoll et al., 1946).

Properties of rayon:

Tensile strength and elongation: Rayon's strength varies based on processing; high-tenacity tire-cord rayon has significantly higher strength than unstretched rayon. Elongation also varies—normal rayon can elongate up to 35%, while highly stretched rayon exhibits less elongation due to greater molecular alignment. Elasticity and Fibrillation: Rayon is less elastic than natural fibers and can fibrillate (split into fibrils) when mechanically stressed after acid hydrolysis. This behavior is particularly observed in highly oriented crystalline regions. Moisture absorption and affinity: Rayon has high moisture regain (11–13%), making it comfortable for clothing applications, though it weakens when wet. It swells in water due to its amorphous structure, enhancing dyeability (Lovell et al., 1946). Dye affinity and drape: Due to its amorphous regions, rayon accepts dyes well, producing vivid colors. It also drapes well, making it desirable in fashion and upholstery textiles. Orientation and lateral order: The fiber's physical performance is closely linked to the orientation of cellulose chains along the fiber axis and the degree of lateral order (crystalline alignment across chains). Higher orientation improves strength, while reduced lateral order allows for better extensibility (Ingersoll et al., 1946).

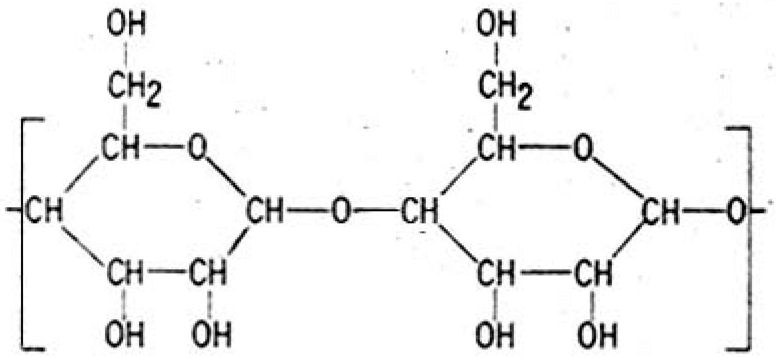

Fig. 3: Molecular structure of rayon (Bortner et al., 2003)

Primary Component: Cellulose : 99%, same as in natural fibers.

Residual Chemicals (depending on process): Traces of sulfur (from carbon disulfide used in viscose process), Sodium or zinc salts

Water Regain: 11–13% under standard conditions (Ingersoll et al., 1946).

2.1.3 Polyester

Polyester, particularly poly(ethylene terephthalate) (PET), has a repeating unit composed of terephthalic acid and ethylene glycol linked by ester bonds. The molecular structure includes:

Crystalline Regions: Chains arranged in an ordered, triclinic lattice (unit cell dimensions: a = 0.456 nm, b = 0.594 nm, c = 1.075 nm) with extended chains and aligned aromatic rings. Amorphous Regions: Disordered chains allowing for flexibility and dye penetration. Orientation: Achieved during fiber drawing, affecting strength, elasticity, and dimensional stability. The performance is determined by the degree of crystallinity, molecular orientation, and chain alignment developed during melt spinning and heat setting (Hansen et al., 2005).

Properties of Polyester

Tensile strength and elasticity: PET fibers exhibit high strength and moderate to high elasticity. High-tenacity PET fibers show a break tenacity of 0.6–0.9 N/tex with elongation at break around 10–25%, while regular PET shows higher elongation but lower tenacity (Hansen et al., 2005). Thermal stability: PET fibers melt at 255–265°C and have a glass transition temperature (Tg) of about 78°C. After drawing, Tg increases to around 120°C, enhancing thermal resistance. Resilience and elastic recovery: Especially in PTT (polytrimethylene terephthalate), polyester fibers exhibit excellent elastic recovery, recovering fully from elongations over 100%. This makes them suitable for carpets, sportswear, and stretch fabrics. Low moisture absorption**:** Polyester is hydrophobic, with a moisture regain of ~0.4%, making it quick-drying but less breathable than natural fibers. (East et al., 2009).

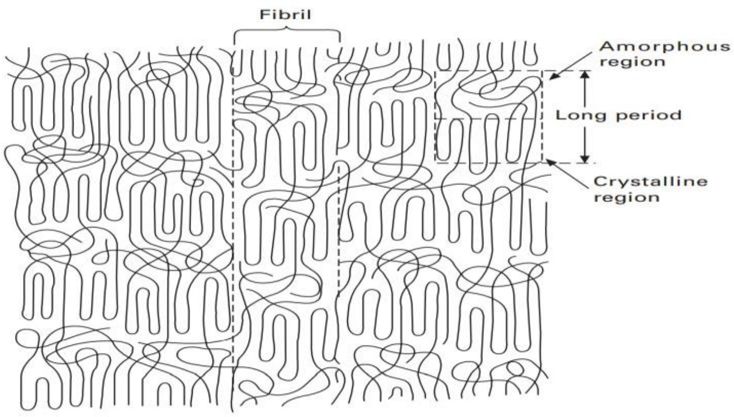

Fig. 4: Morphology of PET fiber showing various features (East et al., 2009)

Chemical composition:

Empirical Formula: $(C_{10}H_8O_4)n$

Elements: Carbon (C): ~62%, Hydrogen (H): ~4%, Oxygen (O): ~34%

Main Monomers: Terephthalic Acid (TA), Ethylene Glycol (EG) (East et al., 2009).

2.2 Overview of the application of natural dye on textile substrates

Jahan and Datta (2015) conducted a comparative analysis of dyeing cotton and silk fabrics with madder as a natural dye, focussed on the role of different mordanting techniques in colour characteristics and fastness properties. Results indicated that silk produced deeper shades and exhibited superior fastness compared to cotton, especially when alum was used as a mordant. Ali et al. (2015) conducted a phylogenetic analysis of the Phytolacca genus (Phytolaccaceae) to address the taxonomic complexity of *Phytolacca*, which has long been debated due to morphological variations and hybridization. Cerempei et al., (2016) studied a novel application of using vegetable waste, such as fall quince leaves for wool fibers dyeing. Natural dye obtained by aqueous extraction of quince leaves (*Cydonia oblonga*) was applied to wool fibers by an exhaustion dyeing process.

Dyeing of cotton fabric with natural colorants extracted from tea leaves had been investigated by Bydoon et al., (2016). The dyeing process was carried out using different techniques with different solvents and applied on Giza 86 Egyptian cotton fabric using some mordants and gelatin modification. Kim et al. (2017) studied natural dyeing with *Terminalia chebula* Retzius (*T. chebula*), highlighting the advantages of natural dyes, such as their non-toxic and non-allergenic properties, while also indicating their limitations, including low dye affinity and poor colour fastness. Vadwala et al., (2017) extracted natural dye from the waste leaves of *Terminalia Catappa* (tropical almond), and its application on silk fabrics pre-treated with eco-friendly and non-eco-friendly mordants has been carried out successfully. Different shades with excellent to good fastness properties have been obtained.

Mansour et al., (2017) used grape pomace, as a source of natural dyes that could be utilized in textile dyeing. Fröse et al. (2018) reviewed the application of natural dyes on various textile materials, discussing their environmental benefits and challenges compared to synthetic dyes. This indicates the historical significance of natural dyes and the increasing interest in their use due to concerns about water pollution and chemical waste from synthetic dyeing processes. Samanta et al. (2018) review the fundamentals of natural dyeing, discussing its historical significance, eco-friendliness, and growing demand due to environmental concerns.

Mozaffari (2018) conducted a comprehensive review of the role of alum as a natural mordant in textile dyeing, emphasizing its industrial significance. The research highlighted the challenges of dyeing cotton with natural dyes and the necessity of alum as a chemical agent to facilitate bonding between dyes and fabrics. Singh and Singh (2018) reviewed the application of natural mordants in textile dyeing, emphasizing their role in improving dye fixation and fastness properties. Abdel-Zaher et al.,(2018) evaluated the effect of silk fabrics dyeing with a natural dye extracted from Azadirachta indica (neem) leaves under different conditions, such as; different dye bath pH values, different dyeing temperatures, and different dyeing times.

Evitasari et al. (2019) conducted a study on the dyeing of cotton fabric using natural dye extracted from the leaves of *Peristrophe bivalvis* (Noja leaf). Mordants like alum, ferrous sulphate, and calcium oxide form chemical bonds with dyes and fabrics, influencing the final shade and durability of the colour. Kumbhar et al., (2019) extracted a new brown-coloured natural dye from the leaves of *Ficus amplissima* using alum, copper sulphate, iron sulphate, and stannous chloride as mordants, using the pre-mordanting method. The dye was fixed on the mordanted cotton by the conventional dyeing methods and optimized dyeing conditions. Amutha et al. (2020) studied natural dyes, focusing on their eco-friendly nature and sustainable application in textile dyeing. They highlighted that while natural dyes have been traditionally used on natural fibers like cotton, silk, and wool, recent studies have explored their application on synthetic fibers such as polyester and nylon.

Gong et al., (2020) investigated the possibility of wool dyeing with natural dye extracted from the *Cinnamomum camphora* middle-aged/mature leaves with the help of natural mordants and chemical mordants. Agarwal et al., (2020) extracted the dye colourant from teak leaves and characterized the dye in terms of yield % to standardize the conditions of application of dye extracted from teak leaves on selected natural and synthetic fabrics using selected natural and chemical mordants. Talib et al., (2020) isolated colourant from black pepper (*Piper nigrum* L.), and bio-mordants have been included to obtain colourfast shades.

Rehman et al., (2021) used *Acalypha wilkesiana* (copper plant) as the source of a natural colorant for auxiliary-free dyeing of cotton, a way forward to eco-friendly dyeing. Without using any metallic salts as mordants, the color fastness properties, like rubbing fastness, washing fastness, were also slightly improved due to greater dye fixation. Fang et al., (2022) studied the usability of *Ipomoea batatas* leaves for simultaneous dyeing and functional finishing (anti-bacterial and anti-ultraviolet) of textile fabrics without the use of inorganic salts and metal mordants for the cleaner production of environmentally friendly value-added products.

Khatun et al.,(2022) studied approaches to extract natural dye from the waste leaves of *Polyalthia longifolia* and evaluate the dyeing properties on silk and cotton fabrics. The color was fixed firmly on silk fabrics without any mordant. Ferrous sulfate and copper sulfate mordanted cotton fabrics showed good light and wash fastness properties. Hayat et al.,(2022) studied the utilization of waste black tea leaf (BT)–based tannin brown natural colorant for silk dyeing.

Ain et al., (2024) explore the efficacy of banana leaf-extracted natural dyes with mordants in dyeing Pima cotton, examining color properties, chemical attributes, and fastness while exploring the potential for industrial applications. Nadeem et al., (2024) evaluated the extraction of natural dyes from *Conocarpus erectus* L. leaves and their application on wool and silk fabrics. Okwudo et al., (2025) investigated the dyeing efficiency of dye extracted from teak (*Tectona grandis*) leaves by dyeing it on alum mordanted cotton fabric and tested the fastness of the dyed cotton fabric to repeated washing and different detergents.

CHAPTER- 3

MATERIALS AND METHODS

3.1 PLANT MATERIAL

SYSTEMATIC POSITION

Kingdom : Plantae

Phylum : Streptophyta

Class : Equisetopsida

Subclass : Magnolidae

Order : Caryophyllales

Family : Phytolaccaceae

Genus : *Phytolacca*

Species : *octandra*

Part used : Leaves

Fig. 5: Leaves of *Phytolacca octandra* (L.)

BOTANICAL DESCRIPTION

The family Phytolaccaceae, in the order of Caryophyllales, consists of 17 genera and 125 species, mainly distributed in South Africa and tropical and subtropical America (Vithya et al., 2018). Inkweed, red-ink plant, and dyeberry are the common names of *Phytolacca octandra*(L.). Herbs, shrubs, more or less woody climbers, or trees, alternate leaves, and small bisexual flowers are the members of this family (Rohwer et al., 1993).

Phytolacca octandra (L.) is a weed whose green leaves are used to extract natural dye by the aqueous method. The leaves were collected and cleaned. 5g, 10g, and 15g of leaves were weighed. The cotton, rayon, and polyester were the textile substrates used for the dyeing process. The steps involved were scouring, tannin bath, mordanting, and dyeing.

3.2 METHODS

3.2.1 Collection of plant material and extraction of natural dye

The fresh leaves were collected, (Fig. 2) from the site (Kochi, Kerala, India, specifically at Th419, Eroor, Kochi (Latitude: 9.980375° N, Longitude: 76.334731° E). Cleaned and weighed.

Aqueous method of extraction was carried out to extract the dye from the selected plant. 5 g, 10 g, and 15 g of leaves were used for the dye extraction. The leaves were crushed and grounded with mortar and pestle and distilled water was added to this to make upto 20 ml. The extracted dyes were filtered with Whatman No. 1 filter paper.

3.2.2 Determination of pH

The pH of the extracted natural dye was determined using a digital pH meter.

3.2.3 Selection of textile materials

100% cotton, rayon and polyester yarns were purchased from Thannikkal Textiles, Ernakulam. The choice of textile substrates used in the present study was based on the availability of the fibres and its properties (Mather et al., 2023).

Fig . 6: Fresh leaves of *Phytolacca octandra* (L.)

Fig. 7: Dye extracted from the leaves by aqueous method

3.2.4 Pre-treatment of the textile substrates

3.2.4.1 Scouring

Scouring is the process of washing with mild soap to get rid of contaminants. To maintain the Material to Liquor Ratio of 1:20, cotton, rayon and polyester yarns were boiled for 30 minutes at 40–45^{0}C in a solution that contained 0.5 g/L sodium carbonate and 2 g/L of non-ionic detergent (labolene). After properly cleaning, the scouring material with tap water, it was allowed to air dry at room temperature.

3.2.4.2 Tanning

The cotton fabric was undergone a tannin bath. Tannic acid was used for this. Cotton yarns was treated with 20% tannic acid. Cotton yarns were boiled in 100 ml of distilled water, and to this tannic acid were added and stirred well for 45 minutes and cooled it at room temperature.

3.2.4.3 Mordanting

Without the application of a mordant, natural dyes typically have no affinity for textile fibres. Mordants act as a chemical bridge that binds the dye molecules to a textile fibre through a metal salt, preventing colour fading from exposure to light, rubbing, washing, and other factors (Repon et al., 2017).

Both natural and synthetic mordants were used for a comparison. Tamarind and *Terminalia chebula* were used as the natural mordants, and alum and copper sulphate were used as the synthetic mordants. 0.5%, 1%, and 1.5% concentrations of each mordant were used for mordanting.

3.2.4.4 Dyeing

The pre-mordanted cotton, rayon, and polyester substrates were dyed with *Phytolacca octandra* dye under different concentrations ranging from 5 g, 10 g, and 15 g at room temperature for 24 hours at its natural pH. (T.N Ansari et al., 2022).

Each yarn was dyed, rinsed with water, and allowed to air dry at room temperature after bein g cleaned with a non-ionic detergent.

CHAPTER- 4

RESULTS

4.1 Extraction of natural dye

A brown shade was obtained from the leaves of *Phytolacca octandra* (L.). The brown color dyes was obtained due to natural pigments such as tannins, flavonoids, phenols (Schrand et al., 2020), (Vithya Eswari et al., 2018).

The substrates dyed with this result in different shades of brown. The various shades produced depend on several factors, such as the concentration of dye, the method of extraction, the effect of mordants, and the type of textile substrates.

4.2 Determination of pH

The pH of the extracted natural dye was 5, which was acidic. pH plays a critical role in dyeing processes, particularly in determining shade, uniformity, and dye uptake efficiency. The interaction of pH with dye concentration and temperature significantly affects the final color of the textile. Direct dyes typically require a slightly acidic pH (around 5.5) to achieve optimal dye uptake and color development (Huang et al., 1999).

4.3 Dyeing

Different shades of brown colour was obtained with different mordant concentration and different dyeing concentration (fig. 8, 9, 10). Based on the visual assessment**,** 5g dye concentration showed higher efficiency, and variations depend on the mordants and substrates used.

Fig.8: Dyeing of cotton, rayon, and polyester fabric in dye concentration of 5 g of leaf extract by using various concentrations of mordants

Fig. 9: Dyeing of cotton, rayon, and polyester fabric in dye concentration of 10 g by using various concentrations of mordants

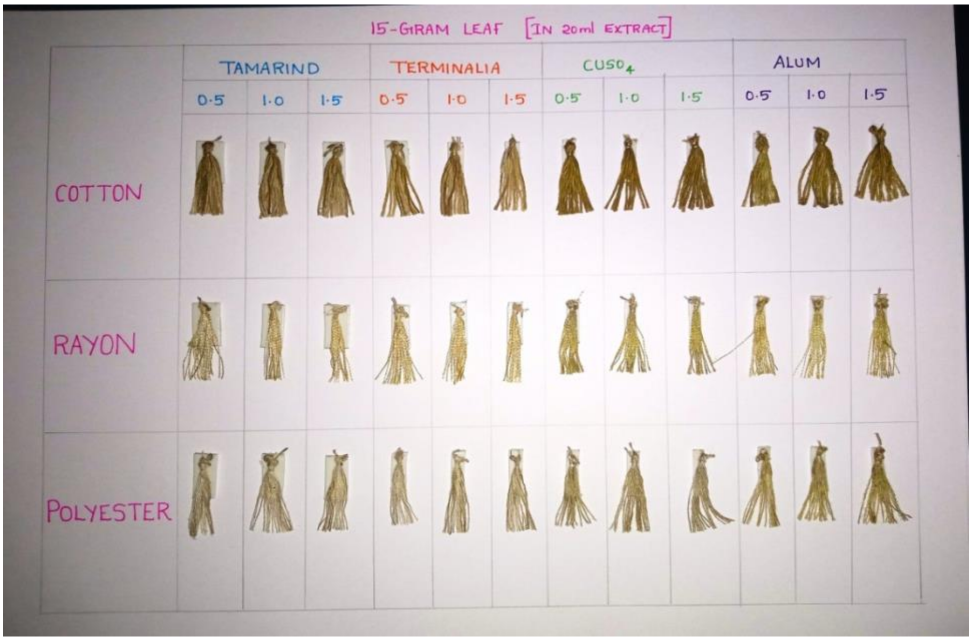

Fig. 10: Dyeing of cotton, rayon, and polyester fabric in dye concentration of 15 g by using various concentrations of mordants

Mordants	Cotton	Rayon	Polyester
Tamarind	Light brown colour	Beige colour	Light beige colour
Terminalia chebula	Brown colour	Golden brown colour	Cream colour
Copper sulphate	Dark brown colour	Dark brown colour	Cream colour
Alum	Yellowish brown colour	Greenish brown colour	Greenish yellow colour

Table 1: Colours produced with different mordants on different textile substrates

4.4 Effect of mordant

Natural and synthetic mordants were used to enhance the colour of the textile substrates. Among them, copper sulphate act as the best mordants by enhancing the colour of the textile substrates into darker shades of brown. Cu (II) ions forms a complex with the natural colouring compounds, resulting in their fixation on the fibre. The higher the concentration of mordant on the fibre, the greater will be the extent of complex formation, which in turn increases colour depth on the fibre (TexNote 2014).

Cotton and rayon show a higher dye absorption property than polyester. Cotton and rayon absorb dyes more effectively than polyester due to their fiber structure. Cotton, being a natural fiber, has hydroxyl groups in its cellulose molecules that form strong bonds with dye

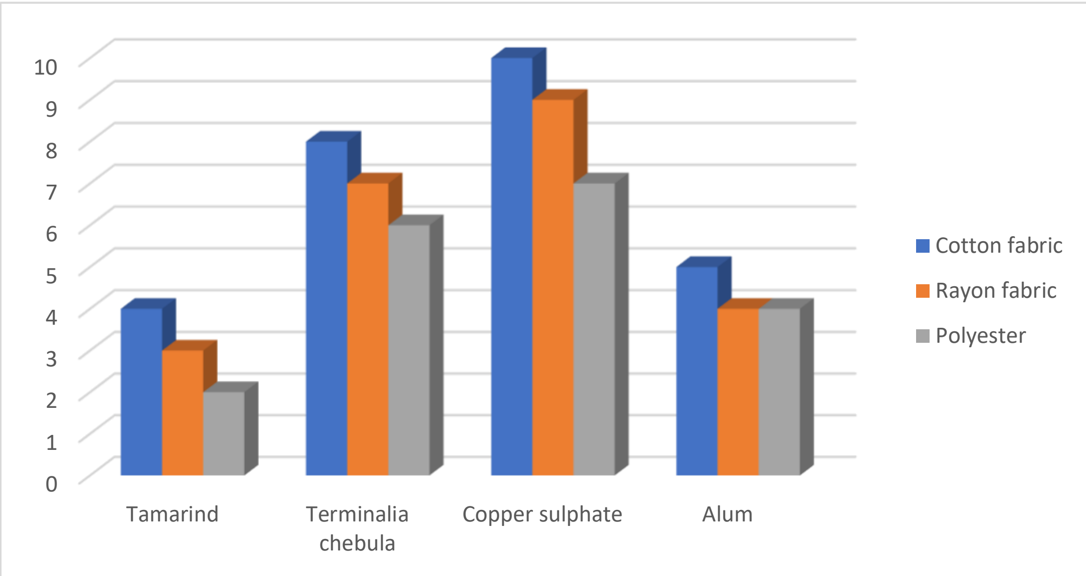

Fig 11: Effect of different mordants on various substrates

molecules. Rayon, a semi-synthetic fiber, also has a similar structure that allows it to bond easily with dyes. In contrast, polyester is a synthetic fiber made from petroleum-based products, which have a non-porous surface and are less receptive to dye absorption. The hydrophobic nature of polyester limits its ability to bond with dyes effectively (Threads Monthly, 2023).

CHAPTER- 5

DISCUSSION

The extraction and application of natural brown dye from *Phytolacca octandra* align closely with the findings from *Ficus amplissima*. Both plant sources are capable of producing brown-colored dyes due to their content of bioactive compounds such as tannins, flavonoids, and polyphenols. Similar results was also obtained from the leaves of *Ficus amplissima* (Kumbhar et al., 2019), outer shells of the (wall nut) Juglans regia (Tutak et al., 2011) and from the leaves of (Henna) *Lawsonia inermis* L. (Qadariyah et al., 2019). Overall, these studies support the relevance of exploring underutilized plants for eco-friendly dyeing. They demonstrate that with proper extraction and mordanting techniques, leaf-based dyes can serve as effective, sustainable alternatives to synthetic dyes in textile processing (Kumbhar et al., 2019).

The present study on the extraction of natural dye from *Phytolacca octandra* leaves and its application to textile substrates aligns with trends in sustainable material use. The natural dye from *Phytolacca octandra* and tannins are plant-derived phenolic compounds that serve as eco-friendly substitutes for synthetic chemicals, contributing to the reduction of environmental pollution and promoting the use of renewable resources. The extracted brown dye from *Phytolacca octandra* showed good affinity for cotton, rayon, and polyester fabrics at an acidic pH of 5. This is comparable to the behavior of tannins, whose extraction efficiency and performance also vary significantly with pH, temperature, and solvent type, they directly influence yield, stability, dye extraction. Tannins are modified or combined with other substances to enhance adhesion to wood or collagen; likewise, the dyeing performance of *Phytolacca octandra* extract may be enhanced by using mordants or pretreatments to improve fixation, fastness, and uniformity across fabric types. The multifunctional potential of tannins such as antimicrobial, antioxidant, and UV-protective properties is relevant when considering the full scope of applications for natural dyes.. Furthermore, while tannins are heavily researched for their roles in adhesives, coatings, and preservatives, the use of *Phytolacca octandra* dye in textiles adds to the expanding scope of plant extracts in functional and aesthetic applications. Both approaches demonstrate the growing interest in replacing petroleum-based and hazardous chemicals with biodegradable, non-toxic, and renewable alternatives (Shirmohammadli et al., 2018).

Research on the extraction of natural dye from the leaves of *Phytolacca octandra* introduces a relatively unexplored and potentially more sustainable source of brown dye. Utilizing leaves as the dye-bearing part offers ecological advantages by allowing for regenerative harvesting without harming the plant's survival. While traditional brown dyes like catechu are mainly tannin-based, *Phytolacca octandra* contain polyphenolic compounds such as flavonoids or tannins, which also have the potential to bind effectively with mordants and produce stable brown shades. The *Phytolacca octandra* performs well on cotton, rayon, and polyester, with mordants, it serve as a practical alternative to more traditional sources (Saxena et al.,2014).

CHAPTER – 6

CONCLUSION

The current study has successfully attempted to extract the natural dye from the leaves of *Phytolacca octandra*. The dye extraction process, optimized through variations in temperature, time, and mordant types, yielded a range of shades from light to reddish-brown. Among the tested yarns, cotton and rayon demonstrated superior dye uptake and retention compared to polyester, indicating their compatibility with natural dyeing. The use of both natural and synthetic mordants significantly influenced the final color and fastness properties, showcasing the importance of mordant selection in natural dye applications.

The study highlighted the eco-friendly nature of *P. octandra* dye, promoting its use as an alternative to harmful synthetic dyes. The research supports broader adoption of sustainable practices in the textile industry, particularly in fashion and artisanal crafts, while also aligning with global efforts to reduce environmental pollution. The study paves the way for integrating traditional dyeing methods with modern sustainable technologies, encouraging environmentally responsible textile production and supporting small-scale industries and local artisans.

In conclusion, this project not only contributes to the scientific understanding of natural dyeing but also emphasizes the economic and ecological potential of *P. octandra* by adopting eco-friendly method of extraction. *Phytolacca octandra* is a fast-growing, invasive weed. This is one of the first successful attempt on dyeing the yarns from *P. octandra* leaves. Further research focused on enhancing dye stability, exploring its bioactive properties, and scaling up production could unlock new commercial opportunities. As a renewable, biodegradable, and non-toxic dye source, *P. octandra* stands as a promising solution for the future of sustainable textiles and green innovation.

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