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Harnessing Natural Colourants from Brown Algae Turbinaria Conoides (J. Agardh) Kuetz for Fabric Dyeing: A Sustainable Eco-Friendly Approach

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ABSTRACT
The demand for natural dyes in the modern world is increasing day by day. These resources have become important for their use in food, pharmaceuticals and textiles Industries, instead of their synthetic dyes. Using these resources we can protect human health and prolong life on the earth. This research focuses on Turbinaria conoides, a brown seaweed collected from Olakuda, Ramanathapuram coast, Tamil Nadu, India (9.2876° N, 79.3129° E). A crude dye was extracted from the seaweed and used to treat cotton fabric using the pre-mordanting technique. To achieve different shades of colors, Turbinaria conoides was combined with other dye-yielding plant materials, including Vachellia nilotica, Oldenlandia umbellate, Rubia cordifolia, and Alkanna tinctoria. The phytochemical analysis confirmed the presence of bioactive compounds in Turbinaria conoides. Colorfastness tests were conducted to evaluate the dye's stability on the fabric. The study concludes that natural dyes hold great potential and interest, especially Turbinaria conoides. India's vast plant resource base presents opportunities for further research and documentation of natural dye usage. Sustainable and eco-friendly practices in the textile industry can be fostered through algal-sourced pigments, contributing to environmental protection and an eco-aware society. Future aspects include a focus on environment-friendly dyes, affordable production methods, and exploring the full potential of natural dyestuffs for various applications, including waste utilization and job creation.

INTRODUCTION
Dyeing is an important element of modern textiles. The first factor for the use ofthe product and advertisement is the colour of the textile product. The colour is essentialwith apparel, carpet, curtains, sheets and towels. All of the items are marketed with anemphasis on the specific fabric colour.

Dyeing is the application of colour to a textile with a degree of permanence. Thesubstances which impart the colouration are referred to as colourants. While these colourants have a natural affinity for textiles, they're known as dyes. The dyes will diffuse into the chemical molecular structure of fibres and develop the final colour of the textile product. The dye-fibre molecular association is also responsible for the degree of colour fastness; dyes are categorized as fibre specific. However, because thebasic structure of cotton is cellulose, dyes that work on cotton will also work on other cellulose-based fibres such as linen and rayon. The other colourant used on textile materials is pigmented.

Pigments in contrast to dyes have no affinity for material fibres. To create a permanent colour on textile products, pigments are bound to the surface of the textile fibres using adhesives that can be described as binders. There are a variety of binder systems accessible with distinct properties. Pigments are not fibre specific, like dyes. The same combination of pigment binder acts simultaneously on polyester and cotton.There can be proof from history that indigo and various other plant-based dyes were recognised and used during 4000 BC. Modern nations such as Egypt, India, and Chinahave archaeological evidence of developed ancient textile products and strategies. Over 2000 years ago there was a common practice of mixing the dyes to produce variousshades in a wide colour gamut.

Dyes are chemical substances that are absorbed by the textile fibres that create the colour of the textile product. In general, textile substrates are dyed using a water bath. The dyeing device is used to store the textile substrate and the dye bath during thedyeing process. Dyeing equipment is used to control the necessary parameters of the dyeing process to maximize dyeing quality.

The goal of the dyeing process is to create a shade on the textile material that corresponds to the colour standard. Another goal is to produce tint with colourfastnessproperties that meet performance specifications. As an example, most garments are washed without colour bleeding. Each dye component must be evaluated for itscolourfastness. The cost of the dyeing method, both in terms of dyes, equipment and processing time, will affect the profits of the manufacturing company. Key factors involved in dye selection include ease of miscibility with other dyes and chemicals, levelling properties of dyeing, dust issues when using powder dyes, and environmentalimpact. Some dye formulations produce huge volumes of coloured wastewater. Some formulations produce non-biodegradable or semi-toxic waste products. Treated water must be properly treated before being returned to the environment, which is a global problem.

All different textile substrates can use the same dyes as long as they have the same fibre content. Natural or synthetic fibres are dyed in bundles. This is known as "stock dyeing". These fibres are often blended for shade in the yarn-making process. They are used to provide shades which may be popular in many different clothing products. ‘Dope dyeing’ is the technique of blending colour into the polymer solution preceding the fibre extrusion. This process yields coloured fibre’s excessive fastness properties. It is not easy to change the extruded colour if off-colouration. Synthetic fibres such as polyethene can be coloured using this method.

In "pack dyeing", one yarn is uniformly wound around a perforated tube. Most of these packages are loaded into the dye container by placing them on the support arms.During the dyeing process, the dye bath is pumped upside down through the packaging.This is the most adaptable and productive way to dye yarn. "Bead winding" is a methodin which multiple yarns are wound onto a single perforated beam. This can be several hundred to thousands of yarns per beam. This depends on the end product and production needs.

"Space dyeing" is a yarn dyeing method of placing blocks of colour along the length of the yarn. These yarns are popularly used for sweaters. Each type of method and machine has its advantages and disadvantages.

The first man-made (synthetic) natural dye, mauveine, was discovered by William Henry Perkin in 1856. Synthetic dyes replaced traditional natural dyes. They are cheaper, offered a wide range of new colours and have better properties for dyed fabrics. Recently Dyes are classified according to their use in the dying process.

All the colours you see today are synthetic dyes. Synthetic dyes are usedeverywhere, from clothing to paper, from wood to food. Today, synthetic dyes have progressed into a multi-billion dollar industry. There are more than 10,000 dyes, and annual production worldwide exceeds more than 7 × 105 metric tons.

Synthetic dyes can be named according to the chemical structure of theirchromophoric group. For example, diphenylmethane derivatives, oxazine compounds, xanthene compounds, and azo dyes are the most popular varieties of artificial dyes. Today it is used up to 90% in dye units because they can be versatile and easy to synthesize. Most synthetic dyes, with some exceptions, are aromatic organic compounds, which can be further divided into groups such as nonionic, cationic, and anionic.

Synthetic dyes are often derived from petrochemical compounds and are commercialised in liquid, powder, paste or granular form [Gita, S. *et al*. 2017]. They are endowed with many prospects, such as fast and consistent colouring with different classes of fabrics. A wide range of colours pigments and shades, the possibility of manipulation, stability against many external factors and economical energyconsumption [Hossen, M.Z. *et al*. 2019]. Therefore, most synthetic dyes had harmful effects when released in untreated or partially treated forms into the environment.

Dyeing wastewater has a high biological and chemical oxygen demand (BOD and COD) and is rich in organic and inorganic pollutants that include chlorinated compounds, heavy metals, sulfur, nitrates, naphthol, soaps, chromium compounds, dyesand pigments. Even after certain cleaning processes, certain toxic elements remain in wastewater. Thus, they have polluting effects on air, soil, flora and water resources, in addition to serious human diseases [Aldalbahi, *et al*., 2021].

The term ‘natural dye’ covers all of the dyes derived from natural sources like flora, fauna and minerals. Natural dyes are non-substantive and are to be applied on textiles with the help of mordants, generally a metal salt, having an affinity for both the colouration and the fibre. Transition metallic ions normally have strong co-ordinating power, and as a consequence can act as bridging material to create substantivity of natural dyes while a textile material being impregnated with such metal salt (i.e., mordanted) is subjected to dyeing with different natural dyes, typically having a few mordantly groups facilitating fixation of such dye/colourant.

Natural dyes may be classified (Gulrajani & Gupta, 1992) in different ways. The earliest classification was according to alphabetical order, based on hue, chemical constitution, application class etc.

a. In “treatise on permanent colourations” by Bancroft, herbal dyes are labelledinto two groups namely: ‘Substantive Dyes’ which include indigo, turmeric etc. directly dyes the fibres and ‘Adjective Dyes’ which include logwood, madder etc. mordantedwith a metallic salt.
b. Humme classify the colouring matter as ‘Monogenetic Dyes’, those that produce only one colour regardless of the mordant present on the fibre or applied together with the dye and ‘Polygenetic Dyes’, which produce distinctive colour with different mordant, e.g., alizarin (Dedhia E M, 1998)
c. In the Colour Index (CI) the natural dyes are categorized based on hue(Predominating shade). Based on hues, natural dyes are classified as follows:

i. Red colour dyes: red dyes are seen in roots or barks of plants or camouflaged inthe bodies of dull grey insects. They are mostly based on anthraquinone and itsderivatives. These dyes are stable to light and washing.

ii. Yellow colour dyes: Yellow is the most abundant of all hues available in nature.

About 90% of the yellow dyes are flavonoids. They produce pale colour with quicker fading which produces dull deep shade but is considered to be susceptible to light as they emit fluorescence. The Wash fastness of natural yellow dyes varies from fair to excellent, e.g., turmeric, Kapila.

iii. Black colour dyes: Black shades are obtained from tannin-rich plant dyes and impart good fastness properties. Examples – logwood, custard apple.

iv. Indigo and woad are blue colour dyes that give excellent fastness to light and washing.

Based on the origin the natural dyes are classified into 3 groups. vegetable, mineral andanimal origin. Vegetable origin dyes, colouring matter derived from root, leaf, bark, trunk or fruit of plants, are as follows in **Table 2**

Part of the Plants	**Dyestuffs**
Root	Turmeric, Madder (Manjistha), Onions,
	Beetroot
Bark/ Branches	Purple bark, Sappan wood, Shillicorai, Khair, Red, Sandalwood
Leaf	Indigo, Henna, Eucalyptus, Tea, Cardamon, Coral Jasmine, Lemon Grass
Flowers	Marigold, Dahlia, Tesu, Kusum
Fruits/Seeds	Latkan, Pomegranate rind, Beetle nut, Myrobalan

Table 2. Some common natural dyestuffs are obtained from vegetableorigins/sources.

Mineral origin colourants are derived from a specific mineral natural source. Some of the important mineral colourants are chrome-yellow, iron-buff, Prussian-blueand manganese brown. Animal origin lac, cochineal and kermes had been the principalnatural dyes yielded from the insects.

e. Natural dyes can also be classified based on their chemical constitution (Dedhia,1998).

1. **Indigoid dyes:** The most common examples of this class are Indigo and Tyrian. Alsoblue dye, woad possesses indigo as the dyeing component.
2. **Anthraquinone dyes:** Almost all the red natural dyes are based on the anthraquinonestructure having both plant and mineral origin. Madder, lacs, kermes, and cochineal are some of the dyes that possess this kind of structure.
3. **Alpha naphthoquinones:** An example of this class is lawsone (henna), cultivated especially in India and Egypt. Juglone obtained from the shells of unripe walnuts is another example. These dyes fall under

disperse dyes and give shades of orange.

4. **Flavonoids,** can be Classified under flavones, isoflavones, aurones and chalcones.

Flavones are colourless natural compounds. Most of the natural yellows are derivativesof hydroxyl and methoxy substituted flavones and isoflavones. An example is a weld which contains luteolin pigment that gives good hues.

5. **Di-hydropyrans:** Closely associated in chemical structure to the flavones aresubstituted di-dihydropyran, viz. haematin, haematoxylin. Those are natural dyes for dark shades on silk and cotton. Common examples are logwood and brazilwood.

6. **Anthocyanidins:** A direct orange dye for wool and cotton is Carajurin which occursnaturally, where it is obtained from the leaves of *Bignonia chica*.

7. **Carotenoids:** The class name carotene is derived from the orange pigment seen in carrots. The colour is due to the presence of conjugated double bonds.

f. Another method of classifying natural dye is based on the method of application(Gulrajani & Gupta, 1992).

i. **Mordant dyes** are dyes which require a mordant of their application as they haven'thad any affinity for the fibre being dyed. A mordant dye must have an electron-donatinggroup. They form an insoluble coloured complex, depending upon mordant used they give different colours. e.g., madder, cochineal etc.

ii. **Vat dyes** are insoluble dyes which are first converted to their leuco compound and then applied to the fibres. The true colour is produced when exposed to air or oxidationfollowed by treatment with a hot soap solution, e.g., indigo.

iii. **Direct dyes** are those dyes that have a strong affinity for cellulosic fibres. They aredyed in a boiling dye bath, suitable for those fabrics which can form H-bond with the dyes. Turmeric, Harada, pomegranate rind etc. are direct dyes.

iv. **Acid dyes** are azo dyes applied from an acidic medium. The dye molecules have either sulphonic or carboxylic group (s). These are applied generally to wool, Silk, andnylon and have no affinity for cotton. Treatment with tannic acid known as back tanningimproves the fastness of these dyes, e.g., saffron.

v. **Disperse dye** usually have low molecular mass and low solubility. Disperse dyes canbe used on hydrophobic artificial fibre with neutral to mildly acidic pH. They are usedto dye silk and wool. These dyes may be post-mordanted with chromium, and copper salts, e.g., lawsone.

vi. **Basic dyes** upon ionization produce coloured cations to form an electrovalent bondwith the –COOH group. They are used to dye modified polyesters, paper, wool, and cotton. They have poor light fastness, e.g., berberine.

Dyes from natural sources are gaining importance as they have health and environmental benefits. Algae contain a huge variety of photosynthetic pigments. The three most important classes of photosynthetic pigments are chlorophylls, carotenoids and phycobilin. Phycocyanin and phycoerythrin belong to the class of phycobilin photosynthetic pigment. While fucoxanthin and peridinin are associated with a carotenoid group of photosynthetic pigment. The table given below elucidates the different types of algae and the foremost pigment they contain. The advantages of algae as the source of dyes and colourants are:

1. Nutritional Value: Unlike their synthetic counterparts, most pigments have high nutritional value.
2. Eco-friendliness: The process of production of natural dyes from algae doesn'tinvolve any usage of harmful chemicals. Mostly these effluents are biodegradable and can be reused as fodder, or

bioplastics.

3. Non-Toxicity: Pigments derived from algae have been licensed as safe for usage as food colourants. Those reasons have contributed to the raise in the need for eco-friendly colourants and dyes from Algae.

The following are industrially important pigments:

Phycoerythrin is a red pigment obtained from red algae (Rhodophyta). *Porphyridium cruentum* is a generally used species for phycoerythrin production. It is cultured in artificial seawater with Potassium Nitrate added to it. The optimum temperature of growth for *Porphyridium* is 21°C.

Phycocyanin is a blue pigment obtained from blue-green algae (Cyanophyta). *Spirulinaplatensis* is the most common source of this pigment. An alkaline pH range of 7.2 to and a salinity of 30 g/l are to be maintained.

Dunaliella salina a halophilic green alga is used for beta-carotene production. This pigment is utilized as a food colourant and it gives a Yellow-Orange colour. It is used popularly as a nutraceutical additive as it is rich in Vitamin A.

This photosynthetic green pigment is derived from *Chlorella sp*. Chlorophyll is found to exhibit anti-mutagenic properties. This is done by the production of Carcinogen Detoxifying Enzymes which in turn reduces the risk of Cancer.

This pigment is obtained from Phaeophytes which can be used for colouring foodproducts to brown colour. It is well known for its fat-reducing properties.

Colour fastness is the resistance of a fabric to alternate in any of its colour characteristics or transfer of its colourants to adjacent white materials or each for different environmental and use treatments like washing, dry cleaning or exposure to heat, light etc. Fading means modifications in the colour with or without loss of depth of shade for exposure to a specific environment either by lightening or darkening the shades. The colour fastness is generally rated either by loss of depth or colour change in the actual sample. when the accompanying white fabrics of similar/dissimilar natureare either in touch by some means of the test procedure.

Extensive work has been carried out to improve the light fastness properties of naturally dyed textiles. A comprehensive assessment of various attempts was taken forenhancing the colour fastness properties of dyes on distinct fibres by different means (Cook, 1982). The tannin-related after-treatments for improving the wash fastness andlight fastness of mordant dyes on cotton; some of these treatments might apply to selective/specific natural dyes. Most natural dyes have poor light stability and therefore,the colours in the textile are often different from their original colours. The relative lightstability of a range of dyes (Padfield & Landi, 1966) involves a change qualitatively.

Some dyes undergo marked changes in hue on washing, shown to be appropriateto small amounts of alkali in washing mixtures, culminating in the necessity of knowing the pH of alkaline solutions used for cleaning textiles dyed with natural dyes. As a general rule, natural dyes have only moderate wash fastness as assessed by the ISO 2 test. Whereas, logwood and indigo dyes show better fastness when applied to differentfabrics. The nature of the detergent solution good enough for the conservation of naturalcoloured artwork has been examined (Hofenk, 1983). A liquor containing 1g/l of sodium polyphosphate is said to be best resulting in slight changes in hue with natural dyes applied on wool or silk (Duff et al, 1977).

In this project, we aim to study the bioactive compounds through phytochemicalanalysis. To obtain a crude extract from *Turbinaria conoides (J. Agardh) Kutzing* and use it on cotton fabric. And also, combine with different plant parts to get various shadesand check to clothe the fastness of the material dyed.

REVIEW OF LITERATURE

A large amount is obtained from plant parts like barks, leaves, flowers, fruits and some roots. The extraction of natural dyes from roots like madder, ratan jot, turmeric, annatto seeds, banajwain seeds, tea leaf, eucalyptus leaf, pomegranate, amla, banana, prickly pear, chandala bark, barberry bark, jackfruit wood, babool bark, manjista, and flowers like marigold, saffron, Ricinus communis etc. (Vankar, 2000; Samanta *et al.,* 2011; M. B. Kasiri, *et al.*,2015; Adeel S., 2019; PS).

Bota Sanda *et al*, 2021, stated that the extraction efficiency of colourant components present in natural sources depends on the various extraction parameters: time, temperature, material-to-liquor ratio, type of liquor and particle size of the substrate.

It is well known that cotton fibres can be dyed through the formation of coordinate bonds involving cellulose chains, mordants and natural dyes. The potential for combining suitable dyes from these dyes to expand the colour gamut from natural dyes on cotton seems worthy of exploration. (Yi Ding *et al*, 2017)

The uses of natural dyes are often linked to terms of fastness properties mainly wash and light fastness. This can be improved by properly selecting natural mordants and extraction along with the best application of technology and ecological process. Mordanting can be achieved by pre-mordanting, simultaneously mordanting and or post-mordanting system. Different types of mordants can be applied to textiles to increase the level of natural dye uptake. (Jahan P & S, 2000; Sengupta, 2001; Prabu & Premraj, 2001; Sunita & Mahale,2002; Bain *et al,* 2002; Paul *et al,* 2002; Mongkholrattanasit R., 2010; K. H. Prabhu *et al*., 2012; Jyoti Vastrad *et al*, 2017; Singh *et al*., 2018)

Balagurunathan *et al*, 2011, stated that natural dyes can also be extractedfrom microorganisms such as Algae, actinomycetes, bacteria, and fungi.

Natural dyes and pigments have been proposed as an eco-friendly alternative to artificial pigments. Among the diverse organisms able to synthesize natural dyes and pigments, several wood-inhabiting fungi produce extracellular compounds which have been tested to dye fabrics under laboratoryconditions with good results. yellow and red dyes producing fungi, *Penicillium murcianum* and *Talaromyces australis*, were isolated from wood samples and used to dye wool fabrics. (Hernandez, Vicente A., *et al* 2019).

The studies were carried out to harness the colourants from the natural dye-yielding algal species to evaluate the dye-yielding potentials for fabric dyeing. Dyeing optimization and mordanting for textile processing were done on*Cladophora glomerata* (Riffat Ayesha Mir *et al*. 2019). Different algal samples were explored in the study for the extraction of pigments and analysis namely, *Spirulina platensis, Turbinaria coinoides, Halymenia dilatate, Caulerpalentillifera, Iyengaria stellata, Sargassum muticum, Colpomenia sinuosa* (MayaS *et al.,* 2019; Muhammad Azeeem *et al* 2019; Fajar Ciptandi 2021).

The study revealed that natural dye extracted from Lichen (*Everniacirrhatum*) was used for dyeing silk fabric. (Rawat, H *et al*., 2018).

These phytochemicals are derived from various parts of plants like leaves,flowers, pulps, barks, seeds and roots. These phytochemicals are used as sourcesof medicinal agents directly. They compose a raw material base for the elaboration of complex semi-synthetic chemical compounds. The natural dyes are loaded with more quantity of phytochemicals, which give characteristic functional finishing to the textiles. The attractive colours and fragrances produced by the planetaries are due to specific phytochemicals present in them.They include tannins, flavonoids, glycosides, saponins, steroids and alkaloids. (Kamboj, *et al*., 2021; Selvam, R. Mari, *et al*. 2015).

Many of the plants used for dye extraction are classified as medicinal andfew of these have been shown to possess remarkable antimicrobial activity. Natural dyes are not only used to impart colour to an infinite variety of materialssuch as textiles, paper, wood etc. but also, they're widely used in other industries. (Gupta, Monika, *et al*. 2013).

MATERIALS AND METHODS

COLLECTION OF PLANT MATERIAL

The fresh samples of *Turbinaria conoides (J. Agardh) Kutzing (J. Agardh) Kutzing* (J. Agardh) Kutzing were collected from Olakuda, Ramanathapuram coast, Rameswaram, and Tamil Nadu (9.2876° N, 79.3129° E). The moisture was removed and dried for four hours. *Turbinaria conoides (J. Agardh) Kutzing* sample was incubated overnight in a hot air oven at 40˚C and was chopped and made into powder using a mixer grinder. The species of algae were identified at the Central Salt and Marine Chemical Research institute, Mandapam camp - 623 519. Ramnad District.

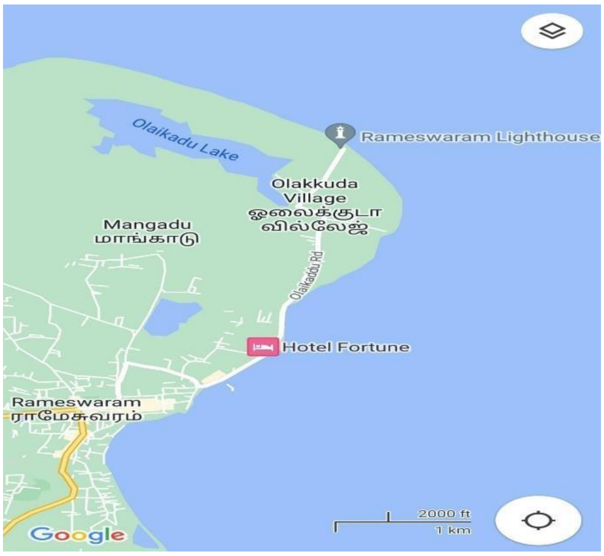


Fig. 1. Map – sample collection

Tubinaria conoides :

Thalli erect, yellowish brown to dark brown in colour, attached by coarse branched holdfasts to the rocky substrate, forming thick, huge colonies. Leaf-like assimilators are 6-12 mm long, having a stalk, small vesicles and marginal blade outlined by coarse teeth; leaves triangular or irregularly rounded in top view; 3.5 to 9.0mm across, often deeply cut on one side. Thalli up to 1.5 m in height. (Trono, G.C. Jr. 2001)

Clade: SAR
Phylum: Ochrophyta Class: Phaeophyceae
Order: Fucales
Family: Sargassaceae Genus: *Turbinaria*
Species: *conoides* (J. Agardh) Kutzing

***Rubia cordifolia* (Manjistha):**

Grows up to 1.5 m tall. The leaves are 5-10cm long and 2-3cm wide, star-shapedwhorls forming around the central stem which is quadrangular and slender. The roots are 1m long and up to 12mm thick. It rises with small hooks on leaves and stems. The flowers are small (3-5mm wide) with 5 pale yellow petals. It has small red to black fruits.

***Arnebia nobilis* (Ratanjot):**

Arnebia nobilis is a perennial herb which grows up to 0.2 m (0ft 8in) by 0.3 m. Has prostrate branched stem. The species is hermaphrodite. Naturally occurring hydroxynaphthoquinone isohexenylnapthazarins are red pigments isolated from the roots. They form the active constituents which are responsible for colour. (Anjali Arora,*et al.*, 2009). They have purple-brown roots, twisted, fusiform covered by a papery layerand pungent odour.

***Oldenlandia umbellate* L. (Chavalkodi):**

Diffuse or prostrate herbs; root-stock woody. Leaves sessile, linear-lanceolate; stipules with several bristles, base triangular. Flowers in the many-flowered terminal, umbellate cymes Seeds are angular and reticulate. Root dye was extracted and used to get red dye (S. Rekha, *et al.*, 2006).

***Vachellia nilotica (*Babul bark):**

Vachellia nilotica is a tree 5–20 m high, branches usually dark to black coloured,exuding a reddish gum. The leaves are bipinnate and have 3–6 pairs of pinnulae and 10–30 pairs of leaflets. The trunk is thick, short, and has grey bark. Flowers are of brightgolden-yellow colour.

Materials required:

Turbinaria conoides (J. Agardh) Kutzing, Babul bark, Manjista, Chavalkodi, Ratan jot,Myrobalan, Alum, soap solution, water bath, cotton fabric.

Preparation of Cotton materials for dyeing:

Washing: Mill bleached, and mercerised cotton fabric has been taken as the basicmaterial for colouring the cotton with dyes. However, this cloth is washed by boilingwith 2% ordinary washing soap solution, in a liquor ratio of 1:30 for 45 mins to getrid of all types of finishing colourant (Fig.2.).

There are five steps for dyeing cotton with natural dyes. (Kashyap, R, 2016)
These are

i. Treatment with Myrobalan.
ii. Removal of Excess Harada powder from the material.
iii. Use of mordant
iv. Washing
v. Dyeing and development,
(a) Extraction of dye solution (b) Actual dyeing of cloth
vi. Soaping
vii. Washing

Fig. 2. Scouring

Fig. 3. Treatment with Myrobalan

Fig. 4. Dyeing

Treatment with Myrobalan: Cotton doesn't have an affinity for all the dyes. Moreover, these dyes don't seem quick on cotton unless they're pre-treated with Tannicacid or mordant (Fig.3).
Myrobalan:

Myrobalan is the fruit of many trees, like *Terminalia Chebula* and *MyrabolanusChebula*. The dried fruit is about an inch long and possesses a bitter astringent taste. The majority of the tannin of the myrobalan is ellagic tannic acid. Myrobalan has a yellowish-brown colouring content. It is used in cotton dyeing and the black dyeing ofsilk. It is regionally called Harada.

Treatment with Myrobalan:
100g of fabric was weighed and the bath was prepared by taking to the Material to Liquor ratio of 1:30. 20 to 25 g per litre of myrobalan was added and the bath was maintained at 40°C for 15to 30 mins. **Mordant**: Natural dyes are substantive, needing no mordant. Natural dyes need a metalsalt to make an affinity between the fibre and the Dye. The metallic salts, due to their corrosive nature, made them extra receptive to colouring matters. A link is formed between dyestuff and fibre which permits bound dyes without affinity for the fibre, to be fastened.

Cotton doesn't have an associate degree affinity for all vegetable/natural dyes. Moreover, these dyes don't seem to be quick on cotton until they're pre-treated with a metal mordant. The Source of natural Tannic acid is obtained from Harada. The washedcloth is treated with a solution containing 20 g/l of Harada powder at 400 C for 30 minutes with constant stirring. Then the fabric is taken out from the bath and squeezedbefore shade drying.

Removal of Excess Harada powder from the fabric:

Excess Harada powder on the surface of the cloth is removed by beating the clothon a Hard surface. It helps in good penetration of mordant and dyes in the cloth leadingto better dyeing/printing qualities.

Treatment with mordants:

The subsequent 5 common mordants are employed to obtain five different shadesof colours from natural dyes namely Alum, Stannous chloride, Ferrous sulphate, Copper Sulphate, and Potassium Di Chromate. This is the distinctive character of such dyes thatgives completely different shades on treating with different mordants. The material is treated with a mordant. Then it is taken out from the bath and squeezed before drying in shade.

Estimation for Treatment with Mordant/Metal salts:
100g of fabric was weighed and the bath was prepared by taking to the Material toLiquor ratio of 1:30.
10g per litre of Alum was added and the bath was maintained at room temperature for15 to 30 mins.

Washing The dried cloth
It is rinsed in soft water rigorously without crushing the cloth to get rid of excess andunfixed mordant.
v) **Dyeing & Developing**
The dyeing or development of vegetable dye is of 2 distinct stages as follows:a.) Extraction of Dye solution.
b.) Actual Dyeing of cloth

Extraction of Dye solution
For extraction of dyes, various vegetable dye-yielding materials are boiled in plainwater. Before adding it to the dye bath the dye solution is sieved.

Estimation for Dyeing or Developing:
100g of fabric was weighed and the bath was prepared by taking to the Material to Liquor ratio of 1:30.
40g per litre of algae powder was added and the bath was maintained at 40°C. The temperature was set at 40 to and then gradually raised to 80°C to 85°C for 45 to 60 mins.
vi**.) Soaping The dyed cloth** is soaped in 1 gm/litre (on the weight of the material) of neutral soap at 40°C for 15 mins to get rid of unfixed dyes. So that overall fastness couldbe improved.
vii) **Washing After soaping**, the dyed cloth is washed thoroughly in normal waterbefore drying in shade.
Note: Washing should be carried out in running water for better results.

Phytochemical Qualitative Analysis
Phytochemical screening helps to acknowledge the constituents of the plant extracts andthe one that predominates over the others and is also helpful in searching for bioactiveagents.

Test for Alkaloids
3 ml of extract was stirred with 3 ml of 1% HCl in a steam bath. 1 ml of the content was taken in two test tubes separately. A few drops of Dragendorff's reagent were added in one tube and the occurrence of orange-red precipitated was taken as positive. Two the second tube Mayer's reagent was added and the appearance of a buff-coloured precipitate indicates the presence of alkaloids. (Harborne, 2005).

Test for Saponins
5.0 ml of distilled water was mixed with crude plant (aqueous) extract in a test tube and Shaked well. The frothing was mixed with a few drops of olive oil and mixedvigorously and the foam appearance indicates the presence of saponins. (Edeoga *et al*.,2005).

Test for Amino acids

A suspension of the sample ~0.2 g in 10 ml of water was prepared. Three dropsof 1% solution of ninhydrin in ethanol are added to 1 ml of the solution and the solutionis heated for five minutes in a boiling water bath. A positive test is indicated by: the formation of red, blue or purple colour. (Yasuma. A., 1953).

Test for Glycosides

Kellar-Killani test was performed, 2ml of the filtrate was taken and 1ml of glacial acetic acid was added. Add 1ml of Concentrated H_2SO_4 and 1ml of Ferric chloride wasadded. The green-blue colour formed indicates Glycoside presence (Chanda, 2007).

Test for Terpenoids

2.0 ml of chloroform was added with the 5 ml aqueous plant extract and evaporated on the water bath and then boiled with 3 ml of H_2SO_4 concentrated. A greycolour formed shows the presence of terpenoids. (Edeoga *et al*., 2005).

Test for Steroids

5 ml of aqueous plant crude extract was taken, to it 2 ml of chloroform and conc.H_2SO_4 were added. A red colour appearance indicates the presence of steroids. (Rohit Kumar B. 2015).

Test for phenols

2 ml extract was taken in a beaker and 2 ml of ferric chloride solution was added.
A dark bluish-green solution indicates the presence of phenols. (Sofowora, 1993).

Test for Glucose

2 ml of Benedict's reagent ($CuSO_4$) is taken in a test tube. The solution is then heated for 3-5 mins in a boiling water bath. Observe for colour change in the solution of test tubes or precipitate formation. (Trease, G.E., and Evans, W.C. 1989).

Combination of algae with other Natural dyes:

A dye bath was prepared with a combination of Algae with other natural dye- yielding plant parts namely Babul bark, Chavalkodi, Manjista, and Ratan jot.

100g of fabric is weighed and different baths were prepared by taking to the Material toLiquor ratio of 1:30 for each. 20g/l of algae powder and 20g/l of different plant materialeach were added separately and the bath was maintained at 40°C. The temperature is set at 40 to and then gradually raised to 80°C to 85°C for 45 to 60 mins. The colours obtained are given in Table. 4.

Optimization of concentration of dye material:

All four different plant materials in combination with algae *Turbinaria conoides (J. Agardh) Kutzing* were taken for this analysis.

Four dye solutions were prepared in a separate beaker by adding 10g/l, 20g/l, 30g/l, and 40g/l of dye material and boiled at 80 degrees for 60 mins. The filtered and pre-soaked cotton material was added to each beaker and dyeing was carried out. Samples were then rinsed in cold water and shade dried. The concentration of dye thatproduced a better per cent of absorption of the dye was visually evaluated and the graphwas plotted. (Harsha Rawat *et al.*, 2018).

Colour fastness:

Colour fastness is defined as the property of pigment or dye to retain its original hue,especially without fading, running, or changing when wetted, or wash-cleaned when exposed to light, heat, or other influences.

a. Colour fastness to washing

The colour fastness of washing the dye sample was determined per ISO: 105 C-10:2006. Test specimen conditioned at 27 ± ***2***°C instead of 21 ± ***2***°C as per ISO' AATCC& ASTM Standards. Method for determination of colour fastness of textile materials to washing, (IS No. 765: 1979). The wash fastness rating was estimated using greyscaleas per ISO-05-A02 i.e., loss of shade depth and ISO-105-AO3 i.e., the extent of staining.

b. Colour fastness to exposure to light

Colour fastness to exposure to light was determined as per ISO 105 B02 - 2013 method. The sample was exposed to UV light in a Shirley MBTF Microsal fade-O- meter which has 500 watts Philips mercury bulb tungsten filament lamp simulating daylight, along with the eight blue wool standards (BS1006: BOI: 1978). The fading ofeach sample against the fading of blue wool standards was observed.

RESULTS AND DISCUSSION

The fresh samples of *Turbinaria conoides (J. Agardh) Kutzing (J. Agardh) Kutzing* (J. Agardh) Kutzing were collected from Olakuda, Ramanathapuram coast, Rameswaram, and Tamil Nadu (9.2876° N, 79.3129° E). The moisture was removed and dried for fourhours. *Turbinaria conoides (J. Agardh) Kutzing* sample was incubated overnight in a hot air oven at 40˚C and was chopped and made into powder. Further, a phytochemicalanalysis was carried out.

Table 4. PHYTOCHEMICAL CONSTITUENTS *OF Turbinaria conoides (J. Agardh) Kutzing* STUDIED

PHYTOCHEMICAL TESTS	*Turbinaria conoides (J. Agardh) Kutzing*
Mayer's Test	**Absence of alkaloid**
Saponins Test	**Presence of saponins**

Ninhydrin Test	**Absence of amino acid**
Salkowski Test	**Presence of Glycoside & Terpenoid**
FeCl2 Test	**Presence of phenols**
Benedict's Test	**Presence of Glucose**

Analysis of the plant extracts revealed the presence of phytochemicals such asphenols, tannins, flavonoids, saponins, glycosides, steroids, terpenoids, and alkaloids.

Table 5. Combination of Algae with different plant materials.

NAME OF THEPLANT PART USED	COLOUR OF THE PLANT DYE ON COTTON FABRIC	COLOUR OF THE PLANT + ALGAE DYE ON COTTON FABRIC
***Vachellia nilotica* (Babul bark)**		

***Oldenlandia umbellate* (Chavalkodi)**		

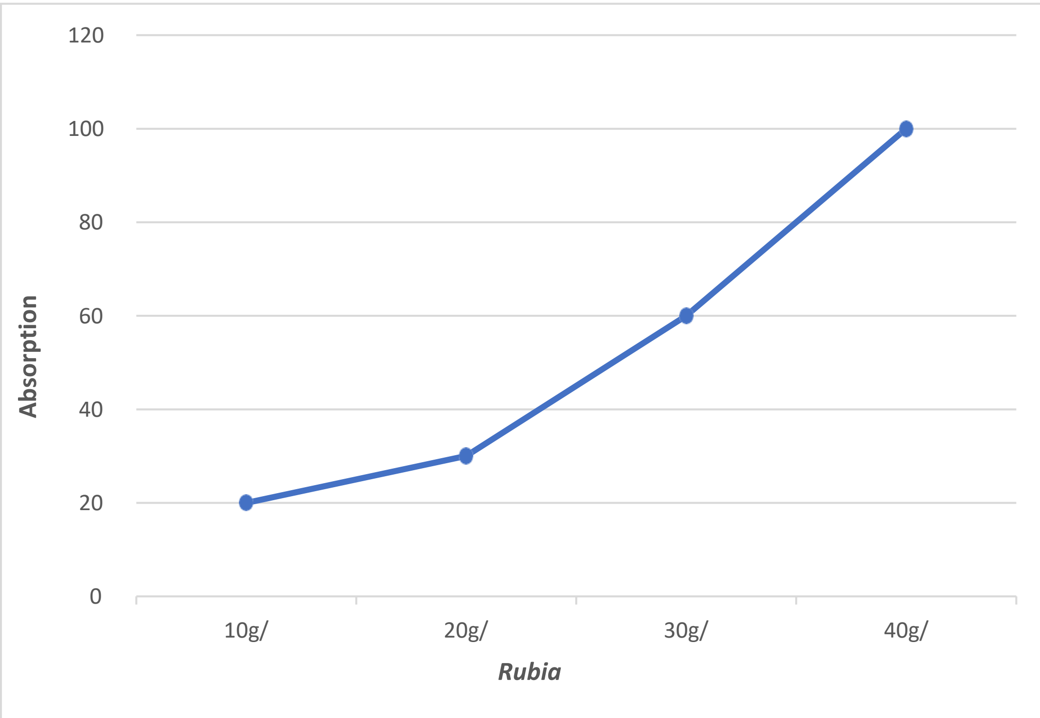
***Rubia cordifolia* (Manjista)**		

***Arnebia nobilis* (Ratanjot)**		

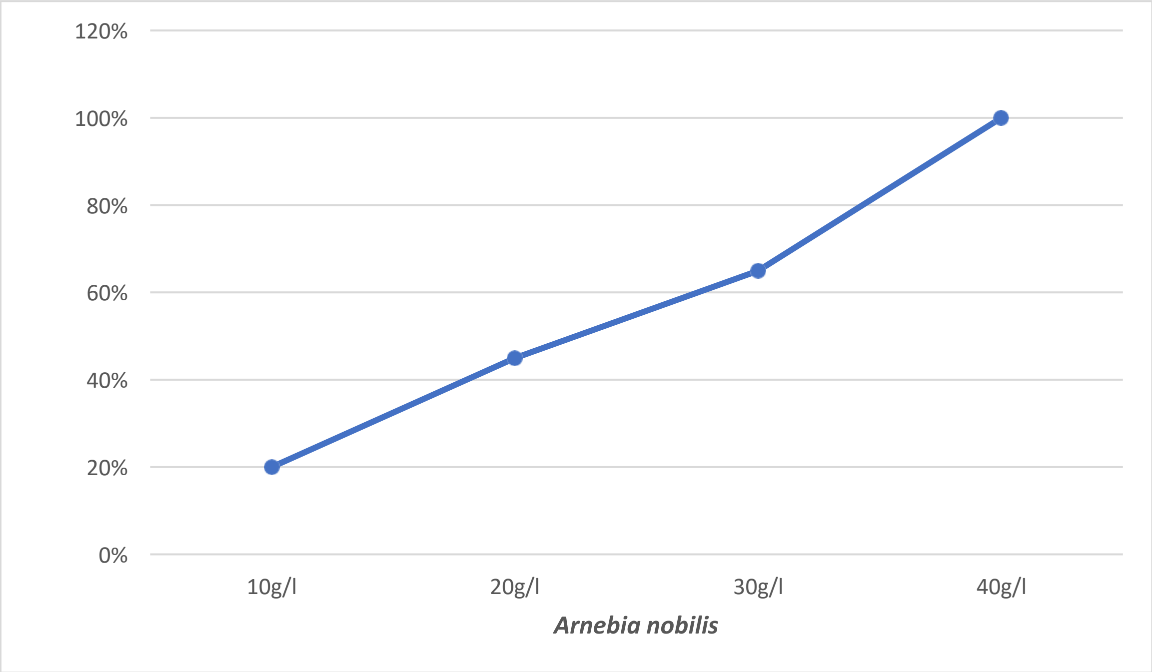
Arnebia nobilis, Rubia cordifolia, Vachellia nilotica, and Oldenlandia umbellate plantparts were used. The tabular column shows the shades of colour obtained when these plant materials were used to dye cotton fabric separately and colour when mixed alongwith the *Turbinaria conoides (J. Agardh) Kutzing.*

EFFECTS OF CONCENTRATION OF DYE:

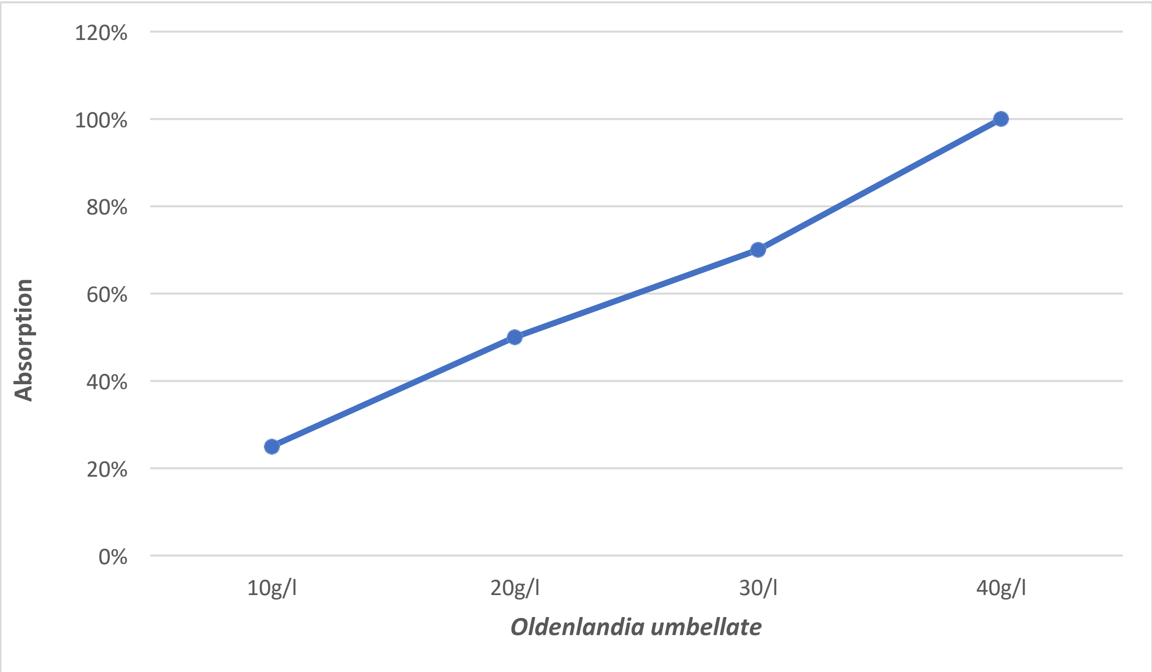
Graph 1:



Graph 2:



Graph 3:



Graph 4:

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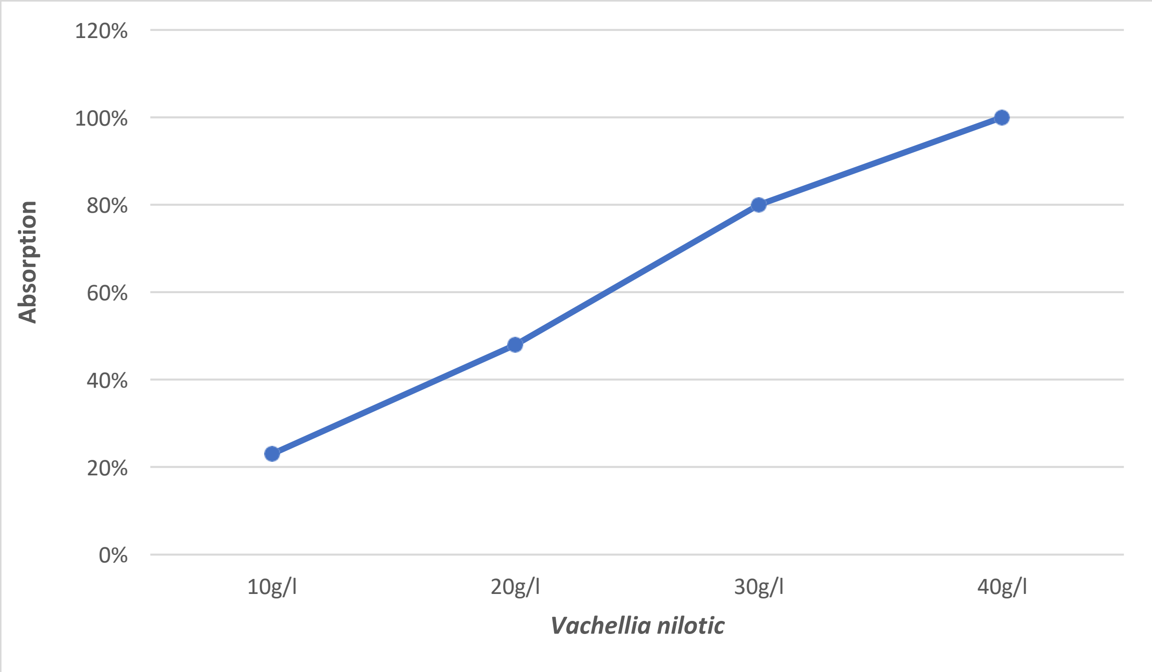
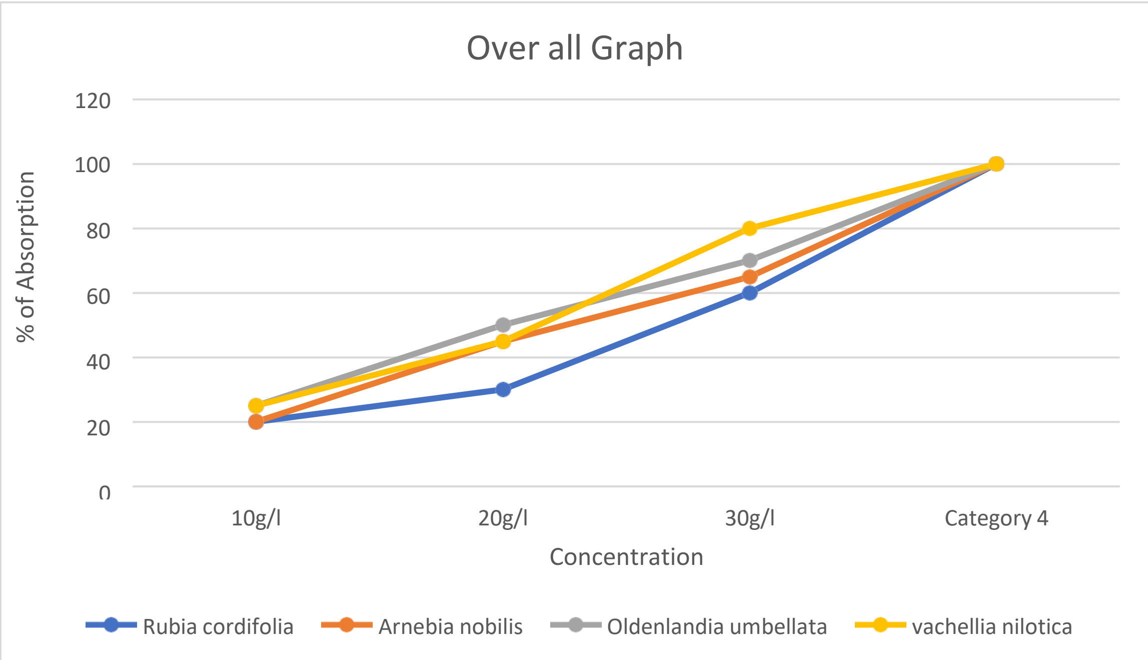
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com





Among the different concentrations (10g/l,20g/l,30g/l,40g/l) taken for observing the highest peak of absorbance. The maximum absorbance was obtained at a 40g/l concentration of the dye solution.

TABLE 6. FASTNESS PROPERTIES OF NATURAL DYED COTTON FABRIC

Colour Fastness to Washing at 30 ºC		**TEST RESULTS**
Change in Colour		4
Staining	Acetate	4-5
	Cotton	4-5
	Nylon	4-5
	Polyester	4-5
	Acrylic	4-5
	Wool	4-5]
(Greyscale rating) 1-Very Poor, 2-Poor, 3-Fair, 4-Good, 5-Excellent		
Colour Fastness to Light	Blue Wool Rating	Class 2 to 3

The colourfastness to washing was done, where according to greyscale rating it falls under the range of 4-5 which indicates it has good washing fastness. The colour fastness to light was done according to the blue wool rating and it gives the class rangeof 2 to 3 which results that it has poor light fastness.

DISCUSSION

During the present work, the extraction of dye was efficiently extracted with an aqueous solution, from *Turbinaria conoides (J. Agardh) Kutzing* and this extract wasused for further analysis. Dyeing experiments were performed on cotton fabric with selected mordant. (Bota Sanda *et al*, 2021). It is known that cotton fibres can be dyed through the formation of coordinate bonds involving cellulose chains, Concentration, mordant and fibre type. (Yi Ding *et al*, 2017). The potential of combining the dyes for dyeing the cotton fabric was worthy of exploration.

Tannic acid is a mordant that makes chemical bonds between the dye molecules and the functional groups of the fibres, and generally changes the colour produced by the dye. Mordanted fabric showed a darker colour uptake, whereas the non-mordanted fabric recorded less colour uptake of the algal dye and loss of colour upon rinsing. The addition of other plant extracts as adjuncts while dyeing can enhancethe colour of the fabric dye.

The studies revealed that obtained the colourants from the natural dye-yielding algal species to evaluate the dye-yielding potentials for fabric dyeing. (Riffat Ayesha Mir *et al*. 2019). Different shades were obtained according to different concentrations of dye and different combinations of plant materials such as *Vachellia nilotica, Oldenlandia umbellate, Rubia cordifolia, and Arnebia nobilis* were obtained.

The different concentrations of the dye were taken and on visual evaluation, thepercentage of absorption was reported (Harsha Rawat 2018). Four dye solutions were prepared in a separate beaker by adding 10g/l, 20g/l, 30g/l, and 40g/l of dye material and boiled at 80 degrees for 60 mins. All four different plant materials in combination with algae *Turbinaria conoides (J. Agardh) Kutzing* were taken for this analysis and a graph was plotted to get the maximum absorption value.

The phytochemical tests were performed to qualitatively analyze the bioactive compounds in the algal extract of *Turbinaria conoides (J. Agardh) Kutzing*. The extractfrom *Turbinaria conoides (J. Agardh) Kutzing* did not exhibit positive results for any tests. (Mona S *et al.*, 2019). Our qualitative analysis of bio compounds results in the presence of phenols, glycosides, glucose, terpenoids, saponins and the absence of alkaloids, and amino acid.

The fastness tests revealed good to excellent results in the dyeing of cotton with pigments obtained from algal biomass. (S Moldovan *et al.*, 2017). The wash fastness rating was evaluated using greyscale as per ISO-05-A02 and ISO-105-AO3. The fadingof each sample was observed against the fading of blue wool standards (Light fastness).The washing fastness in terms of staining indicates the value range of 4-5, which meansrelatively no staining.

SUMMARY

- *Turbinaria conoides (J. Agardh) Kutzing*, a brown seaweed was collected from Olakuda, Ramanathapuram coast, Rameswaram, Tamil Nadu (9.2876° N, 79.3129° E) and crude dye was extracted from it.
- The pre-mordanting technique was used to treat the cotton fabric and crude extract of *Turbinaria conoides (J. Agardh) Kutzing* was used to dye the fabric.
- Combinations were used to get the different shades of colours when *Turbinaria*conoides (J. Agardh) Kutzing were mixed with other dye-yielding plant materials such as Babul bark, Chavalkodi, Manjista, and Ratan jot.
- The presence of bioactive compounds in *Turbinaria conoides (J. Agardh)Kutzing was* obtained by phytochemical analysis (Qualitative).
- The colourfastness (wash fast and light fast) test was done to test the stability ofthe dye in the fabric.

CONCLUSION

Natural Dyes are one of the products of great interest. There is a large plant resource base in India Natural dyes had been extensively used in the past but there is noproper documentation of the usage. The research activities need to be taken more seriously and large in number at the institute, university and also at the individual level.In the days to come it is going to be the most lucrative business in the world. Because of such a new trend in the business, the untapped bio wealth of India can be converted into economic wealth by Science and Technology intervention.

As algal biomass represents one of the resources with the highest availability in nature, the cultivation process for industrial purposes does not generate the pollutants emitted by the production, it can be affirmed that the sustainability and durability concept, in terms of environmental protection, is applied. Therefore, the final textile product is charged with the added value necessary in an eco-aware society by employing algal-sourced pigments.

FUTURE ASPECTS

- The Textile processing industry is one of the major environmental polluters as the effluent from these industries contains a heavy load of chemicals including dyes used during textile processing. The main way to limit the environmental impact of textile processing is to make use of dyes and chemicals that are environment-friendly.
- The availability and use of natural dyes in the current state raise big substantial concerns about the sustainability of the idea. Less expensive production of natural dyes and inexpensive industrial application methods are required.
- Natural dyestuff can produce a variety of colours by a mix-and-match system. Asmall change in the dyeing method or the use of different mordants with the samedye can alter or create new colours, which are difficult to obtain with synthetic dyes.
- Many plants thrive on wastelands; so, wasteland utilisation is extra merit for thenatural dyes. In some cases, the waste in the process enhances the fertiliser for use in agricultural fields.
- This is a labour-intensive industry, which provides job opportunities for all thoseengaged in the cultivation, extraction and application of these dyes on textile.
- Business with natural dyes is still growing, but only a small part is applied to textile dyeing. The greater part consists of dyes for food colouring because the pressure on healthier foods is growing, and there is thus a need to replace synthetic colourings with healthier natural products.
- If natural dyes have to be commercialized, they need to conform to the same stringent standards of performance that are applied to synthetic dyes. It thus follows that much more research and developmental effort needs to go into this area.

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