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Review Article

REVIEW: FROM SCREENING TO APPLICATION OF MOROCCAN DYEING PLANTS: CHEMICAL GROUPS AND BOTANICAL DISTRIBUTION

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ABSTRACT

Many dyes are contained in plants and are used for coloring a medium. They are characterized by their content of dyes molecules. They stimulate interest because they are part of a sustainable development approach. There are several chemicals families of plant dye which are contained in more than 450 plants known around the world. In this article, a study based on literature allowed us to realize an inventory of the main dyes plants potentially present in Morocco. A list of 117 plants was established specifying their botanical families, chemical Composition, Colors and parts of the plant used.

Keywords: Natural dye, Morocco, Chemical structures, Plant pigments, Extraction

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INTRODUCTION

Several hundred species of plants are used around the world, sometimes for thousands of years for their ability to stain a medium or material[1]. The demand for natural colors in the world is around 10 000 tons, equivalent to 1% of the world consumption of synthetic dye [2]. The interest for natural products is experiencing a major craze in this sense that we undertake the study of vegetable dyes.

These plants produce substances, which filter photons, absorb part of the light and reflect the rest of the light spectrum in variable wavelength [3]. A dye plant is a plant able to produce by biosynthesize soluble dyes molecules "dyes" or insoluble compounds "Pigments/lacquers"[4]. These compounds are extracted and used for dyeing various materials, manufacturing colored food, cosmetics, inks or paints [5]. The dye molecules are either contained in the leaves (Indigo), flowers (Saffron), fruits (Walnut stain) or seeds (Annatto), roots (Curcuma), wood (logwood), or the sap (Dragon) [6-8].

In Morocco, some dye plants represent our customs and traditions worldwide. Such as Henna (*Lawsonia inermis)[6],* which is used to color the skin and hair. Or Saffron (*Crocus sativus*)[6], which in addition to its unique taste, is used to color foods.

But the most representative example of using dye plants in Morocco is "traditional tanneries of Fez Chouara" that treat and colors the skins of animals. The dyeing is done in a traditional tank with only natural dyes mostly extracted from plants such as: *Papaver rhoeas* or red poppy for the Red hue, *Indigofera tinctoria* SP gives the Blue tint, *Lawsonia inermis L.* for its Orange dye, or *Mentha* for the green.

Since its discovery in the 18th century by W. H. Perkin [9, 10], the synthetical dye replaced all the natural dyes. The reason is that the natural dyes are very expensive and rare but mainly difficult to use, with bad properties such as fastness to light and low vividness [11]. But the interest in natural dyes takes a new breath. And more specifically the dye plants that contain the most important natural dye with a large range compared to the animals and minerals [5].

In addition to presenting many advantages such as a high diversity and complexity of nuances [7], the use of vegetable dyes mainly falls within a sustainable development approach. They are known to be less toxic, less polluting, safer, non-carcinogenic and non-poisoning [5]. They are also biodegradable and compatible with the environment [12].

In this article, we process methods of extraction and analysis, applications, and different families of natural dyes. Finally, we give examples of dye plants and their chemical compositions and propose a non-exhaustive list of existing dye plants in Morocco could be used for various applications.

For this review, we have grouped a large number of information concerning dye plants. The studies were initially focused on the historical data through works relating the history and evolution of their use since the Stone Age like a wall painting art to more modern use as Dye-Sensitized Solar Cells (DSCC). To make a complete and wide inventory of dye plants existing in the world, we were interested in the studies in the various domains of use: textile, pharmaceutical, DSSC, cosmetic or other.

The most used keywords are Dyes, Naturals dyes, Dyeing plants pigments, the Plant pigments, or the botanical name of the plant. Data chosen at this stage was only from the scientific article, scientific work or a botanical association: a collection of dye plants of the city of Namur. A database of 311 plants was created containing the following data. As regards the list of the Moroccan plants, it was obtained by crossing a large number of ethnobotanical studies in Morocco with our database. The result is a not exhaustive list of 117 dye plants, which are present in Morocco.

Preparation of natural dyes from plants: parameters and methods

Getting a vegetable dye from plants is by extraction. This is the method by which the active ingredient is removed from the plant after treatment with a specific solvent or solvent mixture. A natural dye is usually prepared by boiling the ground powder in a solvent, or a solvent mixture. But sometimes it is left to macerate in cold water. Vegetable dye is extracted by several methods, which may be very simple (decoction of the plant) or extremely complex and long (soaking, fermenting, drying, etching through metal salts) [5, 13].

Several parameters have an important role in the extraction of coloring principle and can change the Colors obtained significantly:

- The part of the plant used: leaves, roots, bark, berries, heart trunk, flowers, stigma, aerial parts of the plant and sometimes the entire plant [4-6].

- The characteristics of the plant: the origin of the plant variety, the harvest season, climate and environmental conditions, the geographical location, the different diseases that can affect the plant, the plant maturity and shelf life [14].
- The extraction techniques: The media type (Aqueous/organic solvent or acid/base), the pH of the medium and the extraction conditions such as temperature, time, hardware, bath ratio and the grain size of the substratum [11].
- The protocol of extractions: agitation, reflux heating or extraction soxhlet [15].
- The mordant or substrate is used to form a lacquer: a large number of dye molecules can be combined with various metal salts as their structure has one or more chelating sites (term characterizing the complexation of a dye with metal). Especially use of metal ions such as Al (III), Cr (VI), Cu (II), Fe (II) and Sn (III). Mordanting iron and copper alters the color rendering darker, unlike mordant aluminum [6, 11].

The extraction is a process that includes transferred masses since the dye molecule is bound to the cell membrane of the plant, which can be a problem. The extraction mechanism is as follows: the disruption of the cell wall; the release of the dye molecule; and the migration to the external environment. New technologies allow for improvement.

However, is required maintain the intact molecule to use it. Table 1 contains some example of some extraction methods [2]. These technologies include the use of ultrasound for excellent returns. Ultrasonic wave's properties, essentially cavitation are applied for years in the plant matrices to improve the classical extraction methods. Its use is experiencing a significant increase either in the laboratory or in the industry since it reduces the processing time with yield increasingly important active ingredients. The effectiveness of ultrasound is now applied to the extraction of colors, flavors, polyphenols, as well as many pharmacological substances [2, 15].

Use natural dyes of plant origin

A dye is a substance that can be used to impart color to other materials such as textiles, papers, and foodstuffs [5]. Natural dyes are used nowadays in many areas from the most traditional to the most innovative: textile industry, the pharmaceutical industry, cosmetic industry, confectionery, food colors, and stationery as a diagnostic agent or as an antibacterial in many products.

Thanks to their nature environmentally friendly, vegetable dyes open the field to several uses especially for applications that require non-toxic products [2].

Table 1: A literature review of some extraction methods

Plant name	Part used	Drying/soaking	Mass/solvent	Extraction	Concentration	References
Eucalyptus	Leaves	**Drying:** under the sun for 1 mo	70g/1l water	Heating for 1h	After filtration, the solution is to boil until evaporated	[16]
Caesalpinia sappan L. *Gardenia jasminoides* *Rhizoma coptidis* *Areca Catechu*	Bark	**Soaking**: 24h in distilled water	150g/800 ml water	Boiling 800 ml to 100 ml by evaporation twice consecutively	Filtration and condensation 50 ml	[12]
Rubia Tinctorium	Roots	**Drying:** oven at 80 ° C and milled every 2 h until stabilization of the mass	10 mg/2 ml Methanol-water (8: 2, v/v)	Ultrasound for 10 min	Removal of the supernatant after centrifugation	[15]
Rubia Tinctorium	Roots	**Drying:** oven at 80 ° C and milled every 2 h until stabilization of the mass	6g/150 ml Methanol-water (8: 2, v/v)	Extraction reflux and stirring for 1H	Filtration	[15]
Rhamnus	Berries	**Drying:** and crushed	25 mg/3 ml Methanol-water (v/v)	Ultrasound for 10 min	Removal of the supernatant after centrifugation	[15]
Harungana madagascariensis	Bark	**Drying:** oven at 50 °C	247g/3,7 kg water	Boil 5 min, then cool for 2 h shaking	Filtration and rotary evaporator	[14]
Allium cepa *Apium graveolens*	Seeds	**Drying:** oven at 60 °C and crushed	1g/10 ml ethanol	Soak for 24 h and filter	Reduced below 60 ° C	[17]

Table 2: Classifications of natural dyes by Codex Alimentarius [3, 27, 28]

Color	Source plant	N ° CE	Common name	Color Index	Some food uses
Yellow	Roots of *Curcuma Longa L.*	E100	Curcumine	75300	Curry, green mustards, soups, syrups, Salam, dairy products.
Yellow to red Variable	Starting strain of edible carrots, vegetable oils, grass, lucerne and nettle. Annatto Paprika	E160a(i) E160b E160c	A: mixed carotenoids B: Rocou, Bixine, Norbixine C: Paprika extract, Capsanthine, Capsorubine	75130 75120 -	Drinks, liqueurs, syrups, soups, condiments, ice cream.
Green	Starting edible herb strain, alfalfa and nettle	E140	Chlorophylle (i) NB: le ii (75815) Synthetic is developed from natural	75810	Green vegetables and fruit to be stored in a liquid, dairy products, delicatessen products and envelope products.
Black	Carbo medicinalis vegetalis	E153	Vegetable carbon	-	Deli meats and envelopes, and caviar substitutes, confectionery, candied fruit, desserts, syrups.

In textile and leather industries, the vegetable dyes are the best known and most used for thousands of years as evidenced by archaeological discoveries in Egypt which confirms the use of plants such as Henne, Safran and Curcuma [18]. They are still present in this area. There are many types of plants such as Gaude, Pastel or Indigo, which are used for dyeing various textile materials: Cotton, wool or silk [7, 8, 11, 19-23].

However, vegetable dyes, although it is renewable and biodegradable sources, can cause over-exploitation of natural resources and lead to deforestation. For this reason, the Global Organic Textile Standard (GOTS) allowed the use of synthetic dyes and banned the use of endangered plants [13].

The usual and known application of dye plants is the food industry. In recent decades, the consumption of natural dyes is increasingly important. Especially in preserves, confectionery, beverages, but also in the deli, butterfat (oil, butter, cheese, and sugar) [3]. The use of these dyes is strictly regulated internationally by the Food and Agriculture Organization (FAO), and the World Health Organization (WHO), or European level according to a strict protocol: CODEX ALIMENTARIUS that includes a large number of establishments. The principle of "positive list" is applied to all food colors, which means that what is not allowed is tacitly prohibited. They are provided with a code number preceded by the letter E1XX which x represents a number as shown in table 2 [3, 24-26].

In the pharmacological field, the majority of dye plants have medicinal properties. In addition to their nontoxic character, natural dyes are excellent candidates for many applications in the production of drugs. They are used to Coloring gelatin capsules shells, as well as the process for coating tablets and pills [5].

The cosmetic is also characterized by the use of vegetable dyes and this since ancient times. Henna is the best-known plant in the world for its ability to color the hair, skin and even nails. But this is not the only one since natural dyes are used for makeup (Eyeshades, red lipstick.), for care, toothpaste mouthwashes, and several other` 1`r applications [5, 29-31].

DSSC (Dye-Sensitized Solar Cell) or Grätzel cell is a photo-electrochemical system based on plant photosynthesis, which exposed to light, produces electricity. Several interesting tracks including natural dyes were explored: the molecules of the group tannins, anthocyanins, carotenoids or chalone and many other compounds sometimes extracted from plant seeds answered as celery or onion. Natural dyes are a less expensive alternative, faster, environmentally friendly and low energy consumption for photosensitive pigment cell (DSSC) compared to the ruthenium complex [17, 21, 32].

Another use is possible for natural dyes: In histology (bone coloring, nuclear staining) for diagnostic deficiencies kidney or liver and even other body tissues. Such as Inulin to make a diagnostic of the kidneys that are not metabolized by the body, or the Rose Bengal, which is used for the liver is to be disposed into 1 minute [5].

By coupling the antibacterial characteristics and its power dyes, natural dyes can be used to offer innovative products such as antibacterial textiles [21].

Characterization of dyes

The natural dyes from plants have the ability to color a solid or liquid substance [5]. Unlike the synthetic dyes, the color is obtained by a combination of molecules contained in the plant [1]. They are formed by atoms of carbon, hydrogen, oxygen and interconnected by single or double bonds forming an electrons flow over molecular orbital "Π".

Every molecule absorbs specific frequencies that are characteristics of their structures. When the molecules are excited, the energy produced is re-emitted as radiation in a wavelength, which determines the color. For example, if the radiation is in the visible area around 600 to 700 nm the color is red.

Principal chemical groups of a dye molecule

The coloring properties of an organic compound are determined by the chemical structure of the dye molecule. Most of them are unsaturated and aromatic organic molecules. As far as the chemistry of dyes is concerned, a dye molecule has three principal chemical groups: Auxochrome, Chromophore, and solubilizing group. They are represented in fig. 1 [5, 33].

The solubilizing group will improve the solubilizing ability of the dye molecule in various substances. This is the main estate of a dyestuff contrary to the pigments that are insoluble [3, 5, 33].

The auxochrome group corresponds to the OH groups, amine groups NH_2, COOH and SO_3H group. These are the ionizable portions of the dye, which will allow the fixing of the dyestuff to the support. This characteristic is very important for dyeing fabrics but not really used in cosmetics or paint [3, 5, 33].

The chromophore group is responsible for the color. Once degraded, the molecule loses its coloring power. This optical property is resulting from the energy absorption in a range of the visible spectrum, while the other wavelengths are transmitted or diffused [3, 5, 33].

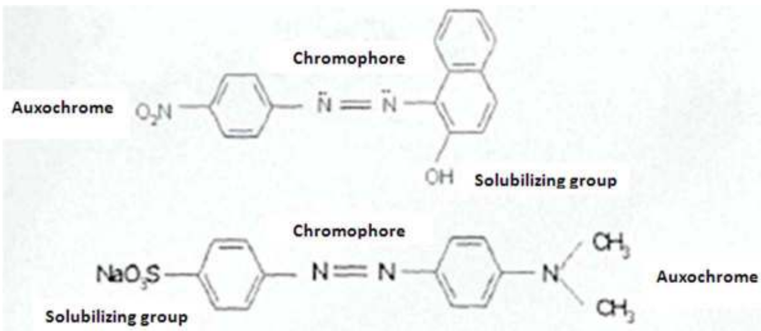

Fig. 1: Principal chemical groups: chromophore, auxochromes et solubilizing group [6]

Classification of natural dyes

The dyes can be classified according to several criteria: Depending on the chemical structure, and depending on the color [1]. In this article, we will focus only on the chemical composition of plants [1, 6, 13].

i. **Quinone dyes**

These are aromatic diketones derived from the oxidation of the diphenol. They are divided into different groups according to their core as shown in the fig. 2: Benzoquinones: (unicycle); Naphthoquinones (bicyclic); Anthraquinones (tricyclic) [6].

These molecules represent three basic structures, which are met in Quinone dye. They are colorless themselves, but the more they are connected to a chemical substituent (in particular the hydroxyl radical OH) the more compounds are intensely colored [6].

Benzoquinones is a Quinone with a single benzene ring. Because of their simple structure, benzoquinones are highly unstable substances, which are rarely found in pure form in plants, especially in vascular plants.

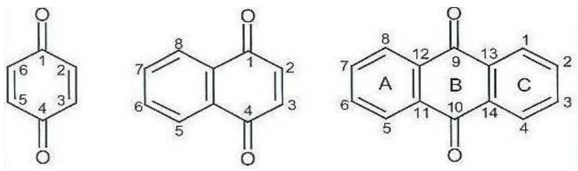

Fig. 2: Chemical structures of Quinones: benzoquinones, Naphthoquinones and Anthraquinones [6]

Naphthoquinones, especially the p-(or 1.4)-naphthoquinones, which are found among the plants. The alkannin is the main dye in the Roots Alkanet and Yellow Alkanet; it exists in these plants as an angelic ester. The most known naphthoquinones is 2-Hydroxy-1,4-naphthoquinone known to Lawsone contained in henna (Lawsonia inermis) as shown in fig. 3 [6, 13].

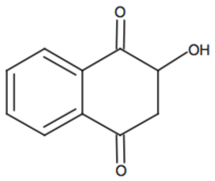

Fig. 3: Chemical structures of Lawsone or 2-hydroxy-1,4-naphtoquinone [13]

Anthraquinones

There are several of these dyes in dyeing lichens and fungi, which are quite important in the plant kingdom [6]. They represent the largest group of red dye [3].

These compounds are characterized by good fastness to light and excellent fastness to washing in the presence of metallic mordant [1, 33].

ii. Flavonoids

Characterized by its yellow color, this type of dye has a particular behavior. When they are in an aqueous solution with low concentration, the most common flavonoids (flavones and flavonols), absorb light of wavelengths between 325 and 370 nm, so they seem colorless or very lightly colored.

In some natural environment, their absorption spectrum is shifted to superior wavelengths, making them appear yellow. The explanation for the appearance of color is attributed to the aggregation of several molecules of flavonoids when they are sufficiently concentrated in a solution and/or complex formation with metal ions [6].

The different groups of flavonoids are given in fig. 4. There is a difference of light stability among several groups of flavonoids. A determining factor appears to be the presence or absence of a hydroxyl group in position 3 in the dye molecule. The absence of this group, for example, the Luteolin, or when glycosylated the dyes have a relatively good light fastness. On the contrary, flavonols as aglycones, present a free OH group in 3, are degraded by light [6, 34].

iii. Carotenoïds

These are yellow dyes to orange-red. They are widespread in the plant kingdom where they give their Color both to the flowers (Coltsfoot, common marigold), to the fruits (tomato) and also the roots (carrot). Their names come from carotene isolated from the carrot in 1881 [1]. The color is due to the presence of longue conjugated double bond, the perfect example is Annatto and Saffron [1].

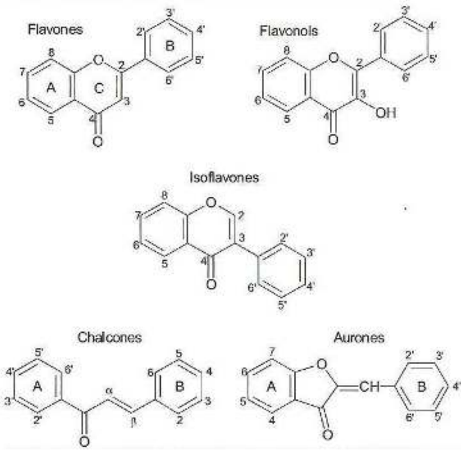

Fig. 4: Chemical structures of Flavonoids sort met in the vegetable kingdom [6]

There are different types of carotenoid:

- Bixin with the Norbixin, are present in the Achiote or *Bixa orellana* at a rate of over 80%. Their chemical structures are given in fig. 5 [6, 13].

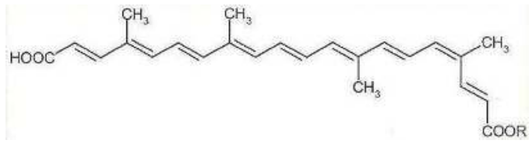

Fig. 5: Structure of Bixin (R=CH3) and the Norbixin (R=H) [6]

In the saffron crocus, Crocetin is presented mostly as his di gentiobiose-ester, Crocin [6]. The different structures are given in fig. 6 and 7:

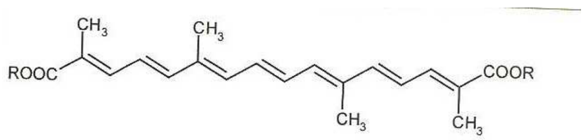

Fig. 6: Chemical structures of the Crocetin [6]

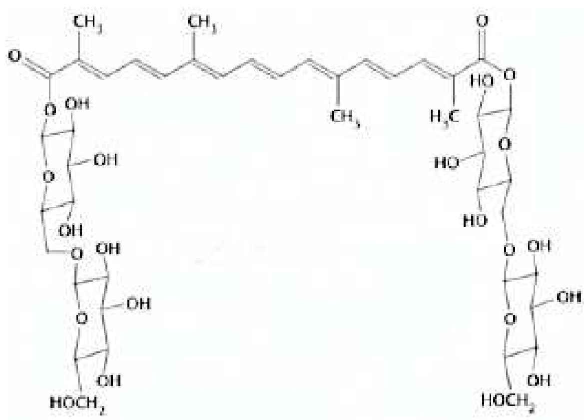

Fig. 7: Crocin structure [6]

They are soluble in oils. These are unsaturated compounds having a plurality of conjugated double bonds whose number influences the coloring. Highly oxidized, they are easily destroyed by light [1, 6].

iv. Tannins

Practically all plants contain tannins. Some of them are rich enough to be used as dyeing plants. They are not usually distributed in the plant and are extracted as a specific part [13], for example [6]:

- Bark: mainly used those Oak, Pine, Alder, or Acacia;
- Wood: it operates mainly chestnut or acacia catechu (*Acacia catechu*);
- Leaves: using various Sumac (*Rhus sp.)* or The tea plants;
- Fruits: they have used Sappan beans (Brazil wood) or Bark grenades.

The tannins are polyphenolic compounds that can be divided into two groups: hydrolyzable tannins and condensed tannins as shown in fig. 10 [6].

Tannins hydrolyzable: formerly called "tannins pyrogallic" are esters. Under the action of a dilute acid or an enzyme (tannase), they hydrolyze to release a phenolic acid and another compound (generally sugar). There are two main families [6]:

Gallotins are producing Gallic acid as shown in fig. 8 and Di-Gallic acid. In most structures, a central molecule is linked to several groups Gallolyl ester [6].

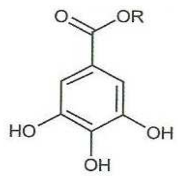

Fig. 8: Gallic acid [6]

Ellagitannins: their acid hydrolysis product of Ellagic acid as shown in fig. 9.

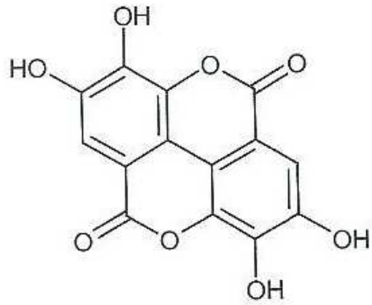

Fig. 9: Ellagic acid [6]

Tannins condensed are flavonoid derivatives. They are not decomposed by hydrolysis. On the contrary, heating in an acidic environment, they polymerize forming insoluble compounds. So it belongs to the category of pigments (they will not be discussed) [22].

Tannins are water-soluble. They produce coloration with iron salts and combine with proteins and certain polyols. They are more or less soluble in hydrophilic solvents (for example alcohol or ketone), but insoluble in hydrocarbons, oils, fats, and waxes. Aqueous solutions are colloidal. For the stability of aqueous solutions, it is not always good, especially in boiling water and in acidic milieu.

They are very soluble in alkaline solutions, in ammonia and gives brownish precipitated with potassium dichromate or chromic acid. They precipitate the salts of heavy metals (copper, iron, lead, zinc, etc.). They form precipitates or colloidal solutions of various colors with ferric salts (known as lacquer) [6].

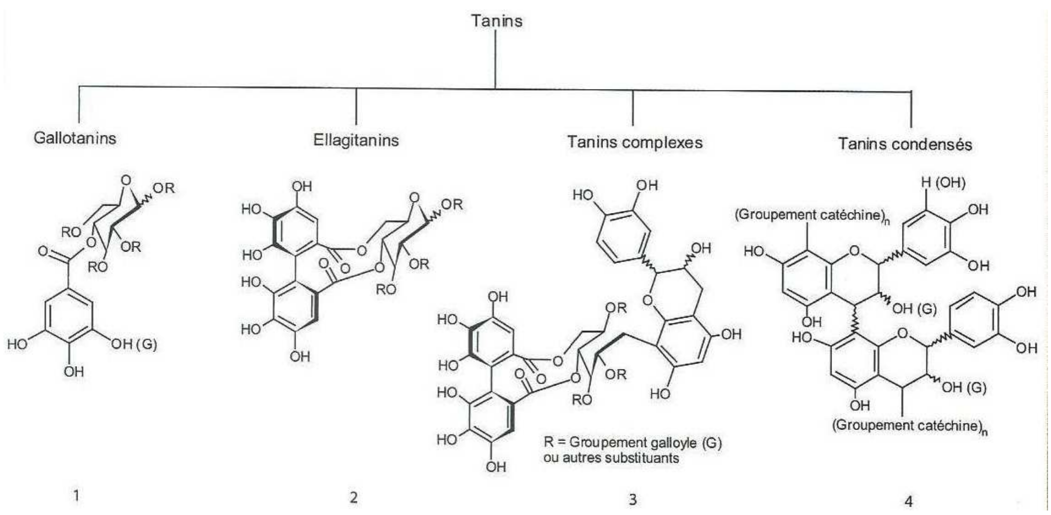

Fig. 10: Tannins classification [6]

v. Indigoids dye

This is perhaps the most important group of natural dyes, obtained from indigo plants. These involve a heteroside form of colorless Indoxyl from which the indigo dyes are biosynthesized [13].

Very few colored pale yellow tint; it is mainly present in the leaves. Indican is the first of these precursors have been identified Indigofera which is different from the one found in *Reseda luteola* or *Isatis tinctoria L.* (Isatan B) [6].

The color indigo is composed of several dye molecules produced from the Indoxyl. Indeed, whatever the glycoside present in the plant that will give precursor decomposition after enzymatic hydrolysis. Indoxyl provides several components after oxidation of Indigo: the Indigotine which is the main component as shown in fig. 11 (Color Index Natural Blue 1 No. 75780) [13]; Or Isatin which is generated in accordance with temperature; or the Indirubin violet dye isomer of indigo, obtained by condensation of Isatin under unknown factors (Color Index Natural Blue 1 No 75790) [6]. Fig.12 show the different ways to synthesis indigo dyes.

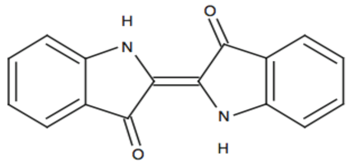

Fig. 11: Chemical structure of indigotin (Color Index Natural Blue 1 No. 75780) [13].

The natural indigo is the largest representative of the vat dye technology for textile dyeing. The Indigo compound is insoluble, so we have to make it soluble in an alkaline environment by reduction process that produces leucoindigo.

At the output of bath, under the action of ambient oxygen, the product turns indigo on the fiber and gives a blue color. This transformation as shown in fig. 13 is visible to the naked eye [6].

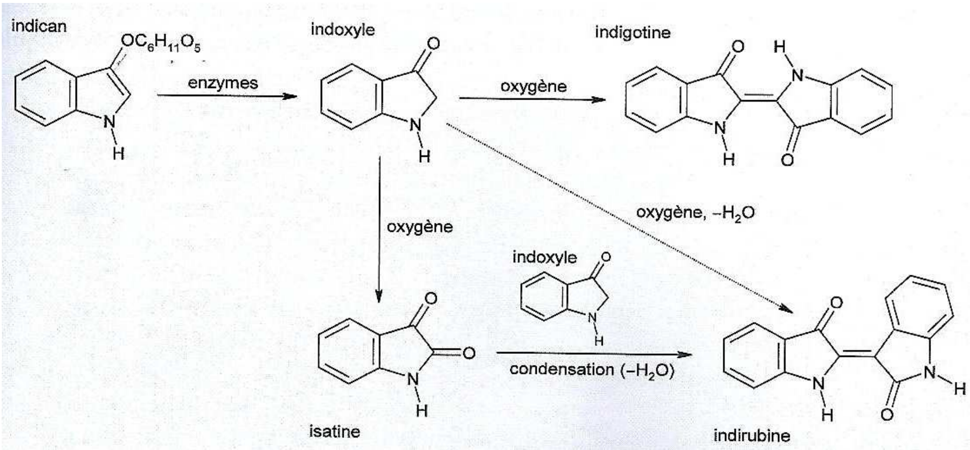

Fig. 12: Synthesis of indigo from Indican and Indoxyl [6]

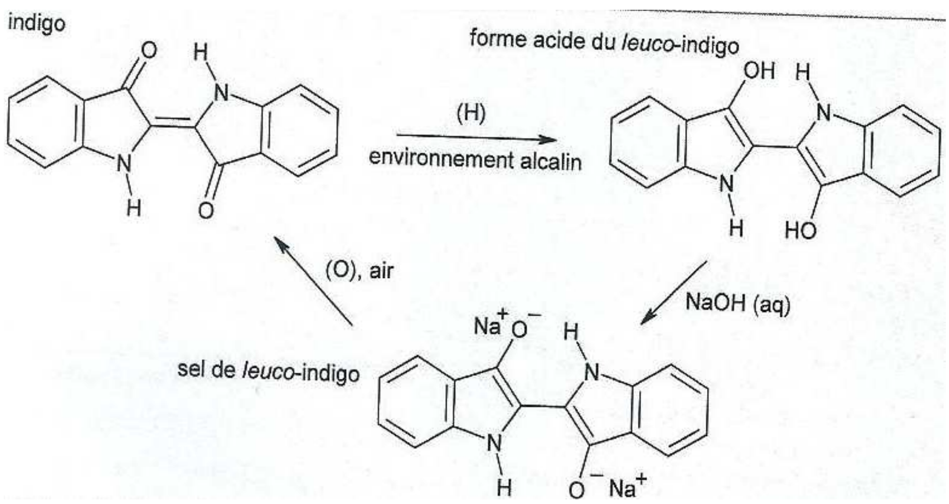

Fig. 13: Reduction of indigo to soluble Leuco-indigo salt through acid leu co indigo and regeneration of the insoluble pigment by the ambient oxygen [6]

The dyeing plant in morocco

There are numbers of important dye plants producing several colors like red, yellow, blue, black or brown. These colors can be achieved using one or more plant parts either roots, leaves, flowers, wood, seeds. About 2000 pigments are obtained from plants and nearly 150 pigments were used. In India, there are around 450 plants are known for their dyeing characters [7].

In Morocco, several plants are used as a natural dye. But they are little known because the majority of dye plants are classified as Medicinal and Aromatic Plants and some of them have been identified having antibacterial activity. The most used are:

- **Brown-orange as: the Henne or *Lawsonia Inermis L.:*** During times of celebration such as a wedding or the eve of a religious celebration, women tattoo their hands and feet to express their joy. This ritual has been part of Moroccan customs for centuries. Henna is also often used for coloring hair. It is widely used by Moroccan women of all ages and was imitated worldwide. Using Henna with different dye plants such as onion peel, Pomegranate or other plants, this blend gives various shades from red to dark brown. The leaves of this shrub contain a dye of the most important principles: Lawson (or Isojuglone). This is an orange-red naphthoquinone, which represents about 0.5 to 3% by weight of the dried sheet.

As with all natural dyes, a second naphthoquinone, the iso plumbagin is present with Lawsone in the bark of the trunk and branches. But in the leaves is also found flavonoids yellow colors such as Luteolin, Apigenin; And tannins in the bark of twigs (5% to 10% Gallic acid), which play a role of organic mordant and contribute to the final color.

- **Red as: Saf. flower of or *Carthamus tinctorius L.*:** Carthamin, extracted from the flowers without the heads, is a red dye of Safflower. This is a quinoa chalcone C-glucoside which is biosynthesized by the end of flowering, from a yellow precursor, précarthamine. Other minor red pigments, compositions close to Carthamin were identified. Carthamin is the Colour Index Natural Red 26 (CI75140).

- **Yellow exclusive as: saffron or *Crocus sativus L.*:** Saffron, the star of the Taliouine region of Morocco, is known for its unique composition with its many culinary and medicinal properties. In addition to its unique taste, is also used to color food, textiles or cosmetics. Morocco is the 4th exporter of Saffron the quantity varies from 2 to 3 tons of product per year (2008/[35]) that is largely required for cosmetic uses, culinary or therapeutic. Its stigmas contain a soluble yellow dye in water, with a very coloring power: a small portion of saffron is enough to color yellow 100 000 times its volume in water. It contains the carotenoids Crocetin (fig. 6) and digentobiosylester Crocin (fig. 7). Overall good quality saffron can contain up to 30% of its weight. They constitute el dye Color Index No: 75100 and Natural Yellow No: 6.

- **Blue as: *Indigofera tinctoria L.*:** The leaves of this shrub contain Indican which is the precursor of dye molecules composing the Indigo (see fig. 13). It decomposes into sugar and Indoxyl by enzymatic hydrolysis. By condensation of Indoxyl, one molecule of indigo is formed in the presence of oxygen. The dye molecules of indigo are the Natural Blue No: 75780 Color Index.

- **Beige brown as Pedunculate oak *Quercus robur L.*:** The oak tree is a high tree found in Europe, the Caucasus, and Morocco. One uses the bark, sold in powder form, TAN. Sometimes dry acorns pulverized are used. The bark of oak contains 12 to 16% of tannins which are a complex mixture of polyphenols, "hydrolysable tannins" especially ellagitannins and "condensed tannins" mainly procyanidins.

According to my literature research, there are no established screenings for dye plants in Morocco. Most of the scientific works are more interested in the MAP (Medicinal and Aromatic Plants). It was easier to find several ethnobotanical screening by regions of these plants. From this information and the database that I collected to come up with a non-exhaustive list of 117 dying plants, which emerge. They are distributed as follows in table 3:

Tableau 3: Botanical distribution of dye plants

Botanical family	Repartition
Asteraceae (cf. table 4)	22
Fabaceae (cf. table 5)	9
Rosaceae (cf. table 7)	8
Fagaceae (cf. table 6)	7
Other Family (cf. table 8)	71

The database includes the following information: The botanical name, the chemical family, color and part used.

Table 4: Dye plants in morocco asteraceae family

Botanical nomenclature	Color	Chemical composition	Parts used	Réf.
Anthemis tinctoria	Yellow, green, Kaki	Flavonoids	Heads flowers	[4]
Artemisia abrotanum	Yellow	Flavonoids/*Aurone*	Flowers and flowering branches	[4, 36-38]
Artemisia vulgaris	Yellow	Flavonoids et tannins.	Entire plant	[4, 36, 37]
Bidens pilosa SP.	Yellow	Flavonoids	Flowers and flowering branches	[6, 39]
Calendula officinalis	Yellow to orange	Carotenoïds et Flavonoids	Flowers	[37, 38, 40, 41]
Calluna vulgaris	Yellow to green	Flavonoids et tannins.	Flowering branches	[4, 39]
Carthamus tinctorius	Red	Quinochalcone NY2 75130 et 75135; NY27: 75125; NR26: 75140 Carthamine	Flowers	[6, 34, 40, 41]
Centaurea cyanus	Blue	Anthocyanins/Cyanidine	Flowers	[4, 34, 37]
Cichorium intybus	Brown, blue	Anthocyanin	Entire plant, Flowers	[4, 34, 36, 37]
Conyza canadensis	Yellow	Flavonoids et en Tannins	Flowers	[4, 37]
Coreopsis SP.	Yellow	Flavonoids: Chalcones and Aurone	Flowers and flowering branches	[6, 37]
Cynara cardunculus	Yellow	Flavonoids	Leaves	[4, 37, 38, 42]
Cynara scolymus	Yellow	Flavonoids	Leaves	[4, 36, 38]
Eupatorium cannabinum	Yellow	*ND	Entire plant	[4, 37]
Helianthus annuus	Yellow	Flavonoids	Leaves	[4, 34, 37, 41]
Inula helenium	Yellow blue	Inuline	Roots and flowers	[4, 36, 38, 43]
Matricaria recutita	Yellow	*ND	Aerial part of the plant	[4, 37, 38, 44]
Scabiosa/knautia arvensis	Green, blue, purple	Rich in tannins: Dipsacan and after the oxidation dipsacotine	Flowers	[4, 39, 41, 45]
Solidago virgaurea	Yellow	Tannins Flavonoids	Aerial parts of the plant	[4, 6, 37]
Tanacetum vulgare	Yellow to brown	Tannins Flavonoids	Flowers and leaves	[4, 38]
Taraxacum sp.	Yellow, magenta	Flavonoids: Luteolin	Roots and rhizomes	[37, 38]
Tussilago farfara	Yellow	*ND	Roots and rhizomes	[37]

* ND: not determined.

Table 5: Dye plants in Morocco of the Fabaceae family

Botanical nomenclature	Color	Chemical composition	Parts used	Réf.
Acacia dealbata	Red to brown	Tannins/proanthocyanidins.	Bark	[6, 46]
Acacia decurrens	Brown	Tannins/proanthocyanidins.	Bark	[2, 6, 46]
Acacia nilotica L. = Acacia arabica	Red, brown and black	Hydrolysable tannins and tannins	Seed pods and bark	[1, 5-7, 13, 39]R13/FEN v1
Acacia pycnantha	Red to brown	Tannins/proanthocyanidins.	Bark	[6, 46]
Cytisus scoparius	Yellow to green	Flavonoids, Carotenoïds; NY2, 75610: Genisteol, 75590: Luteolol	Flowers and flowering branches	[4, 6, 39]
Indigofera coerulea	Blue	Indigoïds: Indican	Leaves	[6, 39]
Ononis repens	Yellow	*ND	Flowering branches	[4, 39]
Trifolium pratense	Yellow to green	Flavonoids	Entire plant	[4, 39, 47]
Trigonella foenum-graecum	Red to brown	Tannins et flavonoids	Seeds	[38, 39, 41, 42, 48-52]

* ND: not determined.

Table 6: **Dyeing plant in morocco family Fagaceae**

Botanical nomenclature	Color	Chemical composition	Parts used	Réf.
Castanea sativa	Brown	Tannins: NB6 gallotin acid.	Bark	[6, 39]
Quercus	Beige to dark	Tannins/Quercitine and Flavine NY10 75670 Quercetol; 75720 Quercitrons.	Bark and leaves	[6, 17, 39]
Quercus cerris L.	Beige brown, grey to black	Tannins	Bark in the form of powder called TAN	[6](R13)
Quercus coccifera L.	Beige brown, grey to black	Tannins	Bark in the form of powder called TAN	[6, 22, 38, 39, 51, 53]
Quercus iles L.	Beige brown, grey to black	Tannins	Bark in the form of powder called TAN	[6, 39]
Quercus robur	Beige brown, grey to black	Tannins	Bark	[4, 6, 36]
Ulex Parviflorus	ND	Flavones, Chalcones et carotenoïds. Genistein, 7-O-glucoside of Genistein.	Bark	[6, 37]

* ND: not determined.

Table 7: Dye plants in morocco of the rosaceae family

Botanical nomenclature	Color	Chemical composition	Parts used	Ref.
Agrimonia eupatoria	Yellow, green, brown	Tannins	Entire plant or leaves	[4, 39]
Alchemilla vulgaris	Light orange	Tannins	Entire plant	[4, 39]
Malus domestica	Yellow	Flavonoids	Bark	[7, 34, 41]
Prunus amygdalus	Green	* ND	The shell of the kernel	[36, 38, 42, 51]
Prunus padus	Orange to brown, purple and grey.	Anthocyanins	Fruits, branches and bark.	[4, 39]
Prunus spinosa	Blue, Pink	* ND	Fruits	[4, 36, 38, 39, 41, 42]
Rosa damascena Mill	*ND	Carotenoids: Quercitin	Flowers	[40, 42, 43, 54]
Rubus fruticosus	Purple and blue, gray	Anthocyanins, tannins	Leaves, branches, fruit, roots and rhizomes.	[4, 34, 36, 38]

* ND: not determined.

Table 8: **Dye plants in Morocco other botanical families**

Botanical Family	Botanical nomenclature	Color	Chemical composition	Parts used	Réf.
Adoxaceae	*Sambucus nigra*	Blue, purple, green	Anthocyanins	Leaves and berries	[4, 44]
Amaranthaceae	*Beta vulgaris subsp. Vulgaris*	Red	Betanine not listed.	Roots	[27, 28, 39]
Amaryllidaceae	*Allium cepa*	Yellow, green, orange	Flavonoids, tannins, and anthocyanins.	The onion skin	[4, 17, 34, 36, 38, 43]
Anacardiaceae	*Pistacia terebinthus L.*	Yellow	Anthocyanins, tannins: Myrisitine; Gallotanique acid	Leaves and galls	[39, 55]

	Rhus [52] Pentaphylla	Beige brown, grey to black	Tannins: Gallotanins Myricetine	Leaves	[4, 13, 36, 39, 51, 52]
Apiaceae	*Anthriscus sylvestris*	Yellow	Flavonoids: Luteolin	Leaves	[4, 39]
	Apium graveolens	Yellow	Flavonoids: Luteolin	Leaves	[17, 36, 39, 43]
	Daucus carrota	Yellow	Carotenoids et anthocyanins	Rhizomes and roots	[4, 34, 36, 39]
	Petroselinum crispum	Yellow	*ND	Leaves	[4, 36, 39]
Araliaceae	*Hedera helix*	Violet blue	Anthocyanins	Fruits	[4, 36, 39]
Berberidaceae	*Berberis vulgaris*	Yellow	Berberine	Bark, roots, stems and leaves and berries	[4, 13, 36]
Betulaceae	*Alnus glutinosa*	Yellow, kaki, brown, black	Tannins et flavonoids	Leaves, bark	[1, 4, 6, 7, 39]
	Betula pendula	Yellow to brown	Tannins	Leaves, branches, and bark.	[4, 39]
Boraginaceae	*Alkanna tinctoria*	Carmine to dark purple	Naphtoquinones. NR20 75535 Alkannine	Roots	[6, 39, 55]
	Echium vulgare	Violet	*ND	Roots and rhizomes	[4, 39]
	Onosma Fastigiata	Violet	Anthraquinones	Roots	[6, 39]
	Origanum vulgare	Violet rouge	Anthraquinones	Leaves	[4, 36, 39, 44]
Brassicaceae	*Isatis tinctoria L.*	Blue	Indigotine	Leaves	[4, 6, 39]
Cesalpiniaceae	*Caesalpinia spinosa*	Black	Hydrolysable tannins	Cloves	[6, 56]
Chenopodiaceae	*Chenopodium album*	Yellow and green	*ND	Aerial Parts	[4, 36, 39, 51]
	Spinacia oleracea	Yellow to brown	Carotenoids	Leaves	[4, 31, 39, 43]
Clusiaceae	*Hypericum perforatum*	Yellow, orange, green	Anthraquinones: hypericin	Entire plant and flowers	[4, 39]
Cupressaceae	*Juniperus Communis*	Ocher, apricot brown, gold or purple	*ND	Fruits and branches	[4, 36, 39, 44]
Dennstaedtiaceae	*Presidium aquiline*	Yellow, green brown, grey, black	Flavonoids et tannins	Roots and rhizomes	[4, 39]
Dryopteridaceae	*Dryopteris filix-mas*	Brown, grey, black	Condensed tannins	Roots and rhizomes	[4, 39]
Ericaceae	*Arbutus unedo*	Yellow to grey	Tannins	Flowering branches bark and leaves.	[4, 39]
Euphorbiaceae	*Chrozophora tinctoria (L.)*	Green, Blue, violet	Anthraquinones flavonoids	Leaves	[5, 7, 39, 57]
Gramineae	*Phragmites australis*	Yellow	Flavones: Tricine.	Aerial parts	[4, 36, 37]
Herbaceae Rubiaceae	*Rubia tinctorium*	Red to orange	Anthraquinone: Alizarin and Purpurin	Rhizomes contain a red pigment	[1, 4, 7, 13, 36, 39]
Iridaceae	*Crocus sativus*	Yellow	Carotenoïds NY6, 75100 Crocetine.	Red stigmas of the flower	[4, 6, 7, 13, 36, 58]
	Iris pseudacorus	Black	*ND	Roots and rhizomes	[4, 37]
Juglandaceae	*Juglans regia*	Green, grey, brown, black	Anthraquinones	The fleshy green shell nuts are known as brou.	[4, 36, 39]
Lamiaceae	*Clinopodium vulgare*	Yellow	*ND	Leaves	[4, 39]
	Lycopus europaeus	Black	*ND	Aerial parts/roots and rhizomes.	[4, 39]
	Rosmarinus Officinalis	ND	Flavones	*ND	[54]
	Stachys officinalis	Brown	Tannins	Leaves	[4, 39]
	Thymus vulgaris	Yellow, orange	Flavonoids Luteolin	Entire plant	[4, 36, 38, 39, 44]
Lythraceae	*Lawsonia inermis*	Yellow to brown, red, orange	Naphthoquinone: Lawsone NO6 75480 Lawsone.	Leaves	[1, 4, 7, 29, 36, 39, 42, 43]
	Lythrum salicaria	Pink, red	*ND	Flowers	[4, 39]
Malvaceae	*Alcea rosea "nigra"*	Violet, blue	Anthocyanins	Rose petals	[4, 6, 39]
	Hibiscus sabdariffa L.	Red	Flavonoids Anthocyanins	Red chalices, fresh or dried.	[6, 17, 38, 42]
Moraceae	*Ficus carica*	Yellow	Flavonols–anthocyanins: Quercitine	Leaves	[4, 34, 36, 38, 39, 42, 43, 51, 55]
	Morus nigra	Yellow, green, brown	*ND	Leaves	[4, 36, 38, 39, 43]
Myricaceae	*Myrica gale*	Yellow	*ND	Leaves	[4, 36, 58]
Myrtaceae	*Eucalyptus*	Yellow to brown	Quercitin	Leaves	[16, 36, 41, 49-51]
Nymphaeaceae	*Nymphaea alba*	Grey to black	Tannins	Roots and rhizomes	[1, 4, 5, 7, 13, 39]
Oleaceae	*Ligustrum vulgare*	Blue, yellow	Anthocyanin et Flavonoids.	Leaves, bark, fruit and branches	[1, 4, 5, 7, 39]
Papaveraceae	*Papaver rhoeas*	Red, pink, violet	Anthocyanins et flavonoids	Flowers	[4, 39, 43, 51]
Phytolaccaceae	*Phytolacca americana*	Red, pink	Betalaines	Berries.	[4, 24, 39]
Pinaceaes	*Pinus sp*	Yellow to brown	Tannins and anthocyanins	Cones, fresh bark	[4, 39]
Poaceae	*Sorghum bicolor*	Sogho's Red carmin	Anthocyanins et tannins	Stems, leaf sheaths	[4, 6, 34]
Polygonaceae	*Polygonum aviculare*	Yellow	Quercetol	Entire plant	[4, 39, 43, 59]
	Rumex crispus L.	Red, violet, orange	*ND	Roots and leaves	[4, 39]

Punicaceae	*Punica granatum*	Yellow	Ellagitannins	Bark and fruits	[5, 6, 13, 17, 36, 38, 39]
Resedaceae	*Reseda luteola L.*	Yellow	Flavonoids: Luteolin NY2: 75580 Luteolol, 75580; 75590 Apigenol	Flowers, aerial parts.	[4, 6, 13, 39, 51]
Rhamnaceae	*Frangula alnus*	Brown, blue, green	Flavonoids	Bark and berries	[4, 6, 15, 39]
	Rhamnus cathartica	Yellow, brown, red, green	Flavonoids Anthraquinones	Bark and berries	[4, 39]
	Rhamnus alaternus L.	Red, violer, orange	Flavonoids: Anthraquinones	Bark and berries	[6, 15, 39, 41]
	Rhamnus lycioides subsp. Oleides L.	Yellow	Flavonols: Anthraquinone/Rhamnétine (CI75640), Quercétine (CI75670).	Unripe fruit, fresh or dried	[15, 39]
Rubiaceae	*Galium aparine; Galium verun (jaune), Galium cruciata galium mollugo*	Red, pink	Anthraquinones	Roots and rhizomes and flowering tops	[4, 7, 39]
	Rubia peregrina L.	Red	Anthraquinones	Roots and rhizomes	[15, 39]
Salicaceae	*Salix alba*	Brown, grey, black	Tannins	Branches, leaves, bark	[4, 39]
Solanaceae	*Atropa bella-donna*	Green	*ND	Leaves	[4, 39, 60]
Thymelaeaceae	*Daphne gnidium L.*	Yellow	Flavones/luteolin, apigenine…	Aerial parts	[6, 36, 39, 41-43, 51, 59]
Urticaceae	*Urtica dioica*	Yellow	Flavonoids	Entire plant	[4, 7, 38, 39, 43, 53]
Vitaceae	*Vitis vinifera subsp. sylvestris*	Purple, blue, grey, yellow	Anthocyanin	Berries and fruits	[4, 24, 34, 36, 38, 39]
Zingiberaceae	*Curcuma longa L.*	Yellow, orange	Curcumine NY3 75300: Curcumine	Root or rhizome	[5, 7, 19, 31, 36, 48]
Zygophyllaceae	*Peganum harmala*	Pink to red	Anthraquinoniques	Seed	[36, 38, 41-43, 45, 49, 52, 59, 61]

* ND: not determined.

CONCLUSION

There are a large number of containers plant dye molecules. They are often known for their medicinal and aromatic properties. Most of the coloring plants have antibacterial activity. Interest in these plants will grow in the coming years and despite several studies conducted worldwide commercial exploitation is very limited since their users and their properties are quite low. Nevertheless, they represent an interesting option as products environmentally friendly.

CONFLICTS OF INTERESTS

Declared none

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