Aloevera and Banana Sap as Biomordant for Dyeing of Bamboo Fabric with Natural Dyes

A MAJOR PROJECT REPORT
SUBMITTED IN THE PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE
IN
CHEMISTRY

SUBMITTED BY

MANIK PULYANI
(2K21/MSCCHE/29)

SARANSH CHAUHAN
(2K21/MSCCHE/59)

Under the supervision of

PROF. ROLI PURWAR

DEPARTMENT OF APPLIED CHEMISTRY
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering Bawana Road, Delhi-110042

CANDIDATE'S DECLARTION

I Manik Pulyani (2K21/MSCCHE/29) and Saransh Chauhan (2K21/MSCCHE/59) students of M.Sc (Chemistry) hereby declare that the project Dissertation titled " **Aloevera and Banana Sap as Biomordant for Dyeing of Bamboo Fabric with Natural Dyes** " which is submitted by us to the Department of Applied Chemistry, Delhi Technological University, Delhi in the partial fulfilment of the requirement for the award of the degree of Master of Science, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title or recognition.

Place: Delhi

Date: May, 2023

MANIK PULYANI (2K21/MSCCHE/29)

SARANSH CHAUHAN (2K21/MSCCHE/59)

Department of Applied Chemistry
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I/We hereby certify that the Project Dissertation titled " **Aloevera and Banana Sap as Biomordant for Dyeing of Bamboo Fabric with Natural Dyes** " which is submitted by Manik Pulyani(2K21/MSCCHE/29) & Saransh Chauhan (2K21/MSCCHE/59), Department of Applied Chemistry, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the Master of Science, is a record of the project work carried out by the student under my supervision. To the best of my/our knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date: May, 2023

PROF. ANIL KUMAR
(Head of Department)

PROF. ROLI PURWAR
(SUPERVISOR)

ACKNOWLEDGEMENT

The success and final outcome of this project required a lot of guidance and assistance from many people and We are extremely fortunate to have got this all along the completion of this project work.

We wish to express our gratitude towards my project supervisor, **Prof. Roli Purwar**, Department of Applied Chemistry, Delhi Technological University, who provided us a golden opportunity to work under their able guidance. Their scholastic guidance and sagacious suggestions helped me to complete the project on time

We wish to thank **Prof. Anil Kumar**, Head of the Department of Applied Chemistry, Delhi Technological University for his constant motivation.

We are thankful to and fortunate enough to get constant encouragement, support and guidance from all teaching staffs of Department of Applied Chemistry, which helped me in successfully completing my project work. We are also thankful to PhD scholars for their constant support and motivation.

Finally, yet importantly, we would like to express our heartfelt thanks to our beloved family and friends who have endured our long working hours and whose motivation kept us going.

MANIK PULYANI **SARANSH CHAUHAN**

ABSTRACT

As synthetic dyes have dominated the market for the last sixty years, natural dyes and natural mordants are being rediscovered by consumers. With the current environmental and economic consciousness, research in this area should be focused on natural mordants for dyeing textiles. The purpose of this article is to present an in-depth analysis of the mordants used to dye textiles with natural dyes as well as methods for and types of natural mordants, colour fastness properties of natural dyes, and classification of natural mordants based on their chemical structure. This paper also discusses the different classes of mordants used for fixing the colouration of textile substrates, their mechanism, and the sources of the mordants. Natural mordants are a good alternative to synthetic mordants for textile dyeing and can be used to overcome the challenges associated with synthetic dyes in textile dyeing.

In the present work, a natural mordant Aloevera and Banana Sap was extracted and used alone and in combination with each other in Bamboo fabrics with Rheum Emodi and Rubia Cordifoilia, Yellow and Red natural dye to make the Bamboo Fabric Colourful which is already a highly breathable and anti-allergic fabric. The colour of the Bamboo Fabric revealed bonding between Bamboo fabric and green materials. The colours of the Bamboo fabrics dyed with Rheum Emodi and Rubia Cordifolia extracted was quantified in terms of CIELab (a*, b* & c*) and K/S values. The effects of different treatment on fastness properties including Light and Wash fastness were assessed by ISO standard test method and Simultaneous mordanting gave best result in both fastness properties as well as higher K/S values.

Keywords

Textile, Natural Mordants, Natural Dye, dyeing, Aloevera, Bamboo Fabrics, Banana Sap.

CONTENTS

List of Table & Figure Captions

1. INTRODUCTION & OBJECTIVES OF WORK

Researchers have found that colors have a greater impact on your mood. Colours are often associated with happiness for some people. We will feel happier when we wear bright colors like yellow, orange, and red, etc. Humans associate different meanings with different colors. There are different emotions and values associated with it.

A dye is a material that plays an important role in the dyeing process for textiles, fibers, or fabrics [1]. There are two types of dyes that can be used in dyeing: natural and synthetic. It is important to note, however, that overuse of synthetic dyes in textile production causes environmental problems [2,3]. Chemical dyeing and textile processing cause water pollution that poses health risks to humans. Due to their biodegradability and renewability, natural dyes have recently gained in popularity [4,5]. Natural dyes have gained much attention in recent years for use in textiles, food and drugs [6].In dyeing textiles, particularly cellulose fibers, most natural dyes lack substantivity, so mordants must be applied before dyeing. Mordants function by creating a coordinating complex between fibers and natural colorants. This improves the color intensity and ensures adequate fastness. Natural dyes have also been dyed with ultrasonic assistance [7,8,9,10,11].

In recent years, consumers have become more aware of the importance of buying safe products. In order to avoid toxic metal mordants, extensive research has been conducted on natural dyeing and natural mordanting [12, 13].Several eco-friendly biomordants have been recommended by researchers, including chitosan [14,15], chlorophyll [16] and tannins [17,18].

A mordant is a substance that binds textile fibers and dyes, although there is no great affinity between the fiber and the dye. The presence of mordant in cotton can enhance its color by compensating for the absence of active sites that allow dye molecules to settle in fibers [19]. An oil-based mordant, a metal-based mordant, and a tannin based mordant are the three most widely used mordants in dyeing and finishing processes [20,21]. A comprehensive analysis of mordant types and mordanting techniques has been conducted in order to determine the efficiency of natural textile dyeing [22].

Thus, eco-friendly antibacterial agents derived from plants and animals should be researched and developed for textile applications [23,24]. Tannins have been widely used as natural mordants since the first colorations appeared on textiles. In natural dyeing, myrobolan, commonly known as Harda, is important natural tannin used as mordant [25]. It is possible to introduce additional hydroxyl and carboxyl groups into fibers by first mordanting with natural tannins, which increase the fibers' affinity for different natural dyes and facilitate the fixation of natural colorants to fibers through the formation of complexes with dyes. The tannins in tannins act as astringents and antimicrobials [26,27].In previous review papers researchers discussed mainly about the natural colourants to provide colours to textile and they classified natural colourants on the basis of structure. We have discussed the natural mordants along with natural colourants (Dyes) and we also came across classification of mordants on the basis of structure. As a result, we can now produce colours using eco-friendly natural mordants, rather than old technology. To conclude, this paper provides a scientific overview of natural mordants derived from plants, along with a classification of them.

2. LITERATURE REVIEW

2.1. Dyeing in Textiles:

2.1.1. MORDANTS:

Mordere is the Latin word for "bite". Mordants form a chemical bond with natural colorants as well as being able to fix themselves to fibres. As a result, natural dyes are absorbed and fixed better, and the dyed fabrics are more resistant to bleeding and fading, which improves their fastness properties [38,39].This complex can be formed by either the application of the mordant and then dyeing, or by combining the two. Additionally, the dyed material can be mordanted after it has been dyed. A variety of mordants are available, including: such as metallic, oil, and tannins [40]. The solution used for mordant preparation significantly improves the properties of naturally dyed fibers, such as their wash-fastness and light[41].Metal salts are used as mordants, but only a small amount is fixed in textiles, leaving the rest as effluent, which causes contamination of soil and water [42,43,44].

2.1.2. Techniques of Mordanting:

(i) Pre-Mordanting:-The substrate is first mordanted and then dyed. It is also known as on-Chrome

(ii) Simultaneous-Mordanting:-The dye bath is treated with a mordant during the dyeing process. It is also known as eta-chrome.

(iii) Post-Mordanting:-A mordant is applied to dyed material. It is also known as after-chrome.[41]

2.1.3. Tannin (Natural Mordant):-

This name is derived from the french word ‘tanin’. Tannins occur naturally in many plant parts and can form crosslinks between macromolecules and proteins, including fruit, bark, wood, roots, plant galls, and plant leaves [45].Natural dyes can be made from neem bark because of its high tannin content [46,47,48,49].These compounds are characterized by high molecular weight and are known to have various polyphenols.
They are mainly used in the preservation of various leather products, such as leather glues, stains, mordants, and mordants. Cotton, on the other hand, has a low affinity for most natural dyes. The presence of tannins in cotton helps retain the color of the finished product.[50]. In earlier research, tannin-rich plants like Quercus castaneifolia [51] , Pomegranate [52], Terminalia chebula[53], Rhus coriaria[54] and Eucalyptus [55] were used for dyeing textiles.

The various plant parts that are commonly used include the bark, leaves, fruit pods, roots, and plant galls. Tannin is a type of water soluble phenolic compound that can form a cross link between macromolecules and proteins. It has a high molecular weight and is composed of various phenolic hydroxyl groups.

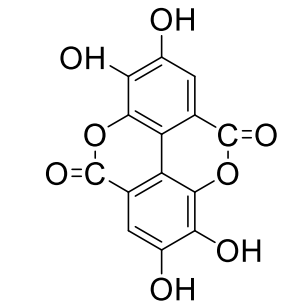
Tannins are molecular compounds that have a molecular weight of 1701.22 and a melting point of 220C. In general, they refer to multiple compounds rather than a single one. Instead, They consist of a wide range of organic compounds with diverse chemical compositions [40]. $C_{76}H_{52}O_{46}$ tannin formulae. Since natural mordants have antibacterial properties, they have gained a lot of attention in recent years [56,57].

Tannings are classified into two types based on how and with what kind of phenolic nuclei they contain. Tannins that can be hydrolyzed are classified as hydrolysable tannins, while tannins that can be condensed are classified as condensed tannins [40].

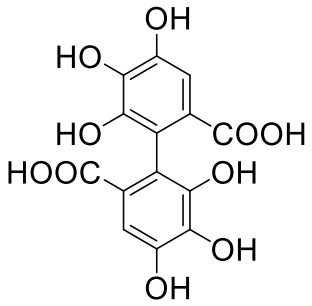
2.1.4. Hydrolysable tannins:

Polyphenolic compounds called hydrolysable tannins (HTs) have been implicated in plant-herbivore interactions. They are heterogeneous groups of polyphenols.
It has been demonstrated that the chemical structures of these organisms differ in their biological activity. An important measurement of tannin bioactivity is protein precipitation capacity, which varies greatly between tannins in general.[58]

Often called pyrogallol tannins, hydrolysable tannins are obtained by dry distillation of phenolic acids to generate their pyrogallol derivatives. By reacting ferric chloride with hydrolysable tannins, blue colour is produced [59].



Hexahydroxydiphenic Acid



Ellagic Acid

Figure 1: Some examples of hydrolysable tannins

2.1.5. Condensed Tannins:

A condensed tannin is formed when flavan-3-ol subunits have been linked in an oligomer or polymer to form a condensed tannin. In addition to their astringent property which reduces feed intake, condensed tannins pose some nutritional problems for ruminants. There are a variety of flavan-3-ol subunits found in Condensed tannins, butgallocatechin, catechin, epigallocatechin, epicatechin and are the most commonly occurring. Among flavan-3-ols. The most important component is a group of polyflavonoids known as condensed tannins [60.61].

The substituents on the C-2 and C-3 C-rings differ in terms of substitution patterns and stereochemistry(circled in figure below).[62]

The condensed tannin in the solution is also soluble in water and gives green colour when ferric chloride is added. [63]

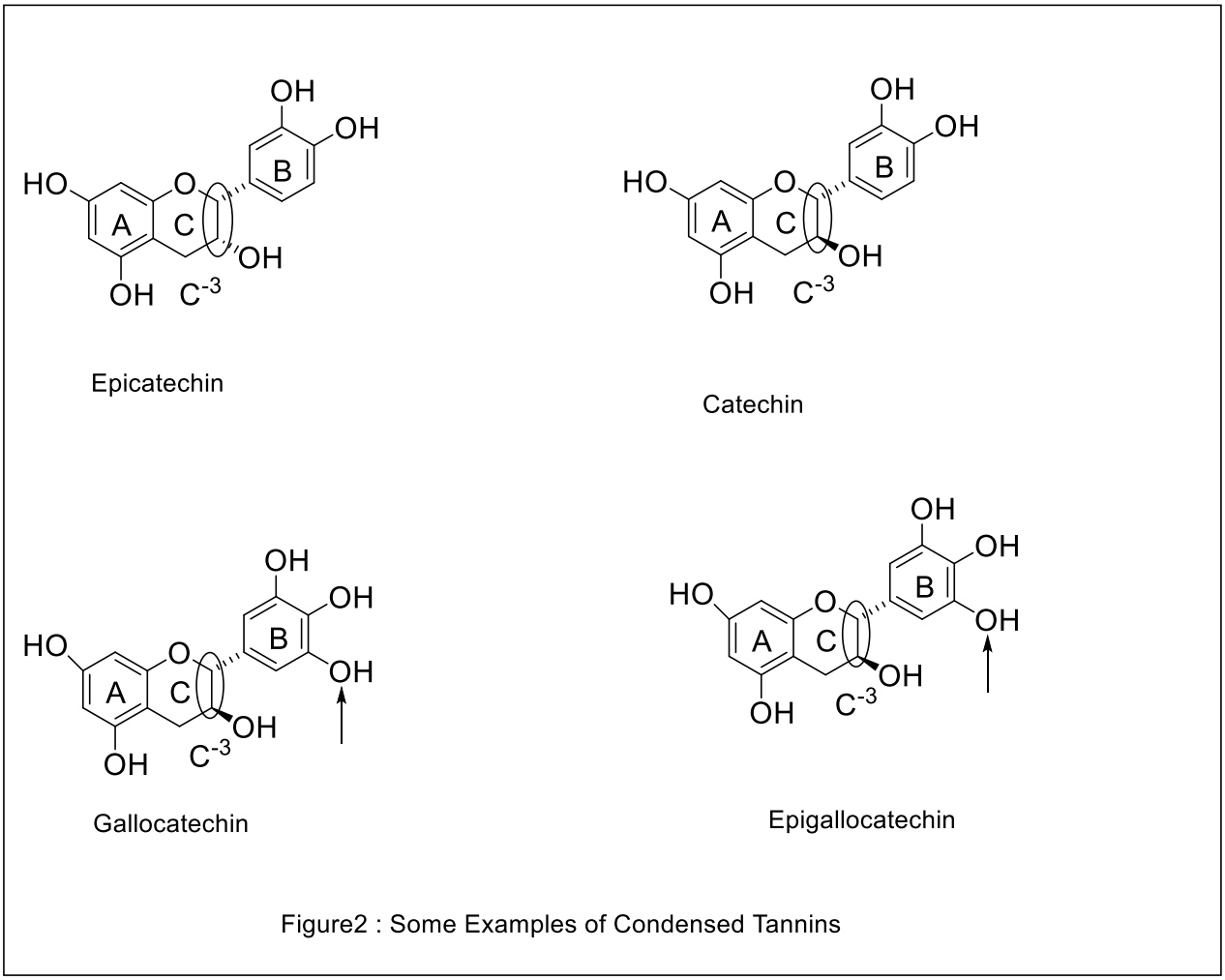


Figure2 : Some Examples of Condensed Tannins

2.2. Textile substrates bonded with tannin:

2.2.1. They form 3 types of bonds with Cellulose (cotton & viscose rayon) and Proteins (wool & silk).

1. **Hydrogen Bond:** A natural dye is formed when the free amino and amide groups of the proteins are combined with the phenolic hydroxyl groups found in tannin.

2. **Ionic Bond**:The natural dye contains anionic groups that form an ionic bond with the protein cationic groups.

3. **Covalent Bond:**This is formed when the tannin's quinones or semiquinones react with any protein or polymer with suitable reactive groups.[64]

2.2.2. Resources for natural tannins:

The amount of tannin present in different types of plants& Vegetables act as a natural tannin. The amount of tannins are given in the table.[65].

Table 1 :- Some Sources of Tannins in Plant Parts			
Name	Botanical Name	Source	Chemical
Myrobolan	Terminalia Chebula Retz	Ripe fruit	_
Algarobilla	Caesalpina Brevifolia	Pods	Ellagitannin
Babul	Minusops Elengi	Bark	-
Divi-Divi, Libi-Devi	C. Coriaria wild	Pod	Ellagitannin, Free ellagic acid
Tanner's Sumac	Rhus Coriaria L	Leaves	Hydrolysable

Table 2:- Percent Composition of tannin in Vegetable source			
Sources	Tannin (%)	Sources	Tannin (%)
Chestnut Wood	8-13	Divi-divi	40-50
Myrobolan	30-40	Mangroce Cutch	55
Que Bravo	20-23	Wattle bark	37-40

Valonia	40	Gambia	35-40
Gall nuts (Hemlock)	8-12	Eucalyptus	60-63

2.3. Characteristics of Tannins:

Amorphous compounds, tannins can not crystallize. Aqueous solutions, ethyl alcohols, glycerols, acetones, as well as diluted alkalis, dissolve them. A sharp astringent taste is associated with their aqueous solution. In most cases, tannin compounds precipitate, tin, glycosides, gelatin, lead, alkaloids and copper salts. When potassium ferricyanide and ammonia are combined with tannins, they produce a deeply red color. Hydrolyzable tannins produce blue-black precipitates in fresh ferric chloride solution, while condensed tannins show brownish green precipitates.

2.4. Application of Tannin in textiles:

There are many uses for tannins, including dyeing, ink manufacturing, sizing paper and silk, and printing fabric .There are several reasons why tannins are important for textile dyeing.It is important that they produce mordants for dyeing cotton and linen, which are essential for the dyeing of vegetable fibres.Another factor is that they are often dyed with Red, violet, Yelow, and Orange colorants, whose pigments strengthen their own color. It is easy to wash and light fasten materials dyed with tannins.The Indian vegetable dyers and printers have been using harda powder as a mordant since ancient times and so far there has not been any commercially viable substitute for harda that can replace the same effect.

A lot of studies and reports showed the various use cases of tannin that help the fabric to be printed like after treatment with Oil & removal of starch , Multani style was mordanted with Myrobalan.[66].Textile dyes use Divi-divi fruit (Caesalphiniacoriaria) fruits as mordanting agents [63]. Previous studies use different types of mordants like alum, iron,

tin,copper sulphate, potassium dichromate,harda ,tannic acid in which harda and tannic acid are examples of natural mordants for dyeing wool with turmeric.As a result of themordant application, the dyed samples had increased a* and b* values.Harda mordanted samples had higher values than many synthetic mordantes.Alum, tin, and iron mordanted samples, as well as harda mordanted samples, demonstrated better wash fastness than harda mordanted samples. As described in [67], woollen cloth was treated with tannin-containing solution before printingwith thickener and Synthetic mordant, resulting in a woollen cloth dyed with vegetable dyes.

2.5. Classification of natural Mordants:

Mordants derived from natural sources can be categorized into several types based on their chemical functional group structure.

2.5.1. Based on Chemical Structure:

Harda, tamarind, pomegranate peel, orange peel, and tannic acid are some of the most commonly available natural mordants.

2.5.1.1. Pomegranate Rind:

Components: Gallotannin and ellagotannins.

A galllotannin is an organic compound containing galloyl units or their meta-depsidic derivatives bound to diverse polyols, catechins, or triterpenoids.Glucose and gallic acid are produced when gallotannins are hydrolyzed by acids, bases, or enzymes.Ellagitanins are characterized by at least two galloyl units that are C–C coupled, and without any glycosidic linkage to catechins. By C-C coupling the polyphenolic residue with the polyol unit, the hydroxydiphenoyl residue undergoes lactonization to produce ellagic acid, which is difficult to hydrolyze.Despite not being hydrolysable, ellagitannins are still classified as hydrolysable tannins for historical reasons.[68]

Upon hydrolysis with acid or enzymes, the tannins found in Acacia arabica Willd yield water-soluble products.In this study, the outermost bark of matured Acacia arabica Willd

(referred to hereafter as Acacia arabica) was removed without damaging the plant and then cut into small pieces.After that, the chips were dried.South Gujarat region was used to collect the bark skin of Acacia arabica for the present investigation.[69]

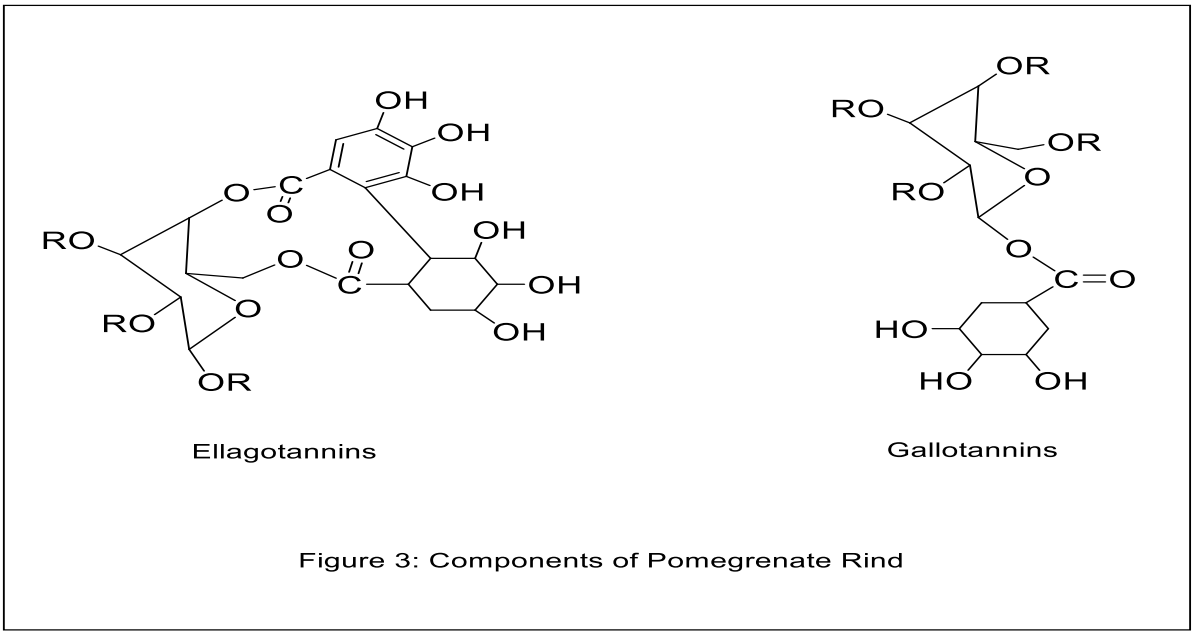
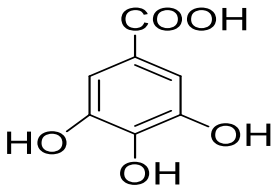


Figure 3: Components of Pomegrenate Rind

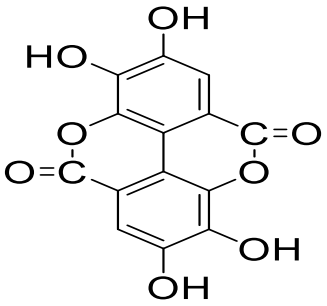
2.5.1.2. Babool:

Component: Acacia Arabica Willd Bark (Gallic Acid, Ellagic Acid)

Upon hydrolysis with acid or enzymes, the tannins found in Acacia arabica Willd yield water-soluble products.In this study, the outermost bark of matured Acacia arabica Willd (referred to hereafter as Acacia arabica) was removed without damaging the plant and then cut into small pieces.After that, the chips were dried.South Gujarat region was used to collect the bark skin of Acacia arabica for the present investigation.[69]



Gallic acid



Ellagic acid

Figure 4 : Components of Babool

2.5.1.3. Amla:

Component: Stem Bark(8%-9% tannin)

It is usually given in the form $C_{76}H_{52}O_{46}$, which is comparable to decagalloyl glucose, but it consists of a mixture of polygalloylquinic acid esters or glucoses, and the amount of galloyl moieties per molecule varies according to how the tannic acid is extracted from the plants. Minerals and asparagic acid are concentrated in the fruit to a greater extent. Among the total asparagic acid, 14.6% are asparagine, 29.6% are 2aminoglutaric acid, 8.1% are pyrrolidine-carboxylic acid, 5.3% are lysine, and 5.4% are asparaginate. When dried and liberated from nuts, the soft delicate part of the seed contains 1.33% tannin, 1.33% tannic acid, 13.75% gum, 17.08% c cellulose, and
4.12%mineral matter.[70]

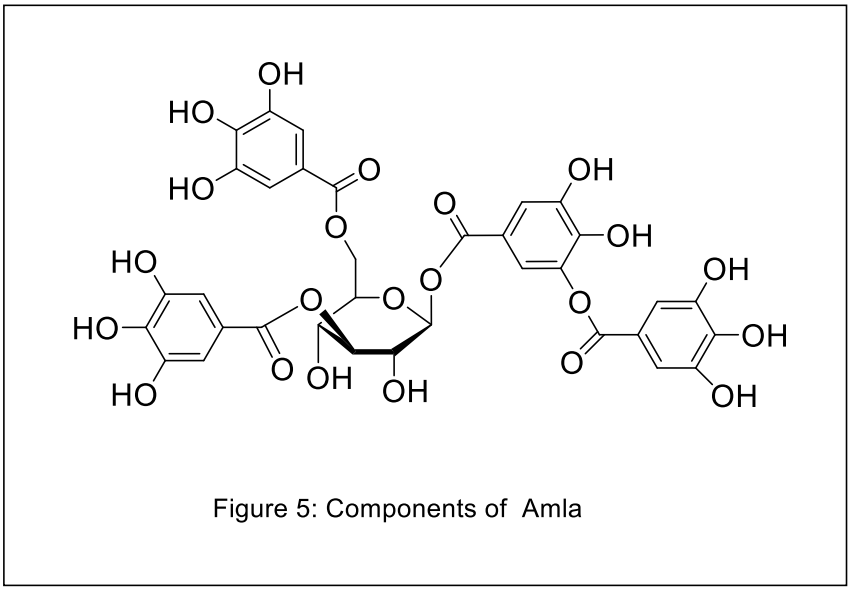


Figure 5: Components of Amla

2.5.1.4. Chestnut:

Components: Chestnut bark and timber(contains 75% tannin)

The chestnut extract is one of the most important vegetable tannins.By extracting the bark and timber with hot water and spray-drying the solution, the extract is prepared. About 75 percent of the extract contains tanning agents.There is a significant amount of castalagin, as well as smaller amounts of castalin, vescalagin, and vescalin.

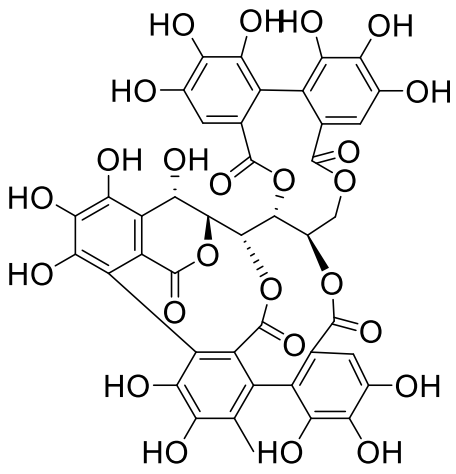


Figure 6: Components of Chestnut

NATURAL MORDANTS	DYEING FIBRE	DYE USED	REFERENCE
1.Harda& Tamarind seed	Wool	Turmeric henna	[71]
2.Salixalbaho(willow) & Populusdeltoids bartam exmarsh(wood ash)	Wool & Cotton Silk &Pashima	Quercus roburL.(fruits cups)	[72]
3.Harda powder & Pomegranate & Orange Peel & Amla Powder	Wool	Carica Papaya L. dry powder	[73]
4.Rare ea rth metals(Chlorides) (ecofriendly)	Ramie	Natural dye	-
5.Harda& Amla & pomegranate Orange &	Wool	Kalanchoi-pinnata, Papaya, Peepal, Banyan	[74]
6.Emblicaoffianalus G. dried fruit tannin	Cotton & Silk	Natural dye	[75]
Potassium 7.bitartarate& Gallnut	Wool & Silk &Polyster& Cotton	Madder(Rubia ticterium)	[76]
8.Tannic acid & Pomegranate peel	Linen & Silk	Vitus vinifra l. leaves	[77]
9.Zeera, Neem, Ilaichi,	Cotton	Arjuna Bark	[78]
10.Oak-tannin	Yarn	Madder weed	[79]
11.Iris Germanica, valix, Pomegranate, roseberry leaves	Wool	Prina (by-product of Olive oil)	[80]
12.Harda(15%)	Cotton & Khadi	Babul bark	[81]
13.Harda& Alum	Cotton & Khadi	Red sandalwood waste	-
14.Pumpkin extract	Natural Yarn (Wool)	Reesdalutwa ,Madder	[82]

15.Alum & mild mordants.	Silk	StictaCowntalichen	[83]
16.Acacia extract & pomegranate extract.	Silk	Waste black Tea leaf (BT) based tannin	[84]
17.Yellow myrobalan & Black myrobalan	Wool & Natural modern fibre	Iranian madder	[79]
18.Bio mordants	Cotton	Bittergourd leaves extract	[85]
19.Alum	Polyster/Viscose blended fabrics	Juglausregia(walnut shells)	[86]
20.Tannic acid & alum	Cotton fabrics	Green Coconut soft husk	[87]
21.Myrobalan & Potash alum extract	Jute Fabrics	Manjistha. Annatto, Ratanjot	Pan-2018
22.Aloevera	Hair dye	Walnut green bark	Tavoos-2017
23.Pomegranate peel & Myrobalan	Wool	Madder &Ruseda	[82]
24.Waste of sugarcane bagasse, wheat bran, rice husk	Cotton	Same as mordant	[88]
25.Tannins(Qeurcusspp, Enterolobiumcycloarpun, Caesalpinia coriarian.	Cotton	Cochineal extract	Gabriela-2010
26.Bark of terminalia Arjuna	Cotton	Tannic acid & Alum	Keka-2016

2.6. An overview of natural dyed textile color fastness:

It is fundamental for coloured textiles to be fast when exposed to the conditions encountered during the coloring process and when they are used later on [40]. (Colour

fastness is usually determined by grey-scale testing, either by removing the colour from the original sample or by staining adjacent white material. Colour fastness is important for all textiles, but Rub fastness, Light fastness, and Wash fastness are the very important ones [89, 90].

2.6.1. Light Fastness:-

Many natural dyes, especially those extracted from flower petals, have poor to average light fastness. Consequently, a large amount of work has been done to improve natural dyed textiles' light fastness [91]. According to the previous work,On dyed textiles dyed with henna, harda, catechu and babool, henna exhibited fairly good light fastness, while catechu showed very good light fastness.Natural dyed jute textiles improved by one to half unit in light fastness when treated with 1% benztriazole in specific conditions [89].A combination of natural tannins and metal mordant bonding has greatly reduced the rate of fading.By using this eco-friendly process, the dyed fabric also provided good antimicrobial protection [40].A number of researchers have examined the lightfastness properties of natural dyes on natural fibers [92,93].

2.6.2. Wash Fastness:-

Several factors influence dye wash fastness, including dye diffusion rate and dye state inside fibers.There may be a slight change in hue in some natural dyes after washing, which is caused by the alkaline nature of the washing solution.There is a good to excellent wash fastness of the marigold dye; this is due to the dye's tendency to aggregate within the fibers[89].The logwood dye and the indigo dye, however, have better fastness when used on different textiles.Colour fastness varies with dye type, shade, shade depth, dyeing process, and most importantly the washing mixture, as well as the dyeing process. A number of researchers have examined the Wash fastness properties of natural dyes on natural fibers [94].

2.7. Conclusion:-

There is a lack of Scientific Reports and Systematic reviews on the Textile Dyeing with ecological natural mordants. In the present day, people increasingly recognize the benefits of using ecological natural mordants because they are biodegradable and environmentally friendly. There is no toxicity, no allergic reaction, no carcinogen, they are abundant, and they are renewable. The properties of natural mordants are, however, comparable to synthetic mordants in most cases, according to detailed scientific studies. By selecting the right natural mordants and extraction methods, along with best technologies and ecological processes, fastness properties can be improved. It is therefore important to increase research and development efforts to produce natural mordants that are comparable to some of the highly rated synthetic mordants.

3. EXPERIMENTAL OR MATERIAL & METHODS

3.1. Introduction

Human life has been enriched by natural dyes since time immemorial. Food, textiles, printing, painting, and printing materials are all colored with these dyes around the world. As synthetic dyes and synthetic mordants became more prevalent, natural dyes and natural mordants suffered a setback. Due to environmental concerns and pollution control regulations, dyeing textiles with natural dyes as well as natural mordants are gaining popularity. The natural dyes and mordants used in these fabrics are not harmful to the environment and do not causes skin disease when they are worn [102]. In order to prevent the dye from fading when washed and sun-dried, however, natural dyes should be used with mordants, which are metallic salts of aluminum, iron, chromium, copper, among others, for ensuring sun and moisture fastness. By forming coordination bonds with the dye molecules, the metal ions of these mordants can act as electron acceptors for electron donors [106]. But again the environmental constraint comes into picture in the use of metallic mordants. It is becoming increasingly popular to use biomordants as a substitute for metallic mordants. Biological mordants that come from vegetation are chemically structured with metal ions or tannins to anchor natural dyes to textiles [102]. The determination of banana sap's chemical composition has been made in this article. Tannin has beautiful dye fixation properties in its chemical composition. As tannin binds to free amino and amido groups in proteins, it forms hydrogen bonds with their phenolic hydroxyl groups. As amorphous, non-crystallisable compounds, tannins show acidic reactions in their aqueous solution [103]. Dye is fixed by tannins present in banana sap and alovera extract. In this research paper the use of natural mordants with the natural dyes is shown and the properties like wash and light fastness is observed. Two natural dyes-*Rheum Emodi* (Apsara Yellow Dye) and *Rubia Cordifolia* (Turkish Red Dye) are used to dye the bamboo fabric with the help of two natural mordants which is Banana Pseudostem sap and Alovera Extract.

3.2. Mordants

The process of mordanting involves adding chemicals to the textile to create a chemical bridge between it and the dye [109]. Mordants are the substances which creates an affinity between the fiber and the dye. Mordant ions serve as electron acceptors, which enable them to form co-ordinate bonds with dye molecules, making them insoluble in water [106]. Mordants were traditionally found in nature. Acids, such as oxalic acid in rhubarb leaves, may have been used in conjunction with alkali mordants, such as wood ash or stale urine. There are several types of mordants, most of which are prepared in solutions and sometimes with the addition of an 'assistant' that enhances the fixing of the mordant to the fiber. In most cases, alum is used as an additive or assistant to cream of tartar as a mordant.

There are three types of Mordants are as follows:-

3.2.1. Metallic mordants

3.2.2. Tannins or Tannic acid (Natural Mordants)

3.2.3. Oil Mordants

3.2.1. Metallic Mordants

In the past, mordants were primarily composed of naturally occurring metal salts. However, mordants are nowadays made with aluminium, chromium, iron, copper, and tin metal salts and they are called Metal Mordants. The most common mordants are alum, Stannous chloride, copper sulphate, Potassium dichromate and ferric sulphate [107].

3.2.2. Tannins or Tannic Acid (Natural Mordants)

'Tannin' refers to a wide variety of natural polyphenols and is derived from the French word 'tanin' (tanning substance) [108]. Preserving leather is the primary function of tannins. As well as glues and stains, they are used in mordants and glues. It is commonly found in bark, fruit, and galls of plants, as bitter and astringent excretions. Tanning is accomplished either directly or by extracting tanning substances and then employing them in a concentrated form [107]. Tannin’s structure can be divided into two distinct classes according to the type of phenolic nuclei it contains and how it is linked. Hydrolyzable tannins are the first class, while condensed tannins are the second. Tannins are not comprised of only one compound. There is a wide range of organic substances that differ greatly in their chemical compositions and reactions [108].

3.2.3. Oils Mordants

To dye turkey-red color, oil mordants are mainly used with madder. Mordants, such as oil-mordants, are used primarily to form a complex with alum. Water and cotton do not have an affinity for alum, therefore it can easily be washed out of fabrics treated with it. There are fatty acids and their glycerides naturally present in the oil such as palmitic, stearic, oleic, ricinolic, etc [107-108].

3.3. Banana Sap as a natural mordant

Bananas (*Mimosa pudica*) are commonly found in India. Fruit is often harvested from banana trunks and then thrown away. Waste material can be biodegraded. The Indian banana industry cultivates about 7.1 lakh hectares of land, yielding 26.2 million metric tons of fruit and contributing 14.7 percent to global production [102]. Banana fruit production generates a large amount of biomass, or pseudo-stems, which are discarded as waste or thrown into the fields as waste. Pseudo-stems are materials without wood and trunks. During pseudo-stem formation, a thick, dusty-brown liquid called banana pseudo-stem sap is naturally produced. From one hectare of pseudo-stem, it is possible to extract 1500-20000 liters of sap. Tannin, phenols, and aromatic amino compounds were detected in sap phytochemical analysis [103]. In recent years, pseudo-stem sap has been discovered to be a biomordant, fire retardant, as well as having natural coloring properties [104]. The Banana Pseudo sap can also be used to treat stings and bites, blood arthritis, diabetes, blood pressure, skin nourishment, and arthritis [105].

3.4. Aloevera as a natural mordant

It is well known that textile effluent is a major source of pollution of water and the environment in general. Biodegradable textiles and non-polluting textile finishing products are in demand due to increasing respect for nature. It is of major importance to protect and improve the environment. This is beneficial to the well-being of people and the economic development of the entire world. Its fumaric acid content makes aloe vera gel antimicrobial. Staphylococcus aureus, Streptococcus, Escherichia coli, and Salmonella were tested and found to be effective against this product. As a result, both gram plus and gram minus bacteria would be efficacious against it. A variety of studies have also investigated the antifungal activity of Aloe vera. There has been evidence that

it is effective against Candida albicans and Trichophyton rubrum, as well as the presence of various types of fungi [109].

3.5. DYE:

In textiles, cosmetics, leathers, plastics, printing, and rubber industries, dyes are used to color their products. Anions, cationics, and non-ionic dyes are the most common categories of dyes. As far as dyes used in industries are concerned, textile industries are top of the list when it comes to coloration of fibers with dyes. Textile dyeing involves applying dyes or pigments to textile materials to achieve a desired color and color fastness. Dyes can be produced from natural or synthetic sources as shown below [110].

3.5.1. Synthetic Dyes:-

The textile processing industry is the largest user of synthetic dyes, among many others. Most colors seen today are synthetic dyes, which are widely used in a number of industries to dye and print. Synthetic dyes are usually named based on their chromophoric groups. There are a few exceptions to this rule, but most of the synthetic dyes are aromatic organic compounds, and they can be classified in two groups: cationic dyes (basic) and ionic dyes (acidic).It is known that pigments reflect only certain wavelengths of visible light. Their color is enhanced by this. Colors are provided by pigments, which are found in plants, corals, and even animal skin. It is more important for pigments to absorb certain wavelengths of light than to reflect them. In plants and other autotrophs that make their own food using photosynthesis, pigments are useful because they absorb certain wavelengths of light [110].

3.5.2. Natural Dyes:-

A natural dye is derived from organic compounds that found naturally in plants, animal, insects, minerals. It is the absorption of light in the visible region of 400-800 nm that gives rise to these colors in organic and inorganic molecules (pigments).To display the variety of colours, the dye-producing plant contains various chromophores that contribute to the absorption of light. The majority of natural dyes are non-substantive and must usually be applied to textiles by a mordant, which is usually a metallic salt, which is able to bind both the colourant and the fibre. Several natural dyes are non-toxic as well. Mutagenic effects have been observed with certain natural dyes.

3.6. *Rheum emodi* (Apsara Yellow Dye)

Apsara dye is made of Rheum emodi also known by the name Himalayan rhubarb, is a conventional natural dye used for textile. It makes bright yellow colour and obtains an odoriferous property. This dye is produced by drying the rhizome and roots of a *Rheum Emodi*. Dye is extracted in aqueous medium from dry powdered materials. The dye when dissolved in soft water and gives golden yellow shade with the salt Alum and copper sulphate on wool and silk. These plant shares core medicinal values in the Indian Ayurveda, it acquires anti-inflammatory and anti–bacterial properties. The medicinal properties of the same are as purgative and astringent tonic [111].

Natural Dye of *Rheum emodi* was purchased from Sodhani Biotech Pvt. Limited, Jaipur. It contains a wide variety of anthraquinone derivatives with significant biological effects. An alkaline extract on mordanted substrate creates yellow, brown, and gray tones of good fastness. Natural dyes are still lacking scientific studies and systematic reports on dyeing textiles with them. The present study uses the colouring component of Rheum emodi on silk fabric in order to increase the use of natural dyeing with natural mordants by establishing the optimum conditions for dyeing (such as pH, dye concentration, dyeing time, mordant concentration, mordanting method) and assessing different colourfastness characteristics [112].

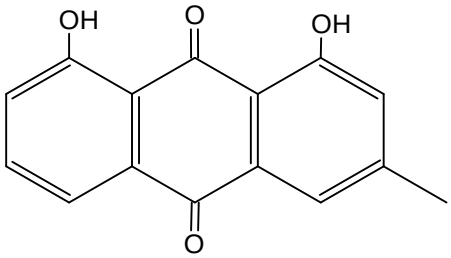
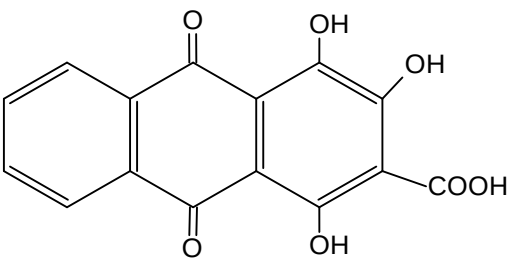


Figure 7. Chrysophanic acid (main Coloring matter of Rheum Emodi)

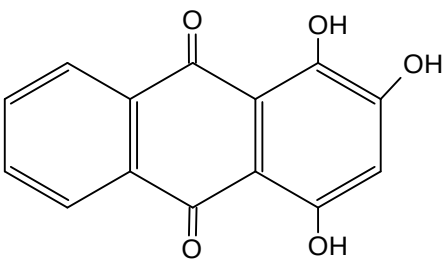
3.7. *Rubia Cordifolia* (Turkey Red Dye)

Indian madder is an evergreen plant native to the Himalayas known as *Rubia Cordifolia*. For the textile industry, it is an important and economical source of red dyes. A variety of red colors can be produced by the roots of Madder, including orange red, brick red, blood red, and fiery red. In addition to the climatic condition of the environment where the plant grows and the soil where the roots grow, the mineral content of the dye water, the setting of the dye temperature, the dye pot used, and the amount of madder used relative to the fiber, the color depends also on the age of the plants. Wool, silk, leather, leather, and cotton can all be treated with madder. Among the most valuable herbs in Ayurveda is madder. As a coloring agent, it is called artificial colorant.

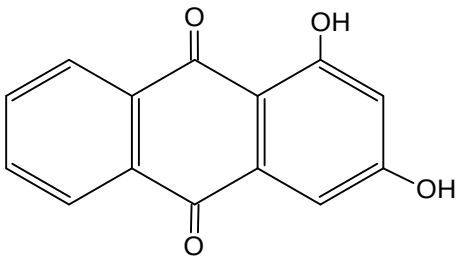
Natural Dye of *Rubia Cordifolia* was purchased from Sodhani Biotech Pvt. Limited, Jaipur. The medicinal properties of Ayurveda are also highlighted. Among the many benefits of madder are its capability to purify the blood and its ability to treat various skin diseases. Different tribes and cultures use it for treating a variety of diseases in different ways. *Rubia Cordifolia* has glycosides, saponins, anthraquinones, tannins, hexapeptides, quinones, and triterpenoids as phytochemical constituents [113]. The red bark of madder plants (*Rubia Cordifolia*) is thin and red, and the roots are long, cylindrical, and flexuous. The stems of this plant often have long, rough, grooved, woody bases. The roots of older plants have a deeper color than those of younger plants. Through advanced techniques and mordants, madder has been used to produce red dyed textiles with varying characteristics since the ancient times. With people becoming more conscious of the environment and their comfort, the demand for greener textiles has increased, and biomordants have gained popularity as a result [114]. Main Coloring matter of *Rubia Cordifolia* are represented in figure 2.

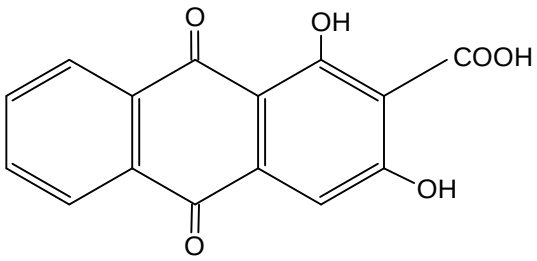


(a.)

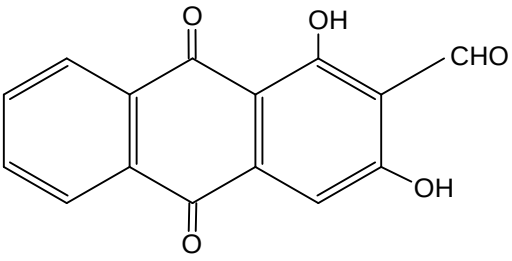


(b.)





(c.) (d.)



(e.)

Figure 8. (a.) Purpurin, (b.) Munjistin, (c.) Xanthopurpurin, (d.) Pseudopurpurin and (e.) Nordamncanthal

3.8. Materials & Methods

The Bamboo Fabric (93GSM) was purchased from H.P Singh Agencies Private limited, New Delhi, India. The purity for bamboo fabric was tested by Burning and Chemical identification methods. For Fabric authenticity testing, Thermal Gravimetric analysis (TGA), Differential Scanning Calorimeter (DSC) and FTIR (ATR) was done in Delhi Technological University, Delhi, India. The fabric has been scoured with 1 *g/l* soap solution for 60 min at 50^{o}C. Banana pseudo-stem sap was collected form Sarode Banana farm house, Tehsil Raver, Maharashtra, India and Aloevera was collected from Delhi Technological University campus. The natural dyes namely *Rubia Cordifolia* and *Rheum Emodi* were purchased from Sodhnai Biotech pvt limited, Jaipur, India.

3.9. Dyeing and Mordanting Process

Dyeing of Bamboo Fabric was carried through three processes namely Pre- mordanting, Simultaneous mordanting, and Post-mordanting. Bamboo fabrics was introduced into the dye bath containing required amount of extracted dye, mordant and water for dyeing. The dyeing was carried out 90 minutes at 80^{o}C. 20% (owf) dye and 10% (owf) mordant concentrations were used for sll the dyeing and mordanting process.

In a simultaneous dyeing and mordanting process, a laboratory beaker dyeing machine was used with programmable temperature and time controls using a material to liquor ratio of 1:50. Two bath processes were used for pre-mordanting and post-mordanting. In both dyeing and mordanting, the material to liquor ratio was kept at 1:50. In combine mordanting 10% of each of the mordant (banana sap and Aloevera) is used in equimolar concentration for dyeing of bamboo fabric.

3.10. Method of Extraction

3.10.1. Aloevera: Plants such as aloe vera, which grows between 1-2 feet tall, produce slushy translucent gel that is regarded as a powerful healing agent. There are 18 types of amino acids in the gel, as well as a small amount of organic and inorganic compounds. Nearly 96% of the gel consists of water. The wearer's health can be enhanced by fabrics dyed with natural herbs or finished with them. The external skin of two aloevera leaves was peeled off after they were freshly cut. Each leaf was then cut into a small piece. A blender was used to extract juice from the small pieces. There was a light olive color to the juices. It was then kept below room temperature for a period of time and after that it was used as a mordant.

3.10.2. Banana Sap: As banana pseudo-stems grow, a thick, dusty-brown liquid known as banana pseudo-stem sap is naturally produced. A phytochemical analysis of sap revealed tannins, phenolics, and aromatic amino acids. This study investigates the use of banana pseudo-sap as a dyeing biomordant. Banana tree stems were collected. A blender was used to blend the stem after it had been cut into small pieces. The banana sap is maroon in color as a result. After that, it was stored below room temperature.

3.11. Color Measurement

To remove any residual unfixed dyestuff, dyed samples were thoroughly washed several times with deionized water solution after dyeing. At room temperature, the samples were dried overnight before measuring their K/S values. The colorimetric properties of dyed wool fabrics were studied using a Premium colorscan SS5100H dual beam Spectrophotometer in terms of CIELab values (a*, b* and c*). Based on kubelka-munk equation as shown below, the K/S values were calculated.

$$K/S = (1 - R)^2 / 2R \quad \text{.....(1.)}$$

Using the formula below, K represents absorbance, S represents scattering, and R represents reflectance.

3.12. Fastness properties of dyed fabrics

Tests were conducted on dyed fabrics to determine their fastness properties like light fastness and Wash fastness of the fabrics as per ISO standard. In order to evaluate dyed fabrics washing and light fastness, the following ratings were given: ratings have been assigned from 1 to 5 and 1 to 7 respectively. The rating of 1 indicates a poor fastness grade, while the rating of 5 and 7 indicates an excellent one.

4. RESULT & DISCUSSION

4.1. FTIR Spectra of Bamboo Fabric

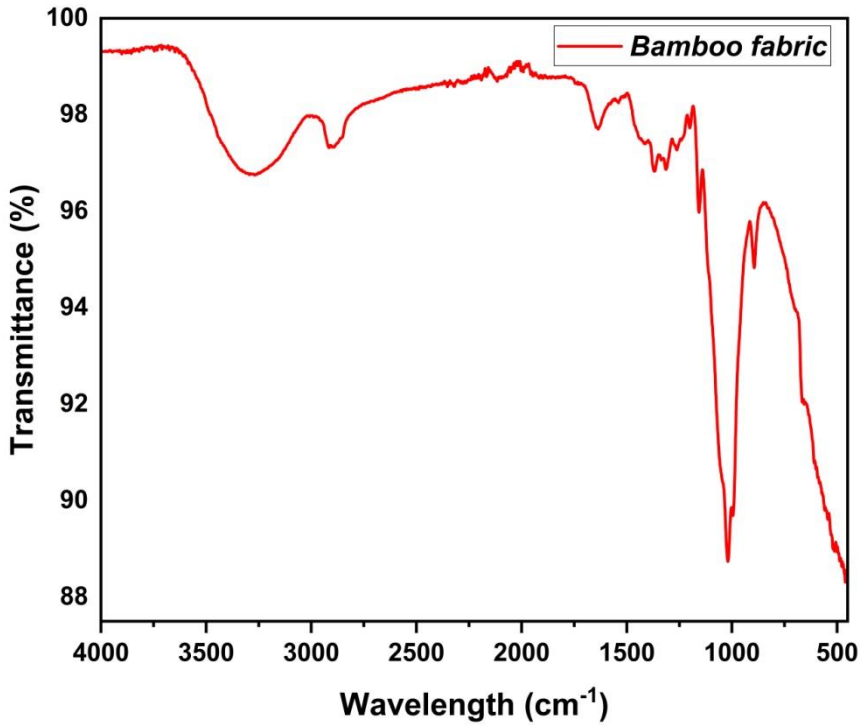


Figure 9. FTIR Spectra of Bamboo Fabric.

FTIR spectra of Bamboo fabric which consists of cellulose (45-50)%, Hemi-cellulose (20-25)%, Lignin (20-30)% and extraction (2.5-5) % are shown in **figure,** As shown in **figure,** a broad peak corresponding to the hydroxyl group of bamboo fabric is observed at 3293 cm^{-1}, and a peak of Carbonyl group is observed at 1635 cm^{-1}. Peak at 2914 cm-1 is assign to symmetric C-H stretching. Other characterstics peaks at 1420 cm^{-1}, 1162 cm^{-1}, 1020 cm^{-1}, 898 cm^{-1} can be identified as Cellulose. Furthermore, there is also an association between NH_3^+ symmetric deformation and the characterstic peak at 1531 cm^{-1}.

4.2. Dyeing & Mordanting (Color Measurements)

In this work on use of natural dyes on natural fibres and use of naturally ecofriendly mordant, Banana sap and Aloevera, as a natural tannin source, was utilized as a natural

mordant for dyeing of Bamboo Fabric with natural dyes like *Rubia Cordifolia* and *Rheum Emodi* and the results are presented in Tables 3 & 4 .

The initial attempt was to find out the best mordanting method i.e Simultaneous mordanting and optimum concentration of mordant and dyes. Previous research showed that the K/S values were improved with dye and mordant concentration.

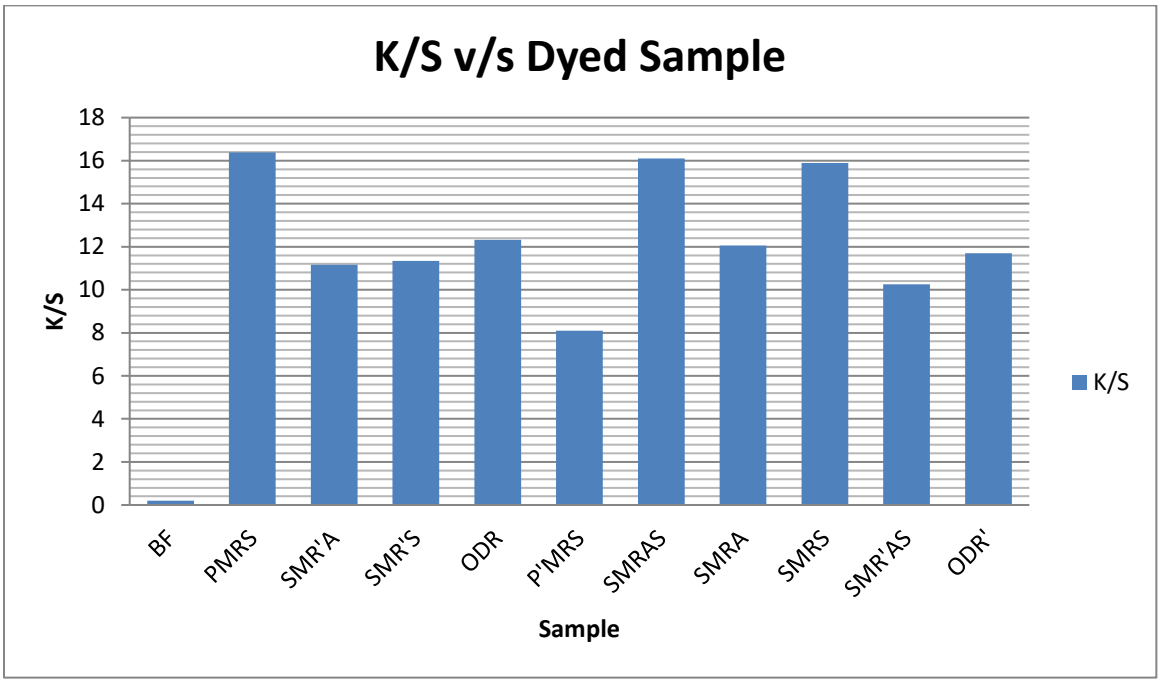


Figure 10. Graph between K/S value v/s Dyed Sample (here, **BF**- Bamboo Fabric, **PMRS**- Pre Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'A**- Simultaneous Mordanting with *Rheum Emodi*with Aloevera, **SMR'S**- Simultaneous Mordanting with *RheumEmodi*with Banana Sap, **ODR**- Only Dyeing with *Rubia Cordifolia*, **P'MRS**- Post Mordanting with *Rubia Cordifolia* with Banana Sap, **SMRAS**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera and Banana Sap,**SMRA**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera**, SMRS**- Simultaneous Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'AS**- Simultaneous Mordanting with *Rheum Emodi* with Aloevera and Banana Sap, **ODR'**- Only Dyeing with *Rheum Emodi.)*

Sample Name	Dye (20%)	Mordant (10%)	Color Value (K/S)	Color coordinates			RFL
				a*	b*	c*	
BF	-	-	0.196	0.117	0.431	0.447	-
PMRS	*Rubia Cordifolia*	Banana Sap	16.387	4.129	34.032	34.282	17.359
ODR	*Rubia Cordifolia*	-	12.328	2.218	32.816	32.891	20.907
P'MRS	*Rubia Cordifolia*	Banana Sap	8.104	0.825	18.478	18.496	29.643
SMRAS	*Rubia Cordifolia*	Banana Sap & Aloevera	16.106	4.568	27.789	28.162	18.629
SMRA	*Rubia Cordifolia*	Aloevera	12.051	3.109	30.995	31.151	22.189
SMRS	*Rubia Cordifolia*	Banana Sap	15.892	5.291	28.664	29.148	18.364

Table 3. Effect of Mordant (Banana Sap &Aloevera) and dye *Rubia Cordifolia* on color strength of Bamboo Fabric. (here, **BF**- Bamboo Fabric, **PMRS**- Pre Mordanting with *Rubia Cordifolia* with Banana Sap, **ODR-** Only Dyeing with *Rubia Cordifolia*, **P'MRS-** Post Mordanting with *Rubia Cordifolia* with Banana Sap, **SMRAS-** Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera and Banana Sap, **SMRA-** Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera**, SMRS-** Simultaneous Mordanting with *Rubia Cordifolia* with Banana Sap

Sample Name	Dye (20%)	Mordant (10%)	Color Value (K/S)	Color coordinates			RFL
				a*	b*	c*	

BF	-	-	0.196	0.117	0.431	0.447	-
SMR'A	*Rheum Emodi*	Aloevera	11.166	-0.271	27.409	27.410	22.713
SMR'S	*Rheum Emodi*	Banana Sap	11.340	1.371	24.929	24.967	23.110
SMR'AS	*Rheum Emodi*	Banana Sap &Aloevera	10.250	0.371	23.583	23.586	25.035
ODR'	*Rheum Emodi*	-	11.696	-0.226	27.426	27.427	21.848

Table 4. Effect of Mordant (Banana Sap &Aloevera) and dye *Rheum Emodi* on color strength of Bamboo Fabric. (Here, **BF**- Bamboo Fabric, **SMR'A**- Simultaneous Mordanting with *Rheum Emodi*with Aloevera, **SMR'S-** Simultaneous Mordanting with *RheumEmodi*with Banana Sap, **SMR'AS-** Simultaneous Mordanting with *Rheum Emodi* with Aloevera and Banana Sap, **ODR'-** Only Dyeing with *Rheum Emodi.)*

It is found that best results were shown by Pre-Mordanting done with Banana sap treated with *Rubia Cordifolia* used as natural dye which binds to the bamboo fabric by giving the best K/S value by taking K/S value of Bamboo Fabric as standarad. This might be because of higher mordant (Banana Sap) and dye (*Rubia Cordifolia*) absorption by the Bamboo fabric.

Similarly Simultaneous Mordanting with equal concentration of both of the Mordants (Banana Sap and Alovera Extract) alongwith *Rubia Cordifolia* has shown a little less K/S value than above.

Post-Mordanting done along with Rubia Cordifolia with Banana Sap as Mordant has shown the least K/S value and when only dyeing was performed without any use of Mordant, *Rubia Cordifolia* showed better result as compared to *Rheum Emodi* in terms of K/S value.

The remaining data for the different parameters and processes are shown into table and it has been observed that using Banana Sap as Mordant has shown much better results than Alovera Extract on the Bamboo Fabric.

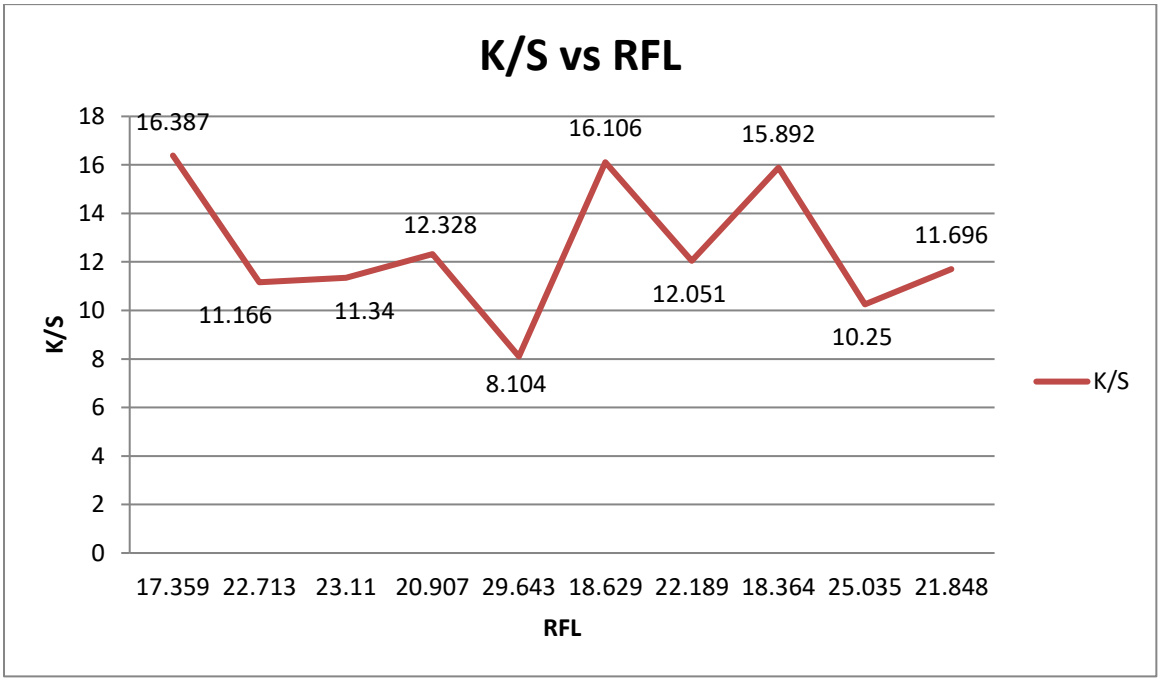


Figure 11. Graph between RFL value v/s Dyed Sample (here, **BF**- Bamboo Fabric, **PMRS**- Pre Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'A**- Simultaneous Mordanting with *Rheum Emodi*with Aloevera, **SMR'S**- Simultaneous Mordanting with *RheumEmodi*with Banana Sap, **ODR**- Only Dyeing with *Rubia Cordifolia,* **P'MRS**- Post Mordanting with *Rubia Cordifolia* with Banana Sap, **SMRAS**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera and Banana Sap, **SMRA**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera**,** **SMRS**- Simultaneous Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'AS**- Simultaneous Mordanting with *Rheum Emodi* with Aloevera and Banana Sap, **ODR'**- Only Dyeing with *Rheum Emodi.)*

4.3. WASH FASTNESS

The results obtained in order of wash fastness for the Bamboo fabric dyed with *Rubia Cordifolia* and *Rheum Emodi* with Banana Sap and Aloevera extract as mordant are presented in table 3.

Sample Name	Dye	Mordant	Colour Fastness
BF	-	-	-
PMRS	*Rubia Cordifolia*	Banana Sap	2-3
ODR	*Rubia Cordifolia*	-	4-5
P'MRS	*Rubia Cordifolia*	Banana Sap	3-4
SMRAS	*Rubia Cordifolia*	Banana Sap &Aloevera	5
SMRA	*Rubia Cordifolia*	Aloevera	4-5
SMRS	*Rubia Cordifolia*	Banana Sap	4-5
SMR'A	*Rheum Emodi*	Aloevera	2-3
SMR'S	*Rheum Emodi*	Banana Sap	3
SMR'AS	*Rheum Emodi*	Banana Sap &Aloevera	3
ODR'	*Rheum Emodi*	-	3

Table 5. Fastness Properties of Dyed Fabrics (here, **BF**- Bamboo Fabric, **PMRS**- Pre Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'A**- Simultaneous Mordanting with *Rheum Emodi*with Aloevera, **SMR'S**- Simultaneous Mordanting with *RheumEmodi*with Banana Sap, **ODR**- Only Dyeing with *Rubia Cordifolia*, **P'MRS**- Post Mordanting with *Rubia Cordifolia* with Banana Sap, **SMRAS**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera and Banana Sap, **SMRA**- Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera**, SMRS**- Simultaneous Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'AS**- Simultaneous Mordanting with *Rheum Emodi* with Aloevera and Banana Sap, **ODR'**- Only Dyeing with *Rheum Emodi.)*

The Wash fastness in Simultaneous mordanting with *Rubia Cordifolia* along with mixed mordanting of Aloevera and Banana sap (taken in equimolar concentration) was observed

as “excellent” and in case of Simultaneous mordanting with colourant as Rheum Emodi shown the “poor” result when treated with aloevera extract as mordant.

The remaining cases have shown “good” to “medium” result which is demonstrated in Table 3.

The reason for the “excellent” wash fastness may be due to strong Bonding of Bamboo fibre with the natural dye as well as Mordant.

4.4. Light Fastness

The results obtained in order of Light fastness for the Bamboo fabric dyed with *Rubia Cordifolia* and *Rheum Emodi* with Banana Sap and Aloevera extract as mordant are presented and comparison made on gray scale of the samples are green in table 4.

Sample Name	Dye	Mordant	Light Fastness
BF	-	-	-
PMRS	*Rubia Cordifolia*	Banana Sap	5
ODR	*Rubia Cordifolia*	-	5-6
P’MRS	*Rubia Cordifolia*	Banana Sap	4-5
SMRAS	*Rubia Cordifolia*	Banana Sap & Aloevera	6
SMRA	*Rubia Cordifolia*	Aloevera	5-6
SMRS	*Rubia Cordifolia*	Banana Sap	5
SMR’A	*Rheum Emodi*	Aloevera	5-6
SMR’S	*Rheum Emodi*	Banana Sap	5-6
SMR’AS	*Rheum Emodi*	Banana Sap & Aloevera	5-6
ODR’	*Rheum Emodi*	-	5

Table 6. Fastness Properties of Dyed Fabrics (here, **BF**- Bamboo Fabric, **PMRS**- Pre Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'A-** Simultaneous Mordanting with *Rheum Emodi*with Aloevera, **SMR'S-** Simultaneous Mordanting with *RheumEmodi*with Banana Sap, **ODR-** Only Dyeing with *Rubia Cordifolia*, **P'MRS-** Post Mordanting with *Rubia Cordifolia* with Banana Sap, **SMRAS-** Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera and Banana Sap, **SMRA-** Simultaneous Mordanting with *Rubia Cordifolia* with Aloevera**, SMRS-** Simultaneous Mordanting with *Rubia Cordifolia* with Banana Sap, **SMR'AS-** Simultaneous Mordanting with *Rheum Emodi* with Aloevera and Banana Sap, **ODR'-** Only Dyeing with *Rheum Emodi.)*

The data clearly shows Simultaneous Mordanting with Rubia Cordifolia with Aloevera and Banana Sap sample showing the "best" result for light fastness followed by other samples as they possess a little less efficient & fastness property and the rest shows "average" property. A higher K/S value and/or higher mordant or dye concentration were found to improve light fastness.

4.5. Conclusion

In this work, the dyeing behaviour of Bamboo Fabric with Natural Dyes along with natural mordants was studied. Red Colour and Yellow colour are obtained using dyes named as Rubia Cordifoilia and Rheum Emodi using Banana Sap and Aloevera as Biomordant individually and in Combination. A higher temperature might also lead to a higher dye uptake because dyestuffs are more soluble at higher temperatures. Use of Natural mordants increases Colour value (k/s) and enhances the longevity of washing and light treatment.

5. REFERENCES

1. M. Hosseeinnezhad, K. Gharanjig, S. Belbasi and S. H. SeiedSaadati, Prog. Color colorant coat., (2017).DOI:10.1007/s11356-022-19389-3

2. E. Forgacs, T. Cserháti, and G. Oros, Environ. Int., (2004).doi: 10.1016/j.envint.2004.02.001

3. O. Avinc, A. Celik, G. Gedik, and A. Yavas, Fiber. Polym. (2013).DOI:10.1007/978-3-030-38541-5_4

4. A. Ahmad khan, N. Iqbal, S. Adeel, M. Azeem, F. Batool, and I. Ahmad Bhattic, Dyes Pigm., (2014).https://doi.org/10.1016/j.dyepig.2013.11.024

5. A. Cerrato, D. De Santis, and M. Moresi, J. Sci. Food Agric, (2002).

6. L. J. Rather, S. Islam, M. Shabbir, M. N. Bulchair, M. Shahid, M. A. Khan, and F. Mohammad, J. Environ. Chem. Eng., (2016).DOI:10.1080/15440478.2018.1441085

7. M. M. Kamel, M. M. El Zawahry, N. S. E. Ahmed, and F. Abdelghaffar, Ultrason. Sonochem., (2009).DOI: 10.1016/j.ultsonch.2008.08.001

8. M. M. Kamel, M. M. El Zawahry, N. S. E. Ahmed, and F. Abdelghaffar, Ind. Crops Prod., (2011).doi: 10.1016/j.ultsonch.2008.08.001

9. H. F. Mansour and S. Heffernan, Clean Technol. Environ. Policy, (2011).DOI:10.1007/S10098-010-0296-2

10. J. T. Li, M. X. Sun, and Y. Yin, Ultrason. Sonochem., (2010).https://doi.org/10.1016/j.ultsonch.2010.05.009

11. N. Baaka, W. Haddar, M. Ben Ticha, M. T. P. Amorim, and M. F. M'Henni, Nat. Prod. Res., (2017).DOI:10.1080/14786419.2017.1285303

12. M. Nakpathom, B. Somboon, N. Narumol, and R.Mongkholrattanasit, J. Nat. Fibers, (2018).DOI:10.1080/00405000.2020.1820708

13. M. M. Kamel, M. M. El Zawahry, N. S. E. Ahmed, and F. Abdelghaffar, Ind. Crops Prod., (2011).doi: 10.1016/j.ultsonch.2008.08.001

14. O. A. Hakeim, A. Abou-Okeil, L. A. W. Abdou, and A.Waly, J. Appl. Polym. Sci., (2005).

15. A. Haji, M. K. Mehrizi, and J. Sharifzadeh, Fiber. Polym., (2016).DOI:10.1007/s12221-016-6457-0

16. A. Guesmi, N. Ladhari, N. B. Hamadi, M. Msaddek, and F. Sakli, J. Cleaner Prod., (2013).DOI: 10.1016/j.ultsonch.2012.04.012

17. Ö. ErdemIşmal, L. Yildirim, and E. Özdoğan, J. Cleaner Prod., (2014).DOI:10.1111/COTE.12047

18. H. F. Mansour and S. Heffernan, Clean Technol. Environ.Policy, (2011).

19. Y. M. Indi, P. D. Patil, and T. D. Jujare, “Studies in Natural Dyeing (Part 2)”, Dye Chem. Pharma. Bus News, (2016).DOI:10.1007/S10098-010-0296-2

20. M. G. Uddin, J. Text., 2014, Article ID 405626 (2014). doi: 10.1371/journal.pone.0109404

21. A. Manhita, V. Ferreira, H. Vargas, I. Ribeiro, A. Candeias, D. Teixeira, T. Ferreira, and C. B. Dias, Microchem. J., (2011).DOI:10.1007/s00216-011-4858-x

22. A. K. Samanta and P. Agarwal, Indian J. Fibre Text. Res., (2009).

23. C. Liolios, H. Laouer, N. Boulaacheb, O. Gortzi, and C. Ioanna, Molecules, (2007).doi: 10.3390/12040772

24. D. Jasso de Rodrigiez, D. Hernandez-Castillo, J. L. Angulo-Sanchez, R. Rodriguez-Garcia, J. A. Villarreal Quintanilla, and R. H. Lira-Saldivar, Ind. Crops Products, (2007). https://doi.org/10.1016/j.indcrop.2004.01.002

25. M. L. Gulrajani, Colourage, (1999).

26. G. Nalankilli, "Application of Tannin in the Colouration of Textiles", pp.13-15, Textile Dyers & Printer, 1997.

27. P. S. Vankar, "Handbook on Natural Dyes for Industrial Applications", National Institute of Industrial Research, Delhi, 2007

28. Luciano Pinheiro, Lais Kohan, Larissa Oliveira Duarte1, Maria Elisa de Paula Eduardo Garavello, Julia Baruque-Ramos-Biomordants and new alternatives to the sustainable natural fber dyeings,2019. DOI:10.1007/s42452-019-1384-5

29. P. S. Vankar, Resonance, (2000).

30. M. L. Gulrajani, Colorage, (1999).

31. Bechtoldt T, Mussak R, Mahmud-Ali A, Ganglberger E, Geissler S, Extraction of natural dyes for textile dyeing from colored plant wastes released from the food and beverage industry. J Sci Food Agric, (2006).**https://doi.org/10.1002/jsfa.2360**

32. Ghorpade B, Darvekar M, Vankar PS, Ecofriendly cotton dyeing with Sappan wood dye using ultrasound energy. Colour-age, (2000).

33. Rungruangkitkrail N, Mongkholrattanasit R, (Eco-friendly of textiles dyeing and printing with natural dyes. In: RMUTP international conference: textiles & fashion, (2012).

34. S. Ghanean and M. GhanbarAfjeh, Color Rea. Appl., (2018).DOI **10.1002/col.22164**

35. R. S. Blackburn, Coloration Technol., (2017).

36. A. Jahangiri, S. M. Ghoreishian, A. Akbari, M. Norouzi, M. Ghasemi, M. Ghoreishian, and E. Shafiabadi, Fiber. Polym., (2018).DOI 10.1007/s12221-018-8069-3

37. Ado A. , Yahaya H. , Kwalli A. A. , Abdulkadir R. S.- Dyeing of textiles with ecofriendly natural dyes: A review,2015

38. K. H. Prabhu, M. D. Teli, and N. G. Waghmare, Fiber. Polym., (2011).DOI:10.1016/J.JSCS.2011.10.01

39. A. D. Broadbent, "Basic Principles of Textile Coloration", The Society of Dyers and Colorists, 2001.

40. K. H. Prabhu and Aniket S Bhute-Plant based natural dyes and mordnats: A Review,2012.

41. Avinash P. Manian, Roshan Paul and Thomas Bechtold-Metal mordanting in dyeing with natural colourants,2015

42. Ismal ÖE, Greener natural dyeing pathway using a by-product of olive oil; prina and biomordants. FibersPolym, (2017).

43. Thanavel M, Kadam SK, Biradar SP et al, Combined bio-logical and advanced oxidation process for decolorization of textile dyes. SN Appl Sci, (2019).

44. Ismal ÖE et al , Metal mordants and biomordants. In:Shahid-ul-Islam, Butola BS (eds) The textile institute book series, the impact and prospects of green chemistry for textile tech-nology. Woodhead Publishing, Sawston, (2019).DOI:10.1016/B978-0-08-102491-1.00003-4

45. E. Haslam, "Plant Polyphenols: Vegetable Tannins Revisited", Cambridge University Press, 1989.https://doi.org/10.1086/417183

46. Hooda, K. Khambra, N. Yadav, and V. K. Sikka, J. Life Sci., (2013).

47. S. S. Muthu, “Roadmap to Sustainable Textiles and Clothing: Environmental and Social Aspects of Textiles and Clothing Supply Chain”, Series editor, Springer, London, 2014.

48. S. Grundas, “Advances in Agrophysical Research: Plant Fibers for Textile and Technical Applications”, Intech Open Limited, London, (2013).

49. M. Joshi, S. W. Ali, and S. Rajendran, Appl. Polym. Sci., (2007).

50. Padma S. Vankar , Rakhi Shanker , Debajit Mahanta , S.C. TiwariEcofriendlysonicator dyeing of cotton with Rubia cordifolia Linn. using biomordant,2006

51. J. Yan-mei, Dyeing & Finishing, (2013).

52. F. S. Ghaheh, A. S. Nateri, S. M. Mortazavi, D. Abedi, and J. Mokhtari, Color. Technol., (2012).DOI:10.1016/J.JCLEPRO.2014.02.050

53. M. B. Kasiri and S. Safapour, Environ. Chem. Lett., (2014).DOI: 10.1007/s10311-013-0426-2

54. C. Zaffino, S. Bruni, B. Russo, R. Pilu, C. Lago, and G. M. Colonna, J. Raman. Spectrosc., (2016).DOI:10.1002/JRS.4786

55. S. Ali, N. Nisar, and T. Hussain, J. Text. Inst., (2007).DOI:10.1080/00405000701556079

56. S. Ul-Islam, L. J. Rather, M. Shabbir, J. Sheikh, M. N. Bukhar, M. A. Kan, and F. Mohammad, J. Nat. Fibers, (2018).DOI:10.1016/J.JECE.2016.06.019

57. M. Shahid, S. Islam, and F. Mohammad, J. Cleaner Prod., (2013).https://doi.org/10.1016/j.jclepro.2013.03.031

58. K.H. Prabhu , M.D. Tel-Eco-dyeing using Tamarindus indica L. seed coat tannin as a natural mordant for textiles with antibacterial activity,2011. DOI:10.1016/J.JSCS.2011.10.014

59. Irene Muller Harvey, Animal Feed Science and Technology, 2001.

60. C. W. Oo, M. J. Kassim, and A. Pizzi, Ind. Crops Prod., (2009).https://doi.org/10.1016/j.indcrop.2014.11.005

61. A. A. Rahim, E. Rocca, J. Steinmetz, M. J. Kassim, R. Adnan, and M. Sani Ibrahim, Corros. Sci., (2007).DOI:10.1016/J.CORSCI.2006.04.013

62. Juha-PekkaSalminena, Vladimir Ossipova, and KaleviPihlajaa-Distribution of Hydrolysable Tannins in the Foliage of Finnish Birch Species,2001. https://doi.org/10.1515/znc-2002-3-409

63. P Scholfield; DM Mbugua; AN Pell. Animal Feed Science and Technology, 2001, http://dx.doi.org/10.1016/S0377-8401(01)00228-0

64. Ansari A A& Thakur B D ,Colourage, 110(7), 2000.

65. ShristiPurwar-Application of natural dye on synthetic fabrics: A review,2016

66. R Rafai. Multani saree and its style of printing. In Natural Dyes and their Application in Textiles, Ed., Gulrajani M L and Gupta D, IIT, Delhi, 1992.

67. M Jain. Printing of wool with Natural dyes In Natural Dyes and their Application in Textiles, Ed., Gulrajani M L and Gupta D, IIT, Delhi, 1992. DOI: 10.5772/intechopen.93161

68. Harley D. Naumann, Luis O. Tedeschi , Wayne E. Zeller , Nichole F. HuntleyThe role of condensed tannins in ruminant animal production: advances, limitations and future directions,2017. DOI:10.1590/S1806-92902017001200009

69. LI MINGSHU, YAO KAI, HE QIANG and JIA DONGYING-Biodegradation of gallotannins and ellagitannins, 2006. **https://doi.org/10.1002/jobm.200510600**

70. Bharat H Patel, Bipin Agrawal-Dyeing of nylon with babool bark extract,2002

71. Javed sheikh, Priyanka S. Jagtap & M.D teli, ultrasound assisted extraction of natural dyes and natural mordants vis a vis dyeing, 2016. DOI 10.1007/s12221-016-5031-0
72. Syed Maqbool Geelani, Shoukat Ara, Naseer A Mir, S.J A, Bhat & P.K Mishra, Dyeing and fastness properties of Quercus robur with natural mordants on natural fibre, 2016.
73. Neetu Rani Lalit Jajpura&B.S.Butole,Ecological Dyeing of Protein Fabrics with Carica papaya L. Leaf Natural Extract in the Presence of Bio- mordants as an Alternative Copartner to Metal Mordants, 2020. https://doi.org/10.1007/s40034-020-00158-1
74. Neetu Rani and Lalit Jaipura, Sustainable Dyeing of Wool by Natural Dyes in Conjunction with Natural Mordants, 2021.
75. KH. Prabhu M. D. Teli& Nilesh G. Waghmare, Eco-friendly dyeing using natural mordant extracted from Emblica officinalis G. Fruit on cotton and silk fabrics with antibacterial activity, 2011. DOI 10.1007/s12221-011-0753-5
76. GorkemGedik Ozan AvincArzuYavas& Akbar Khoddami, A novel eco-friendly colorant and dyeing method for poly(ethylene terephthalate) substrate, 2014. DOI: 10.1007/s12221-014-0261-5
77. Rum Mansour Zine Mighn& Farouk Mhenni, Exploring the potential uses of Vitis vinifera L. leaves as raw material for textile dyeing without metal mordants, 2016. DOI 10.1007/s12221-016-5033-y
78. Noman Habib Shahid Adeel Farhan Ali Nimra Amin & Shahid Rehman Khan, Environmental friendly sustainable application of plant- based mordants for cotton dyeing using Arjun bark- based natural colorant, 2021.
79. Morgan HosseinnezhadKamaladinGharanjig, Raziveh Jafari Homan Imani &NarjesRazani, Cleaner colorant extraction and environmentally wool dyeing using oak as eco-friendly mordant, 2020. doi: 10.1007/s11356-020-11041-2.
80. OzlenenErdemIsmal, Greener natural dyeing pathway using a by-product of olive oil; prina and biomordants, 2017.DOI:10.1007/s12221-017-6675-0
81. H.D Sinnur, Dileep Kumar Verma, Tapas Ranjan Kaur, Ashis Kumar Samanta, Standardization of Dyeing Process Variables for Dyeing of Cotton Khadi Fabric with Aqueous Extract of Babul Bark (Acacia Nilotica L.), 2018. DOI: 10.1007/s40034-018-0127-2

82. Mozhganhosseinnezhad, Kamaladingharanjig, NarjesRazani, Razieh Jafari & Mohammad rezasaeb, green miles in dyes technology: metal-rich pumpkin extracts in aid of natural dyes, 2022. DOI:10.1007/s11356-022-19389-3
83. Heba f. Mansour, S. Heffernan, Environmental aspects on dyeing silk fabric with stictacoronata lichen using ultrasonic energy and mild mordants, 2011.DOI: 10.1007/s10098-010-0296-2

84. Tayyab Hayat Shahid Adeel aralur Rehman, Fatima BatootNimra Amin Tanvir Ahmad &Meral, Waste black tea leaves (Camelia sinensis) as a sustainable source of tannin natural colorant for bio- treated silk dyeing, 2021. doi: 10.1007/s11356-021-17341-
85. Fatima Batool, Shahid Adeel Naeem Iqbal, Muhammad Azeem & Muhammad Hussaan, Sustainable natural coloring potential of bitter gourd (Momordica charantia L.) residues for cotton dyeing: innovative approach towards textile industry, 2022. doi: 10.1007/s11356-021-17803-w
86. Eser, Ferda: Aktas, Ebru Onal, Adem, Dyeing quality of walnut shells on polyester and polyester/viscose blended fabrics, 2016.
87. Kawlekar, Sujata Rajesh; Raja, A SM: Saxena, Sujata Gurjar, R. M, Eco-friendly dyeing of cotton fabric with tender green coconut soft husk, 2022.
88. Faiza Nazir, Amna Siddique, Ahsan Nazir, Sonia Javed Tanveer Hussain Sharjeel Abid, Eco-friendly dyeing of cotton waste-derived natural dyes and mordants, 2022.DOI:10.1111/cote.12629

89. Ado A., Yahaya H. ,Kwalli A. A. , Abdulkadir R. S., Dyeing of textiles with ecofriendly natural dyes: A review, 2014.

90. H. Willemen, G. J. P. van den Meijdenberg, T. A. van Beek, and G. C. H. Derksen, Coloration Technol., (2019).

91. KH Prabhu, MD Teli, NG Waghmare., Fibers and Polymers, 2011.
92. M. Zarkogianni, E. Mikropoulou, E. Varella, and E. Tsatsaroni, Color. Technol., (2011).DOI:10.1111/J.1478-4408.2010.00273.X

93. T. Bechtold, A. Turcanu, E. Ganglberger, and S. Geissler, J. Clean. Prod., (2003).doi: 10.1016/s0960-8524(01)00146-8

94. A. Shams-Nateri, J. Clean. Prod., (2011).DOI:10.1111/J.1478-4408.2008.00173.X

95. ÖzlenenErdemİşmal, Leyla Yıldırım,3 - Metal mordants and biomordants,2019

96. SmitaBhuyan , Dr. NabaneetaGogoi, Dr. B.B Kalita-Natural dyes and its Antimicrobial effect, 2016

97. M. Hosseinnezhad K. Gharanjig, R. Jafari , H. Imani-Green Dyeing of Woolen Yarns with weld and Madder natural Dyes in the Presences of Biomordant,2021.

98. AminoddinHaji , Maryam Naebe-Cleaner dyeing of textiles using plasma treatment and natural dyes: A review,2020

99. N. Ashrafi , K. Gharanjig, M. Hosseinnezhad, M. KhajehMehrizi , H. Imani , N. Razani-Dyeing Properties and Color Fabrics Using Natural Dye and Mordant,2018.

100. Lakshmanan Ammayappan, Jeyakodi Moses-An overview on application of tanning in textile processing,2007.

101. Deepali B. KambleDr. Sanjay M. Chavan Dr. Jotiram G. Gujar-Study of Extraction of Tannic Acid from Emblica Officinalis (Amla).

102. Barahapurkar, S.; Purwar, R.; Baldua, R., Banana Pseudostem Sap as a Biomordant for Dyeing of Silk with Celosia Flower, *Fibers and Polymers*, 21, 2010-2017, (2000).

103. Barahapurkar, S.; Kumar, A.; Purwar, R., "Charcterisation of Banana Pseudostem Sap Used As a Mordant for Dying," *SSRG International Journal of Polymer and Textile Engineering*, vol. 2, no. 3, pp. 1-7, 2015.

104. *Basak, S.; Samanta; Chattopadhyay, S.K.; Saxena, S.; Narkar, R.;* Banana pseudostem sap and boric acid— A new green intumescent for making self-extinguishing cotton fabric, *Indian Journal of Fibre & Textile Research (IJFTR),* 43, (2018).

105. Jayaprabha, J.; Brahmakumar, M.; Vattackatt, M., Banana Pseudostem Characterization and Its Fiber Property Evaluation on Physical and Bioextraction, *Journal of Natural Fibers.* 8. 149-160. (2011).

106. Lourn, J.; Lukyambuzi, H.; Kodi, p., Mordanting for Deying Cotton Fabrics with Dye from Akbizia Coriaria plant species, *Int J Sci Res Publ,* 4(10) (ISSN; 2250-3153), (2018).

107. Har Bhajan, S.; Bharati, K. A.; Mordants and their applications, *Handbook of Natural Dyes and Pigments*, 18–28, (2014).

108. Bhute, A.; Plant based dyes and mordant: A Review, *Journal of Natural Products and Plant Resources,* (2012).

109. Abdouramane, N.; Doina, S.; Nkemaja, D.; Marcel, P.; Anicet, N.; Ebanda, F.; Valery, H.; Aloe vera gel as a biomordant in the finishing of vegetable textiles: a review. 68(72). 31- 36, (2022).

110. Affat, S.; Classifications, Advantages, Disadvantages, Toxicity Effects of Natural and Synthetic Dyes: A review. 8. 130-135, (2021).

111. Nandini S.; Rajesh, K.; Arun, K.S.; Peram, B. R.; Shahid, M. N.; Shashank, D., Anthraquinone derivatives based natural dye from Rheum emodi as a probe for thermal stability of proteins: Spectroscopic and chromatographic studies, *Journal of Pharmaceutical and Biomedical Analysis*, Volume 62, Pages 96-104,ISSN 0731-7085,(2012).

112. Srivastava, M.; Mogra, D.; Gupta, P., Dye extraction from Rheum emodi for colouring silk using natural mordants, *Journal of Applied and Natural Science*. 7. 182-186, (2015).

113. Kumari, I,; Kaurav, H,; Choudhary, G., Rubia cordifolia (Manjishtha): A review based upon its Ayurvedic and Medicinal uses, *Himalayan Journal of Health Sciences*, 17-28, (2021).

114. Basak, S.; Saxena, S.; Chattopadhyay, S.; Narkar, R.; Mahangade, R., Banana pseudostem sap: A waste plant resource for making thermally stable cellulosic substrate, *Journal of Industrial Textiles*, 46(4):1003-1023, (2016)