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Weeds: A Vibrant Source for Eco-dyeing

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ABSTRACT

The concept of color has consistently played a significant role in developing various human societies globally. It impacts all aspects of our lives, including the clothes we wear. As a result, the synthetic textile colouring industry has grown significantly. On the contrary, there has been a resurgence in the attention towards natural dyes due to the environmental apprehensions of synthetic dyes and their harmful health effects, as natural dyes are perceived to be more sustainable. Weeds are plants that are out of place and undesirable in a particular environment. Converting these plants into valorized products will be an efficient way of managing them. Many weeds have been identified as potential sources of natural plant pigments like anthocyanins, betalains, carotenoids, and other natural pigments. Using weed plants for dye extraction not only provides an alternative dye source but also helps to reduce weed plant invasion. A variety of natural colours can be extracted from weeds. Furthermore, several invasive species, including wire weed, siam weed, common purslane, *etc*., can be used to extract different hues and tints.

Key words: Colour, Dye, Natural pigments, Weeds.

Shades and tints have perpetually been pivotal in the evolution of various human societies globally. They influence all facets of our existence, encompassing the furnishings within our residences and the garments we don. Color bestows allure to the textile; however, its utilization in dyeing has emerged as a significant ecological peril. The existence of dye in water bodies results in noteworthy repercussions on biota. The majority of textiles were fabricated using synthetic dyes, consisting of inorganic compounds that pollute water. The textile industries release wastewater into the environment containing many kinds of heavy metals, which are found in textile colors.

The aqueous system allows the released heavy metals to get close to human health, which can have negative effects or lead to a variety of disorders. The intricate configurations of dyes, which include aromatic rings combined with diverse functional groups possessing π-electron, can absorb light within the 380-700 nm spectra range. They induce pigmentation owing to the existence of chromogens and chromophores. These dye molecules exhibit high carcinogenic properties. Furthermore, their non-biodegradable nature contributes to their enduring presence in the environment. Textile effluents are extremely harmful due to the presence of several colors, including sulfur, anthraquinone, phthalocyanine, azoic, indigoids, nitrates, acidic acid, soap, enzymes, complex substances, heavy metals and certain auxiliary chemicals. Basic Red 9 is a chemical under the group Triarylmethane, which destroys bacterial DNA and also causes expansion of the thyroid in rats (IARC 2014). A blue dye Cibacron Blue FN-R of Double azo class has an inhibitory effect on glutathione s-transferase in *Xenopus laevis* tadpoles at elevated concentrations (Güngördü *et al.* 2012). A yellow pigment, Disperse yellow 3 under the Single azo groups increased the incidence of malignant lymphomas and hepatocellular tumors in female mice, suggesting that it has carcinogenic effects (Stahlmann *et al*., 2006).

When azo ionic dyes are disposed of in surface or wastewater, they can bind to suspended organic matter by electrostatic interactions and attach to sediments or wastewater sludge, enhancing the persistence (Soriano *et al.,* 2014). Triarylmethane class dyes have deleterious effects on metabolism, build up and permeate the skin, irritate when swallowed or inhaled, create carcinogenic effects, result in sarcomas and when species are overexposed, cause methemoglobinemia (Mittal *et al*., 2010). Dyeing, printing and finishing industries' effluents contain a variety of dye molecules as well as other compounds added during the colouring process. Because of their high water solubility, these dyes can easily infiltrate lakes and rivers. Furthermore, they have the potential to deteriorate into compounds that are profoundly toxic and carcinogenic, posing a threat to the biosphere (Shafi, 2005). So, It is vitally important to find a different, environmentally friendly method of dyeing in the textile industry and recent environmental consciousness has reignited interest in natural dyes.

Natural dyes are recognized for their ecological attributes as they are both renewable and biodegradable,

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exhibit skin-friendly properties andpotentially offer health advantages to the wearer. Natural dyes are used to dye various natural fabrics and recent studies have shown that they are compatible with certain synthetic fibers. Beyond their textile applications, natural dyes find usage in coloring food, pharmaceuticals, artisanal products, toys andleather processing and several dye-producing plants are utilized in traditional medicinal practices. Plants, animals, minerals and microorganisms serve as potential sources of these hues. Noteworthy advantages of natural dyes over synthetic counterparts include their production of distinct subtle shades from sustainable resources and minimal environmental footprint. A study revealed that the biological oxygen demand (BOD) value of wastewater from natural dye production ranged from 40 to 85 mg L^{-1}, well below the 100 mg L^{-1} limit stipulated by the Central Pollution Control Board of the Government of India. According to Dumitrescu *et al*. (2004), employing natural dyes is essential for both increasing the market's acceptance of eco-friendly products and lowering pollution caused by the widespread use of synthetic colours. To save the environment, customers are now willing to pay a premium for environmentally friendly products. The safety of natural dyes is purportedly higher from a clinical perspective owing to their non-carcinogenic and biodegradable properties. There is a growing interest in natural dyes in the global market, which accounts for approximately 10,000 tons, representing 1% of the total consumption of synthetic dyes worldwide (Sachan and Kapoor, 2007).

Weeds

Weed plants are considered as undesired vegetation in various ecological settings. These plants exhibit aggressive growth patterns, posing a significant threat to the presence of desirable flora within a specific area. Weeds can outcompete other plant species by efficiently depleting substantial amounts of mineral nutrients and moisture, especially excelling over crop plants during periods of drought. In addition, they tend to overshadow crop seedlings, occupying vital space required for the establishment of crop roots. Due to their higher nutrient requirements and efficient nutrient absorption mechanisms, weeds grow at a faster pace, thereby restricting the availability of essential nutrients for crop plants (Murty and Venkaiah, 2011). Furthermore, numerous pioneering weed species have been identified as potential natural sources of various plant pigments such as anthocyanins, betalains, carotenoids andother natural pigments (Choudhury and Chandrasena, 2022). From being unwanted or considered as parasites that grow on plants, Weeds develop into an inventive natural color that benefits the plant as well as the use of the weeds themselves. Managing weeds is an expensive and time-consuming task that will raise the expense of agriculture. However, employing weeds as a source of textile dye will have both commercial and agricultural benefits.

Colours from weeds

Weeds are the plants that are not valued where it is growing and they compete with main crops for survival. In addition to lowering food quality and creating health and environmental risks, weeds have been shown to be responsible for up to one-third of yield losses (DWSR, 2014). Similar to other plants, these have varying concentrations of phytochemicals including tannin, phenols andcoloring compounds, which will open the door for using the plants to make dye.

Not only may employing weed plants for dye extraction provide local textile dyers with a different source of color, but it also reduces weed invasion of food and cash crops. Weeds may be categorized according to the hue derived from the plant material. The primary hues encompass blue, yellow andred. Utilization of primary hues derived from weeds enables the generation of secondary and tertiary colors. Apart from primary hues, various shades and tones can be derived from weeds.

Weeds used for blue colour extraction

Butterfly pea (*Clitoria ternatea* L.) is the weed commonly referred to as blue pea and belongs to the family Fabaceae. Six major anthocyanins, or ternatins (A1, A2, B1, B2, D1 and D2), are responsible for the deep blue colour of the Clitoria flower. These flowers are typically found almost throughout the entire season. A notable feature of this plant is the profound blue color of its flowers. Two significant flavonol glycosides, namely 3-O-(2"-O-alpha-rhamnosyl-6"-O-malonyl-beta malonyl)-beta-glucoside and 3-O-(2",6"-di-O-alpha-rhamnosyl)-beta-glucoside, were extracted from the petals of the blue-flowered plant. Using different mordents like $CuSO_4$ and $FeSO_4$ different colours can be produced (Tantituvanont *et al.,* 2008).

The morning glory plant, Blue bindweed (*Ipomoea tricolor* Cav.), a perennial originating from Mexico, is classified as a noxious weed in certain regions of the United States. Belonging to the Convolvulaceae family, this plant is predominantly found in tropical areas. Peonidin recognized as a Tricaffeoylated anthocyanin and commonly referred to as heavenly-blue anthocyanin, serves as the dyeing agent (Yoshida *et al*., 2009). The utilization of Woad (*Isatis tinctoria* L.) as a source of indigo for coloring the vibrant wrappings of mummies and various ornamental pieces was observed among the ancient Egyptians. The use of woad-derived indigo in Europe dates back to the Roman era, according to historical references. This plant, a Brassicaceae family member, is frequently encountered in tropical and subtropical areas (Hill, 1992).

The most significant and widespread aquatic weed of global importance is the free-floating water hyacinth (*Pontederia crassipes* Mart.). This issue poses a severe challenge in numerous regions, notably in water-abundant states such as Kerala. This plant's flowers are utilized to extract the pigment (Kumar and Kumar, 2017). A work was

conducted by Gopika *et al.* (2018) in Alappuzha. In the present investigation, the aqueous extracts derived from water hyacinth blossoms were examined as a promising reservoir of natural pigments. Utilizing potassium dichromate, copper sulfate, oxalic acid, stannous chloride andferrous sulfate, each at a concentration of 6% of the pigment, as fixatives different hues were produced. After dyeing cotton fabric, an evaluation was performed to compare the efficacy of these fixatives alongside the pigment obtained through extraction. The investigation yielded a spectrum of hues, which remained unaltered after drying in sunlight.

Weeds used for red pigment extraction

Grain amaranth (*Amaranthus cruentus* L.), belonging to the amaranthacae family, represents an ancient pseudo-cereal with the potential for utilizing weeds to acquire natural colors. Amaranths, recognized as ubiquitous annual weeds, are renowned for their production of plentiful and vibrant inflorescences in addition to yielding millions of seeds per plant. This botanical family is accountable for the synthesis of red (betacyanin) and/or yellow (betaxanthin) betalain pigments. Despite the incomplete elucidation of betalains' specific functions in plant physiology, they are acknowledged for their involvement in attracting pollinators and are postulated to have a role in responding to both biotic and abiotic stresses. (Stintzing, 2004). The red amaranth plant encompasses both chlorophyll and betalain pigments within its composition. Sankaranarayanan *et al*. (2022) analysed the dye extracted from amaranth through the use of ethanol and acetone as solvents (Fig 1). The chlorophyll pigment was extracted into the dyes, resulting in a green hue. The betalain pigment, on the other hand, was extracted by utilizing water as a solvent, which gave rise to the pink coloration of the dyes. Compared to leaves, flowers produced a darker dye andthere was no difference between the colours made from fresh and dry leaves.

Boerhavia erecta L. is a type of summer weed that reduces soil moisture and nutrients, which lowers the potential yield of the crop that follows. This weed is commonly known as boerhavia under the family Nyctaginaceae. Compared to *Amaranthus spinosus*, it contains a higher level of betacyanin. Tropical and sub-tropical regions are where it is typically found. Stem is used to extract the pigment, betacyanin (Stintzing, 2004) and can be used as an alternative to synthetic dye. *Morinda angustifolia* Roxb. is a small deciduous shrub belonging to the Rubiaceae family. To get the most coloring matter from its roots and bark, a tree aged three to four years old is ideal. Mature trees have relatively little colouration. Major compounds of anthraquinone that are found in Morinda roots are known as alizarin and morindone, which is responsible for colour. This plant is commonly known as Indian mulberry. Red prickly pears (*Opuntia lasiacantha* Pfeiff) are the source of betalain, a red pigment. Bright red coloured fruit is used to extract the dye, which is an edible pigment. Across tropical and sub-tropical regions of the world, prickly pears are extensively spread (Ali and Mohamedy, 2011).

Weeds used to extract yellow pigments

Renowned for its exquisite blossoms, *Lantana camara* L. is widely acknowledged for its ability to establish itself in disturbed environments, such as woods and bushlands. It has also been involved in inducing toxicity to livestock (Ghisalberti, 2000). The yellow color of newly opened lantana flowers is attributed to chemicals called carotenoids, of which β-carotene is the predominant type. Once pollination is over (post-anthesis), the synthesis of delphinidin monoglucoside causes chromatic changes with the creation of anthocyanins, which change the color of the flower from yellow to orange, fiery red andmagenta (Mathur and Ram, 1986). Fragrant multicolored flower clusters with florets in hues of yellow, white, pink, red, purple, blue, lilac andorange are arranged in a whorl above heads. The colors of the florets change with age and maturity. Local textile dyers can use weed plants to produce dye and eliminate weed invasions in cash and food crops. Coat button (*Tridax procumbens* L.) (family: Compositae) is a common weed found in tropical areas of all countries,



Fresh leaves | Dry leaves | Fresh flowers

Fig 1: Dyes extracted from *Amaranthus cruentus* L.

growing primarily during the rainy season and known as tridax daisy. Dyes are extracted from leaves. Apigenin and quercetin are the major dyeing agents. Apigenin is responsible for the yellow colour while quercetin is responsible for pink colour (Sudhakar, 2020).

Widely spread stem holoparasitic plants are a threat to trees and crop plants. Among them are species of Cuscuta, commonly referred to as dodders. About 200 species of plants in the genus Cuscuta are stem holoparasites on other plants andthey are all members of the Cuscutaceae family. Cuscuta species appear to be stem-only vegetative parts; they lack roots and fully grown leaves. The yellow-colored stems can be used to extract the dye (Syamwil *et al.,* 2021). The poisonous, noxious andinvasive parthenium weed (*Parthenium hysterophorus* L.) (Asteraceae; Heliantheae) poses a danger to global agriculture. Leaves are used to extract the dye and the dyeing agent is carotenoids. Yellow weed (*Reseda luteola* L.) is commonly known as weld under the family Resedaceae. Leaves, stems and flowers are used to extract the dye and the dyeing agent is luteolin which is commonly distributed in temperate regions. Reseda seems to have the most prominent dying strength among several yellow-colored natural dyes andit also performs very effectively when mixed with other dyes. Fig 2 shows the spectrum of colours from *Reseda luteola* L with different mordants (Vankar and Shukla, 2018).

Extraction of natural dye from plants

There are various ways to extract dyes from plant materials. Because of their component polarity and thermal stability, which necessitate a significant amount of solvent and time, a suitable approach was chosen.

The soaking method is a traditional method of dye extraction mostly used to extract indigo from woad. In the first stage, freshly harvested plants are soaked in the steeping vat for about 24 hours. The resulting solution formed due to anaerobic fermentation is then run off into a second tank, the beating vat. Air is introduced by manually kicking the water with legs for two hours. The oxidative conditions lead to the formation of a blue precipitate of indigo, which settles to the bottom of the tank. In the third stage, the indigo is boiled to clean it. After that, it is filtered, cleaned and dried into cakes. When air is added to the fermented mixture, the dye will precipitate and sink to the bottom of the container (Kumar, 2004). Natural colouring materials can also be extracted using organic solvents such as acetone, petroleum ether, chloroform, ethanol andmethanol, or a combination of solvents like ethanol and methanol, water and alcohol and soon, depending on their nature. Betalain can be extracted with 100 per cent ethanol and the amount was high when solid to solvent ratio was 1:2 (Mini *et al.,* 2021). Both water-soluble and water-insoluble materials can be extracted from plant resources using the water/alcohol extraction method. Due to the increased ability to extract a greater variety of chemicals and colouring ingredients, the extraction yield is higher than with the aqueous approach. Alcoholic solvents can also be supplemented with acid or alkali to aid in the hydrolysis of glycosides and the release of colouring agents. Distillation makes it simple to remove and reuse solvents, which facilitates the purification of extracted colour. To obtain a better and more effective separation, the Soxhlet apparatus was employed to filter the solvent and residue. Ethanol, an organic solvent, was also employed in the extraction process. A certain F/S ratio was used to take the measured amounts of marigold powder (F) and the appropriate volume of solvent (S). The Soxhlet extractor's thimble contained the raw material, which was flower powder that had been ground up anda condenser with a high water flow rate was placed over it. The extraction was done for six hours. The additional solvent was evaporated using a rotatory evaporator andthe extracted dye was weighed (Naveed *et al.,* 2019). Plant material was heated to boiling temperature with water for one hour and then cooled to twenty-five degrees Celsius in the boiling process. Following the recovery of the supernatant, deionized water was used twice to wash the

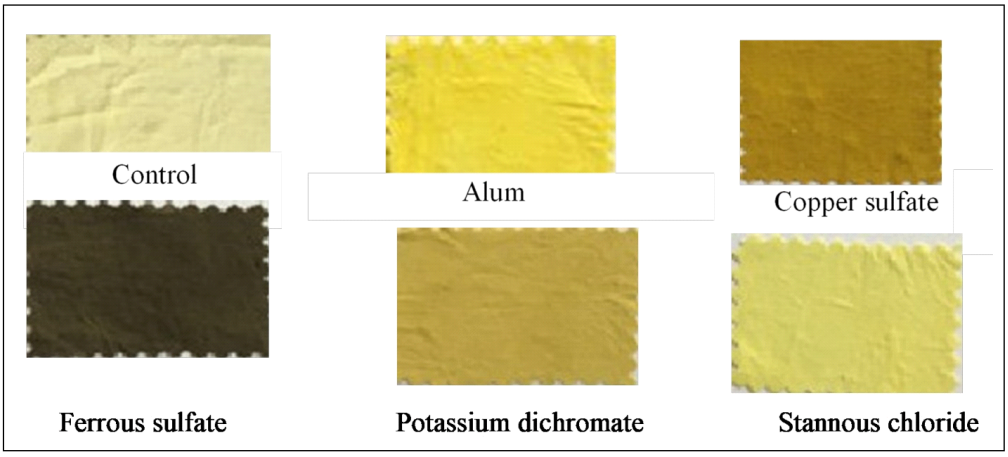

Fig 2: Various colours from *Reseda luteola* using different mordents.

solid residue. Dyes can be extracted from plants using supercritical fluid. A gas functions as a supercritical fluid above its critical values of temperature and pressure. Such a fluid has physical properties somewhere between those of a liquid and a gas. Upper critical fluid extraction using carbon dioxide is an alternative to solvent extraction as it is not toxic, cheap, easily available anddoes not leave any residues. Critical temperature and pressure values for carbon dioxide are 31.4°C and 1,070psi respectively (Kitada *et al.,* 2009). Ultrasonic energy can be used to extract pigments from plants. Microwave extraction is a method in which a minimum amount of solvent is needed. After being struck by electromagnetic beams, polar molecules in a substance become energetic and swing with the alternate movement of the electric field. As a result, the alternate action of the polar molecules' alignment and realignment causes friction between them, which raises the temperature of the surrounding area. The method used for the extraction of pigments depends upon the type of pigments and the plants from which it extracted.

CONCLUSION

Branded naturally coloured fabrics are now commonly available in world markets, due to their minimal environmental impact, renewable nature and ability to produce natural shades through safe methods. With the advantages, disadvantages like high cost, standardization difficulties, Poor brightness and fastness properties and unavailability of plant material are observed with eco-dyeing. Natural dyes are less toxic, worthwhile and sustainable resources for the textile industry with minimal environmental impact. Improving methodologies of extraction and application and generating cost-effective processes are needed to make use of a large diversity of natural dye sources.

Conflict of interest

All authors declare that they have no conflict of interest.

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