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Some potential natural dye yielding plants from the State of Goa, India

Nikita G. S. Verenkar and Krishnan Sellappan*

Department of Botany, Goa University, Goa - 403 206, India

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Goa is a small state on the Western coast of India is gifted with more than 3,000 different species of flowering plants. Some of these plant species are known to produce the colours, thus, recognised as natural dye-yielding plants viz. *Cassia fistula*, *Garcinia indica*, *Tectona grandis*. During the study, natural dyes were extracted from various plant parts such as fruits, seeds, bark, flowers, roots, etc. About 62 dye-yielding plants belonging to 37 different families were recorded. Methods of extraction of dyes such as boiling the barks and grinding or chopping the leaves, fruits, flowers, etc. and various dye colours obtained are provided in this paper. These extracted dyes are showing multiple colours, the sustainable utilisation of these potential dyes may provide employment, economic and ecological benefits to the people and dyeing industries.

Keywords: *Cassia fistula*, Dye extraction, *Garcinia indica*, Goa, Natural colours, *Tectona grandis.*

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Introduction

The use of natural dyes was reported earlier in 2600 B.C. in China. Henna was used even before 2500 B.C[1]. By the 4th century A.D., dyes such as Madder, Brazilwood, and Indigo were known. Natural materials were the only source of dyes until 1856. Herbal dyes were also used to colour textiles, but after 1856 Chemists began producing synthetic substitutes for them. The invention of synthetic dyes produced excellent colours and showed good fastness property and hence, the use of natural dyes was declining[2]. However, studies have found that synthetic dyes are harmful to human health as well as environment[3-6]. But due to the eco-friendly nature of natural dyes, it has great demand in the market. India has a rich tradition of dyeing textiles with natural dyes. There are about 450-500 dye yielding plants reported in India[7,8].

A number of documentation studies on dye yielding plants have also been carried out from different regions of India[9-26]. In Dhar district of Madhya Pradesh, 18 dye yielding plants have been recorded[10]. About 19 plant species belonging to 17 families of dicots, mostly trees and herbs have been identified as traditional dye yielding plants in Firozabad, Uttar Pradesh[21]. The dye from *Acacia catechu* finds its application in the preparation of inks and dyeing cotton fabrics. The pink colour dye from *Celosia argentea* is used for paintings[21].

*Correspondent author
Email: skrish@unigoa.ac.in

The tribal population of Goa such as *Kunbis* is known for keeping their culture and tradition alive. Kunbis are aboriginal people residing in the coastal Indian State of Goa. They exist in Goa, Gujarat, Karnataka, and Kerala. Their population is about 75000. Etymology states that the word *kunbi* is believed to have come from the Marathi word *kunbawa*, or the Sanskrit *kur*, meaning "agricultural tillage". Their songs and dance belonging to the Pre-Portuguese era are uniquely social. They are engaged in dyeing and weaving of *Kunbi* sarees. Traditionally, the sarees were red and white and mostly used during their work in the field. No chemicals were used for dyeing these sarees except the use of natural dye from roots of *Rubia cordifolia* (*Manjeestha*) plant. The dye was extracted by soaking the roots for many days in water. This traditional saree was worn by Goan *Kunbi* tribal woman before the advent of Portuguese in 16th century[27]. Dyes might have been discovered accidentally but its use has become a very important part of man's custom that it is difficult to imagine a world without dyes[8]. Considering the above and the economic value, present study of dye yielding plants of Goa and extraction of potential dyes was carried out.

Materials and Methods

Study Area

The study was conducted in Goa, which is located in the South Western region of India. It encompasses an area of 3,702 km^2. It lies between the latitudes

14°53′54″ N and 15°40′00″ N and longitudes 73°40′33″ E and 74°20′13″ E. It has a rich flora and fauna, owing to its location on the range and thus, is considered as a biodiversity hotspot. Goa, being in the tropical zone and near the Arabian Sea, has a hot and humid climate for most of the year.

Regular field trips and survey were conducted in different talukas of Goa viz. Sattari, Salcete, Ponda, Tiswadi, Quepem, etc. during the year 2013-2015 for the collection of dye yielding plants. The dye yielding plants were identified, and different plant parts have been used for the extraction of dyes.

Plant materials

A variety of plant sources were explored for their dyeing potential. The colourful flowers, fruits, roots, leaves, and barks of the trees were used for extracting the dyes.

Extraction of dyes from plant materials

The plant parts yielding dye were collected and used for extraction of dyes. About 2 g of fresh/dried plant materials were weighed, and then the dye was extracted either by boiling, grinding, or chopping the plant materials to small pieces and placed in 10 mL of distilled water. The barks of the trees were dried and grounded to a fine powder and then boiled in water for easy extraction of dyes. Likewise, the dyes from fruits and flowers were extracted by grinding the fresh parts in mortar and pestle by using distilled water[21]. The detailed dye extraction procedure for each plant parts is provided in (Table 1).

Table 1 — Plant species, parts used and methods of extraction of dyes

Plant Name	Plant part used	Quantity of material used(g)	Quantity of solvent used water in(mL)	Methods of extraction of dyes
Acacia auriculiformis	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Acacia nilotica	Pods	2	10	Powder of pods is dissolved in water and boiled in the water bath at 60 °C for 4-5 h.
Aegle marmelos	Fruit rinds	2	10	The rind of the fruits is dried and grounded to fine powder and boiled in water at 60 °C for 4-5 h.
Allium cepa	Outer skin of bulb	2	10	The outer skin of onion bulb is boiled in water at 60 °C for 4-5 h.
Amaranthus tricolor	Leaves	2	10	The leaves are washed thoroughly and then cut into fine pieces and boiled in water for 4-5 h.
Areca catechu	Nuts	2	10	The nuts are grounded into fine powder and then boiled in water for 4-5 h.
Artocarpus heterophyllus	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Averrhoa bilimbi	Flowers	2	10	The flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.
Azadirachta indica	Leaves	2	10	The leaves are washed thoroughly and then cut into fine pieces and boiled in water for 4-5 h.
Bauhinia purpurea	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Beta vulgaris	Roots	2	10	Roots are chopped into fine pieces and soaked in water to extract the dye.
Bixa orellana	Seeds	2	10	Seeds are boiled in water at 60 °C for 4-5 h. to extract the dye.
Bombax ceiba	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Bougainvillea glabra	Bracts of flowers	2	10	The bracts of flowers are cut into pieces and grinded in mortar and pestle to extract the dye.
Bridelia retusa	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Butea monosperma	Flowers	2	10	Flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.

(*Contd*.)

Table 1 — Plant species, parts used and methods of extraction of dyes (*Contd*.)

Plant Name	Plant part used	Quantity of material used(g)	Quantity of solvent used water in(mL)	Methods of extraction of dyes
Caesalpinia pulcherrima	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Capsicum annuum	Fruits	2	10	Fruits are crushed and soaked in water and grinded in mortar and pestle to extract the dye.
Carica papaya	Leaves	2	10	Leaves are washed thoroughly in water and then cut into fine pieces and boiled in water for 4-5 h.
Cassia fistula	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Casuarina equisetifolia	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Catunaregam spinosa	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Ceriops tagal	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Clitoria ternatea	Flowers	2	10	Flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.
Couroupita guianensis	Fruits	2	10	Fruits are crushed and soaked in water and grinded in mortar and pestle to extract the dye.
Curcuma longa	Rhizome	2	10	Fresh rhizomes are chopped into pieces and soaked in water to extract the dye.
Dalbergia sissoo	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Daucus carota	Roots	2	10	The roots of the bark is chopped into fine pieces and then dissolved in water until the maximum dye is extracted.
Delonix regia	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Eucalyptus globulus	Bark	2	10	Powdered bark is dissolved in water, and heated in the water bath at 60 °C for 4-5 h.
Garcinia indica	Fruit rinds	2	10	The rind of the fruits is dried and grounded to fine powder and then boiled in water bath at 60 °C for 4-5 h.
Hibiscus rosa-sinensis	Flowers	2	10	Flowers are cut into pieces and grinded in mortar and pestle to extract the dye.
Ixora coccinea	Flowers	2	10	Flowers are cut into pieces and grinded in mortar and pestle to extract the dye.
Justicia adhatoda	Leaves	2	10	Leaves were thoroughly washed with water and then cut into fine pieces and boiled in water for 4-5 h to extract the dye.
Lannea coromandelica	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Lawsonia inermis	Leaves	2	10	Leaves are washed thoroughly and then cut into fine pieces and boiled in water to extract the dye.
Mallotus philippensis	Fruit capsules	2	10	Fruit capsules are collected and soaked and boiled in water to extract the dye.
Mammea suriga	bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Melastoma malabathricum	Fruits	2	10	Fruits are crushed and soaked in water and grinded in mortar and pestle to extract the dye.
Mirabilis jalapa	Flowers	2	10	Flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.

(*Contd*.)

Table 1 — Plant species, parts used and methods of extraction of dyes (*Contd*.)

Plant Name	Plant part used	Quantity of material used(g)	Quantity of solvent used water in(mL)	Methods of extraction of dyes
Nerium oleander	Flowers	2	10	Flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.
Nyctanthes arbor-tristis	Flower stalk	2	10	Flower stalk are cut into fine pieces and grinded in mortar and pestle to extract the dye.
Opuntia ficus-indica	Cladodes	2	10	The cladode of the plants are chopped into fine pieces and soaked in water to extract the dye.
Peltophorum pterocarpum	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Phyllanthus acidus	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Phyllanthus reticulatus	fruits	2	10	Fruits are crushed and soaked in water and grinded in mortar and pestle to extract the dye.
Psidium guajava	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Punica granatum	Fruit rinds	2	10	The rinds of the fruits are soaked in water and grinded in mortar and pestle for extraction of dye.
Rhizophora apiculata	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Rhizophora mucronata	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Rubia cordifolia	Roots	2	10	Roots are chopped into fine pieces and then soaked in water until the maximum dye is extracted.
Spathodea campanulata	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Spinacia oleracea	Leaves	2	10	Leaves are washed thoroughly in water and then cut into fine pieces and boiled in water to extract the dye.
Swietenia mahogany	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Syzygium cumini	Fruits	2	10	Fruits are crushed and soaked in water and grinded in mortar and pestle to extract the dye.
Tagetes erecta	Flowers	2	10	Flowers are cut into fine pieces and grinded in mortar and pestle to extract the dye.
Tamarindus indica	Leaves	2	10	Leaves are washed thoroughly with water and then cut into fine pieces and boiled in water to extract the dye.
Tecoma stans	Flowers	2	10	Flowers are cut into pieces and grinded in mortar and pestle to extract the dye.
Tectona grandis	Leaves	2	10	Leaves are washed thoroughly in water and then cut into fine pieces and boiled in water to extract the dye.
Terminalia catappa	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Terminalia paniculata	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.
Ziziphus mauritiana	Bark	2	10	Powdered bark is dissolved in water, and heated in water bath at 60 °C for 4-5 h.

Pantone Matching System (PMS) chart

Extracted natural dyes were matched with the colour chart, i.e. PMS (Pantone Matching System)[35], and the corresponding colour code (PMS number) has been noted, and the same is provided in Table 2.

Results and Discussion

The present investigation revealed 62 dye yielding plants belonging to 37 different families. Maximum of eleven dye yielding plant species were documented from the family Fabaceae, followed by Myrtaceae, Phyllanthaceae, Rhizophoraceae, and Rubiaceae with three species each. Remaining families namely Amaranthaceae, Bignoniaceae, Clusiaceae, Combretaceae, Euphorbiaceae, Lythraceae, Meliaceae, and Nyctanginaceae containing two species, and Acanthaceae, Alliaceae, Anacardiaceae, Apiaceae, Apocynaceae, Arecaceae, Asteraceae, Bixaceae, Bombacaceae, Cactaceae, Caricaceae, Casurinaceae, Chenopodiaceae, Lecythidaceae, Lamiaceae, Malvaceae, Melastomataceae, Moraceae, Oleaceae, Oxalidaceae,

Table 2 — Botanical name, family, collection sites and PMS number of extracted natural dyes based on colour chart

Botanical Name	Family	Season of Flowering/Fruiting	Application of dye	Place of collection	PMS (Pantone Matching System) number of extracted natural dyes
Acacia auriculiformis A. Cunn. ex Benth.	Fabaceae	Throughout the year	Used for dyeing textiles	GU campus, Tiswadi	PMS151
Acacia nilotica (L.) Delile	Fabaceae	Throughout the year	Used for dyeing textiles, used in preparation of ink	Dharbandora, Sanguem	PMS141
Aegle marmelos (L.) Correa	Rutaceae	May-June	Used for dyeing textiles	Shiroda, Ponda	PMS143
Allium cepa L.	Alliaceae	May-July	Used for dyeing textiles	Borda, Salcete	PMS4755
Amaranthus tricolor L.	Amaranthaceae	April-May	Edible dye	Margao, Salcete	PMS412
Areca catechu L.	Arecaceae	April-May	Edible dye	Savoi Verem, Ponda	PMS4665
Artocarpus heterophyllus Lam.	Moraceae	Throughout the year	Used for dyeing textiles	Savoi Verem, Ponda	PMS1505
Averrhoa bilimbi L.	Oxalidaceae	October-December	Used for colouring foodstuffs	Betki, Ponda	PMS412
Azadirachta indica A. Juss.	Meliaceae	Throughout the year	Used for dyeing textiles	Pajifond, Salcete	PMS384
Bauhinia purpurea L.	Fabaceae	September-November	Used for dyeing textiles	GU campus, Tiswadi	PMS143
Beta vulgaris L.	Chenopodiaceae	Throughout the year	Used for dyeing textiles, edible	Pajifond, Salcete	PMS1797
Bixa orellana L.	Bixaceae	Throughout the year	Dye is used in food colouring and cosmetics	Selaulim dam, Sanguem	PMS173
Bombax ceiba L.	Bombacaceae	November-december	Used for dyeing silk, cotton	GU campus, Tiswadi	PMS150
Bougainvillea glabra Choisy	Nyctaginaceae	Throughout the year	Used for dyeing textiles	GU campus, Tiswadi	PMS199
Bridelia retusa (L.) A. Juss.	Phyllanthaceae	Throughout the year	Used for dyeing textiles	Chowgule college campus, Salcete	PMS154

(*Contd*.)

Table 2 — Botanical name, family, collection sites and PMS number of extracted natural dyes based on colour chart (*Contd*.)

Botanical Name	Family	Season of Flowering/Fruiting	Application of dye	Place of collection	PMS (Pantone Matching System) number of extracted natural dyes
Butea monosperma (Lam.) Taub.	Fabaceae	January-march	Used for dyeing textiles, food colouring	Selaulim dam, Sanguem	PMS4695
Caesalpinia pulcherrima (L.) Sw.	Fabaceae	Throughout the year	Used in dyeing textiles	Dhavo, Sattari	PMS136
Capsicum annuum L.	Solanaceae	Throughout the year	Edible dye	Pajifond, Salcete	PMS172
Carica papaya L.	Caricaceae	Throughout the year	Used for dyeing textiles	GU campus, Tiswadi	PMS370
Cassia fistula L.	Fabaceae	March-May	Used for dyeing textiles	GU campus, Tiswadi	PMS484
Casuarina equisetifolia L.	Casuarinaceae	Throughout the year	Used in dyeing textiles	GU campus, Tiswadi	PMS1365
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	Throughout the year	Used in dyeing textiles	Mollem, Dharbandora	PMS103
Ceriops tagal (Pers.) C. B. Rob.	Rhizophoraceae	Throughout the year	Used in dyeing textiles	Chorao island, Tiswadi	PMS158
Clitoria ternatea L.	Fabaceae	Throughout the year	Used for dyeing textiles	Ribandar, Tiswadi	PMS2757
Couroupita guianensis Aubl.	Lecythidaceae	Throughout the year	Used as ink	Chowgule college campus, Salcete	PMS124
Curcuma longa L.	Zingiberaceae	Throughout the year	Dye is used as antiseptic	Valpoi, Sattari	PMS137
Dalbergia sissoo Roxb. ex DC	Fabaceae	March-May	Colouring textiles	Savoi Verem, Ponda	PMS153
Daucus carota L.	Apiaceae	June-September	Orange dye is used as a food dye	Pajifond, Salcete	PMS137
Delonix regia (Boj. ex Hook.) Raf	Fabaceae	April-May	Textile dyeing	GU campus, Tiswadi	PMS139
Eucalyptus globulus Labill.	Myrtaceae	January-August	Dye from bark is used as a food dye	Chowgule college campus, Salcete	PMS1395
Garcinia indica Choisy	Clusiaceae	April-june	Used in cosmetics and textile dyeing	Dhavo, Sattari	PMS1797
Hibiscus rosa-sinensis L.	Malvaceae	Throughout the year	Rich in anthocyanins, textile dyeing	GU campus, Tiswadi	PMS5025
Ixora coccinea L.	Rubiaceae	Throughout the year	Used as acid-base indicator	GU campus, Tiswadi	PMS136
Justicia adhatoda L.	Acanthaceae	Throughout the year	Used for dyeing textiles	Pajifond, Salcete	PMS583
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	Throughout the year	Used in dyeing textiles	GU campus, Tiswadi	PMS173
Lawsonia inermis L.	Lythraceae	Throughout the year	As a natural hair dyeing	Savoi Verem, Ponda	PMS399

(*Contd*.)

Table 2 — Botanical name, family, collection sites and PMS number of extracted natural dyes based on colour chart (*Contd*.)

Botanical Name	Family	Season of Flowering/Fruiting	Application of dye	Place of collection	PMS (Pantone Matching System) number of extracted natural dyes
Mallotus philippensis (Lam.) Muell. Arg.	Euphorbiaceae	April-May	Used for dyeing textiles	Velkashi, Ponda	PMS478
Mammea suriga (Buch.-Ham. ex Roxb.) Kosterm.	Clusiaceae	April-May	Used in dyeing textiles	GU campus, Tiswadi	PMS1375
Melastoma malabathricum L.	Melastomataceae	Throughout the year	Dye is used as natural stain	Farmagudi, Ponda	PMS5115
Mirabilis jalapa L.	Nyctanginaceae	Throughout the year	Used to colour cakes and jellies	Pajifond, Salcete	PMS483
Nerium oleander L.	Apocynaceae	Throughout the year	Used in textiles	GU campus, Tiswadi	PMS434
Nyctanthes arbor-tristis L.	Oleaceae	October-December	Yellow dye is used for colouring foodstuffs	Shantadurga temple, Quepem	PMS130 2X
Opuntia ficus-indica (L.) Mill.	Cactaceae	Throughout the year	Dyeing wool, also as food colouring	Sanquelim	PMS1805
Peltophorum pterocarpum (DC.) K.Heyne	Fabaceae	March-May	Used to colour batik	GU campus, Tiswadi	PMS130 2X
Phyllanthus acidus (L.) Skeels	Phyllanthaceae	April-June	Used in textile dyeing	GU campus, Tiswadi	PMS144
Phyllanthus reticulatus Poir.	Phyllanthaceae	Throughout the year	Used as an ink	Caranzalem, Tiswadi	PMS209
Psidium guajava L.	Myrtaceae	Throughout the year	Used in dyeing textiles	GU campus, Tiswadi	PMS718
Punica granatum L.	Lythraceae	Throughout the year	Dyeing cotton fabrics	Pajifond, Salcete	PMS110
Rhizophora apiculata Blume	Rhizophoraceae	August-December	Used in dyeing textiles	Chorao island, Tiswadi	PMS717
Rhizophora mucronata Lam.	Rhizophoraceae	August-December	Used in dyeing textiles	Chorao island, Tiswadi	PMS717
Rubia cordifolia L.	Rubiaceae	August-September	Used for dyeing textiles	Shiroda, Ponda	PMS711
Spathodea campanulata P. Beauv.	Bignoniaceae	Throughout the year	Used for dyeing textiles	GU campus, Tiswadi	PMS145
Spinacia oleracea L.	Amaranthaceae	Throughout the year	Edible green dye	Pajifond, Salcete	PMS364
Swietenia mahogany (L.) Jacq.	Meliaceae	Throughout the year	Used to flavor puddings	Selaulim dam, Sanguem	PMS1235
Syzygium cumini (L.) Skeels.	Myrtaceae	July-September	Used for histological staining	Chowgule college campus, Salcete	PMS2385
Tagetes erecta L.	Asteraceae	Throughout the year	Used in flavouring cacao	Pajifond, Margao	PMS121
Tamarindus indica L.	Fabaceae	December-January	Used for dyeing textiles	GU campus, Tiswadi	PMS383

(*Contd*.)

Table 2 — Botanical name, family, collection sites and PMS number of extracted natural dyes based on colour chart

Botanical Name	Family	Season of Flowering/Fruiting	Application of dye	Place of collection	PMS (Pantone Matching System) number of extracted natural dyes
Tecoma stans (L.) Juss. ex Kunth.	Bignoniaceae	Throughout the year	Used as substitutes for synthetic dyes	GU campus, Tiswadi	PMS106
Tectona grandis L. f.	Lamiaceae	June- September	Used for dyeing cotton and wool	Savoi Verem, Ponda	PMS1805
Terminalia catappa L.	Combretaceae	November-March	Used in dyeing textiles	GU campus, Tiswadi	PMS1788 2X
Terminalia paniculata Roth.	Combretaceae	April-July	Used in dyeing textiles	GU campus, Tiswadi	PMS145
Ziziphus mauritiana Lam.	Rhamnaceae	February-March	Used in dyeing silk, cotton	GU campus, Tiswadi	PMS717

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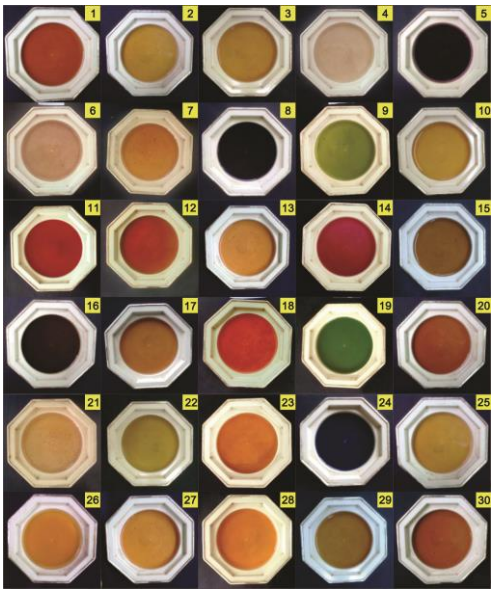

Plate 1 — Different colours obtained from dye yielding plants, 1. *Acacia auriculiformis*, 2. *Acacia nilotica*, 3. *Aegle marmelos*, 4. *Allium cepa*, 5. *Amaranthus tricolor*, 6. *Areca catechu*, 7. *Artocarpus heterophyllus*, 8. *Averrhoa bilimbi*, 9. *Azadirachta indica*, 10. *Bauhinia purpurea*, 11. *Beta vulgaris*, 12. *Bixa orellana*, 13. *Bombax ceiba*, 14. *Bougainvillea glabra*, 15. *Bridelia retusa*, 16. *Butea monosperma*, 17. *Caesalpinia pulcherrima*, 18. *Capsicum annuum*, 19. *Carica papaya*, 20. *Cassia fistula*, 21. *Casuarina equisetifolia*, 22. *Catunaregam spinosa*, 23. *Ceriops tagal*, 24. *Clitoria ternatea*, 25. *Couroupita guianensis*, 26. *Curcuma longa*, 27. *Dalbergia sissoo*, 28. *Daucus carota*, 29. *Delonix regia*, 30. *Eucalyptus globulus*.

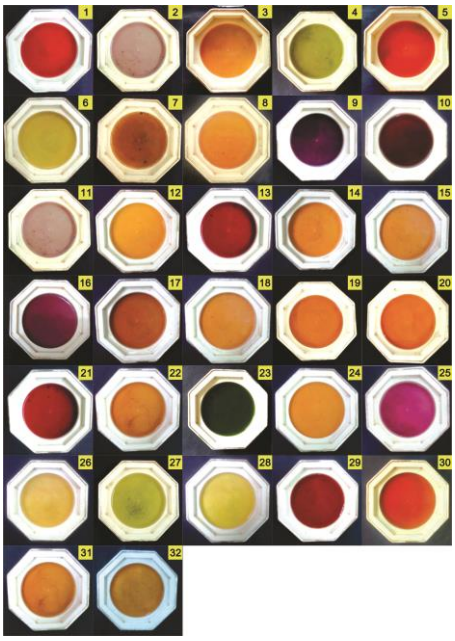

Plate 2 — Different colours obtained from dye yielding plants, 1. *Garcinia indica*, 2. *Hibiscus rosa-sinensis*, 3. *Ixora coccinea*, 4. *Justicia adhatoda*, 5. *Lannea coromandelica*, 6. *Lawsonia inermis*, 7. *Mallotus philippensis*, 8. *Mammea suriga*, 9. *Melastoma malabathricum*, 10. *Mirabilis jalapa*, 11. *Nerium oleander*, 12. *Nyctanthes arbor-tristis*, 13. *Opuntia ficus-indica*, 14. *Peltophorum pterocarpum*, 15. *Phyllanthus acidus*, 16. *Phyllanthus reticulatus*, 17. *Psidium guajava*, 18. *Punica granatum*, 19. *Rhizophora apiculata*, 20. *Rhizophora mucronata*, 21. *Rubia cordifolia*, 22. *Spathodea campanulata*, 23. *Spinacia oleracea*, 24. *Swietenia mahogani*, 25. *Syzygium cumini*, 26. *Tagetes erecta*, 27. *Tamarindus indica*, 28. *Tecoma stans*, 29. *Tectona grandis*, 30. *Terminalia catappa*, 31. *Terminalia paniculata*, 32. *Ziziphus mauritiana*.

Rhamnaceae, Rutaceae, Solanaceae and Zingiberaceae with one species each. All the dye yielding plants were identified at the species level and listed alphabetically along with their botanical name, family, plant parts used, collection site and PMS number (Table 2). Dyes were extracted from all sixty-two plant species, and the colour of the dye obtained from each species is provided in Plate 1 and 2.

Conclusion

The present study revealed 62 dye yielding plants from the State of Goa, India. Extracted dyes have shown multiple colours. Most of the dyes extracted have shown very bright shades, whereas, few dyes have shown lighter shades. The dyes of lighter shades could be used for dyeing the fibres along with natural or chemical mordants. Natural dyes have several applications in textile industries as food colourants, cosmetics etc. Dye from *Bixa orellana* has been used for colouring food products like cheese, butter and in the production of lipsticks. There are several reports on textile dyeing with natural dyes[28-34]. The detailed scientific studies with natural dyes have established that their properties are comparable to that of synthetic dyes[35]. As the natural dyes are eco-friendly and economically viable, the sustainable utilisation of these natural dyes for various applications need to be explored. The commercialisation of natural dyes could be successful with the systematic and scientific approach of identification of plant resources, and extraction of the natural dyes from them would enhance the economy of local people[5]. Evaluating of these extracted natural dyes on silk and cotton fabrics to understand their dyeing properties. This study is encouraging the use of natural dyes by various small and large scale industries for dyeing, which could also contribute to the economy.

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