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Natural Dyes for Eco-friendly Dyeing of Cotton

EXPERT's Column

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She has been awarded the Honorary Fellowship of the Textile Association of India, Mumbai. She is a member of the Textile Division Council of the BIS and ISO Sectional Committee on Textiles (TC 38) and a senior member of the American Association of Textile Chemists and Colorists and member of the Professional Awards Committee of the Textile Association of India.

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Man has always been fascinated by the myriad colours of nature and tried to recreate these in the clothes and other items of usage by harnessing locally available plant, animal and mineral sources. Remnants of coloured cotton or flax textiles have been found in the archaeological excavation sites of almost all ancient civilisations such as India, Egypt, Greek, Aztec and others in spite of the degradable nature of these textiles.

As the civilizations developed, the art of colouration of textiles from natural materials mainly dye bearing plant parts such as leaves, stem, bark, roots and flowers, etc. also progressed. In India, the craft of dyeing and printing of textiles developed to a great extent and contributed significantly to the nation's wealth. All dyes for textile colouration used to come from natural sources till the accidental synthesis of the first dye mauveine in 1856 in the laboratory followed by many more which led to the creation of a new class of dyes known as synthetic dyes. Traditional dyes on account of their origin from natural resources were designated as natural dyes. By the first half of the 20th century, synthetic dyes almost completely replaced natural dyes on account of their easy availability in ready to use form in a wide array of colours at a lower cost with consistency of shades and good colourfastness properties. It was accelerated by the rapid industrialisation of textile manufacturing in Europe and the tradition of using natural dyes world over could survive only in certain isolated pockets.

Synthetic dyes however are of petroleum origin and hence not easy to biodegrade. Unfixed dye remaining in the dyebath along with other dyeing auxiliaries and chemicals used in dyeing gets discharged as effluent which is highly coloured and polluting. Consumer awareness about the pollution caused by the production and use of synthetic dyes resulted in a global revival of interest in natural dyes since the last decades of the 20th century and a niche market for textiles dyed with natural dyes was created. Attempts were made to reconstruct the traditional knowledge of natural dye application processes lost due to the years of neglect by interacting with a few surviving practitioners and scanning old records available with help from the scientific advances made in the field of synthetic dyes. It led to the publication of a number of books and articles about various natural dye sources and their application processes.

Sources of Natural Dyes

Natural dyes unlike synthetic dyes are not available in ready to use form. These are obtained from natural materials and based on their source of origin can be broadly classified as plant, animal, mineral and microbial dyes and a brief description of the same is as follows.

Animal Origin

Apart from the Tyrian purple from the *Murex* mollusc found in the Mediterranean Sea, a prized natural dye in ancient days due to its brilliant purple shade and very good fastness properties, almost all other animal dyes are derived from insects and yield red colour. Lac is the hardened secretion (stick lac) of the insect *Kerria lacca*, cochineal is obtained from the bodies of female insect *Dactylopius coccus*, Kermes which produces crimson red colour is from the insect *Kermes licis*.

Mineral Origin

Mineral pigments found in nature such as cinnabar, red ochre, yellow ochre, raw sienna, malachite, ultramarine blue, azurite, gypsum, talc, charcoal black etc. have been used for coloration purposes. Apart from the red ochre which was used by monks for coloration of their robes, these were mainly used in paintings and murals along with gum as binder.

Mineral pigments found in nature have been used since ancient times for colouration

Bacterial and Fungal Origin

Some bacteria such as *Bacillus, Brevibacterium, Flavobacterium, Achromobacter, Pseudomonas, Rhodococcus spp.* produce coloured substances as secondary metabolites. *Serratia marcescens* produces deep red pigment. Pigments from the fungus *Monascus purpureus* are used for coloration of some traditional oriental food items and also for fabric coloration. Some bacteria have also been reported to produce indigo upon exposure to petroleum products. Orchil dye from lichens was used for violet and purple shades as a cheap alternative to expensive Tyrian purple. Some dye yielding mushrooms such as *Cortinarius* species have been extensively used in Europe for dyeing.

As these sources do not require land and can be grown in fermenters in the laboratories, they may be promising in solving the availability issues of natural dyes in future.

Dyeing with lichens and mushrooms

Plant Origin Dyes

Presently plants are the major source of natural dyes and therefore natural dyes are sometimes also referred as vegetable dyes. Out of the three primary colours - blue, yellow and red - the blue is almost always obtained from indigo while there are various sources for red and yellow dyes. Some important dye sources are as follows

Blue dyes (indigo)- Leaves of plants from the *Indigofera* genus like *I. tinctoria, I. errecta, I. sumatrana* are the best source of this dye. Popularly known as the 'king of natural dyes' it has been in use since ancient times till present day for producing blue colour though most of it used today is synthetic. Woad (Isatis tinctorial), Dyers knotweed (*Polygonum tinctorium*), Pala Indigo (*Wrightia tinctoria*) and Khum (*Strobillanthes flaccidifolius*) are some other plants traditionally used to produce indigo dye.

Leaves of plants from the Indigofera genus are the best source of indigo dye

Red dyes- Main plant sources are European madder (*Rubia tinctorum*- roots) and Indian madder or manjishtha (*Rubia cordifolia*- roots and stem), aal (*Morinda citrifolia*- roots and bark), safflower (*Carthamus tinctorius*-florets), Sappan wood or patang(*Caesalpina sappan*)/ Brazilwood (*Caesalpinia echinata*), ratanjot (*Onosma echioides*- roots and bark).

The root and stem of Indian madder (Manjistha) plant is a major source of red dye

Shades from Manjistha

Yellow dyes- Turmeric (*Curcuma longa*- rhizome), saffron (*Crocus sativus*- dried stigma of flowers), annatto(*Bixa orellana*- seeds), Barberry (*Berberis aristata*- roots, barks and stems), Flame of the Forest, tesu or Palas (*Butea monosperma*- flowers), pomegranate (*Punica granatum*- rinds), Myrobolon (*Terminalia chebula* –fruits and leaf galls), marigold (*Tagetus* sp.), onion (*Allium cepa* –

Shades from Marigold

Turmeric and Saffron are two sources of yellow dye

outer skins), dolu or Indian rhubarb (*Rheum emodi*- roots and rhizome), Kamala (*Mallotus phillipensis*- fruits), etc.

Brown dyes- Catechu or cutch obtained from the heartwood of *Acacia catechu,* dyes cotton, wool and silk to brown colour

Researchers continue to explore local flora for its potential to dye textiles and several plant materials have been utilised for dyeing of various textile substrates with varying results in terms of the deepness of the colour produced and its fastness properties. Every year new additions are being made to the list of plant species which can be used as dye source.

Cotton fabrics dyed with tender coconut husks

Application of Natural Dyes

Dye Extraction

Unlike synthetic dyes which are available in a purified ready to use form, natural dye bearing materials contain only a small percentage of colouring matter and therefore extraction of colouring matter is an essential step in dyeing with natural dyes. Though there are some suppliers of purified extracts in India and other countries, most of the practitioners prepare their own dyes.

Natural dyes except indigo are generally extracted from the dye bearing material by heating with water and removing the residual plant material by filtration through a cloth. Sometimes addition of acidic or alkaline substances such as vinegar or lime may facilitate better dye extraction depending upon the dye material. It may also change the hue of dye by changing the dye components that get extracted.

Indigo is extracted by fermentation wherein soaking the freshly harvested indigo leaves and twigs in warm water releases the indigo present in the leaves in the form of a glucoside by the action of an enzyme also present in leaves. The fermentation gets complete in about 10-12 hours and the greenish yellow indigo containing liquor is then transferred to beating vats where it gets oxidised by the atmospheric air to the blue coloured indigotin which settles down at the bottom. It is collected, washed and after removing excess water is pressed into cakes.

Dye Application

Material preparation: Traditional dyeing procedures have been revisited with the help of modern scientific inputs to suit present-day requirements. Many natural dyes are non-substantive to cotton and other cellulosic fibres as they lack the amino and carboxyl groups present in wool and silk. Hence the use of a mordant is often required which creates a sort of bridge between the dye molecule and cotton which facilitates dye fixation.

Tannin bearing materials such as myrobolon (*Terminalia chebula*) fruits, pomegranate rinds etc., oils such as gingelly or castor oils or sulphated oils and metallic salts like alum or aluminium sulphate, iron sulphate/acetate are used as mordants. Sulphated castor oil known as Turkey red oil along with alum was used as mordant to get the very bright red colour known as Turkey red on cotton with madder dye through an elaborate process. Some of the metallic mordants like chrome and tin used in the past and to some extent copper, are now restricted for use by eco-regulations. Mordants can be applied to the textiles before dyeing (pre-mordanting), during dyeing (simultaneous mordanting) or after dyeing (post mordanting). The hue and the fastness properties of some natural dyes can vary with a change in the mordant used which can lead to creation of varied shades from a single dye (polygenetic dye). Even for direct dyes, the use of mordants increases the fastness properties as mordants form an insoluble complex with the dye.

Garments made from naturally dyes cotton

As in dyeing with synthetic dyes, the textile material to be dyed is first made free from accompanying impurities like wax, pectin, oil, grease etc. and made white and absorbent through scouring and bleaching. Traditionally, multiple treatments with sheep or cow dung along with alternate wetting and sun bleaching of the fabric were used for this purpose and the process used to take many days. Presently, the fabric is usually scoured with soap or an alkali and bleached with hydrogen peroxide.

Dyeing and fastness properties: Natural dyes can be used to dye textiles at all stages such as fibre, yarn or fabric. Traditional dyers working at cottage level prefer yarn dyeing in hank form as it offers versatility in designing through weaving. They use metal vessels, but machines like Jigger and winch machines can be used for dyeing larger lots of fabric.

Impurities free purified textile material is mordanted if necessary and then introduced into the dye extract at room temperature. It is then slowly heated to the required temperature which usually ranges from 60°C to boil. Dyeing is continued at the required temperature for 45 to 60 min and the bath is then allowed to cool. Dyed material is squeezed out, rinsed with water, soaped, rinsed again and dried. If it needs post mordanting, instead of soaping, the dyed material is first put into the mordanting bath and then soaped. The dyeing procedure in terms of dyeing temperature, pH, etc. may differ from dye to dye as they differ in chemical constituents and therefore have be optimised for each dye. A special feature of natural dyes is that, different colours can be obtained from the same dye by changing the mordant and its application sequence. Variations in the mordants used along with changes in the dye extraction and dyeing conditions can give rise to a large number of shades from a single dye. The inherent variations in the dye content of natural dye bearing materials on account of age, climatic conditions, season etc. can cause variation in shades. It causes difficulty in matching shades but creates unique shades.

Indigo, the prized blue dye does not require any mordant and has a special application process wherein water insoluble blue indigo is reduced to leuco indigo which is soluble in water and also has affinity for textile materials including cotton. Continuous fermentation vats were being maintained in the past with periodic nutrient replenishment to facilitate this transformation through microbes. Today some practitioners have developed such vats while some are using chemicals for this conversion. Textile materials after dipping in the leuco indigo vats are exposed to air, whereby the blue dye gets regenerated. Multiple dips and exposure cycles are used to build deeper shades.

Colourfastness properties of natural dyes are perceived to be poor, but with careful selection of dye sources and due experimentation in dye application process, very good colourfastness properties similar to the best of synthetic dyes can be achieved.

Advantages of Natural Dyes

Natural dyes are eco- friendly as these are obtained from renewable resources and are biodegradable whereas synthetic dyes are derived from non- renewable petroleum resources and are difficult to biodegrade. No harmful chemicals are released during the production and use of natural dyes. The residual vegetal matter left after dye extraction can be easily composted and used as fertiliser. They produce unique and soft colours soothing to the eye which are in harmony with nature. These are especially suited for use by cottage level artisans who can use locally available natural materials to create unique eco-friendly textiles.

In addition to the above benefits, natural dyes also offer functional benefits to the wearer and users of such textiles. Many natural dyes absorb in the ultraviolet region and therefore fabrics dyed with these dyes offer good protection from ultraviolet light. Some dyes may also impart antibacterial or bacteriostatic properties to the textiles. Natural dyes such as manjishtha, arjuna etc., are Ayurvedic medicines hence they may also impart therapeutic properties to the dyed textiles.

Challenges and The Way Forward

Availability of natural dye bearing materials is the biggest challenge in increasing their usage. It can be solved to some extent by adopting measures like utilisation of agro and agro-processing by-products and wastes as dye sources, cultivation of suitable dye plants on waste lands, breeding and agronomic interventions for high colour content, sustainable harvesting of dye bearing materials, etc. There are also some safety concerns in the usage of natural dyes. Care has to be taken in handling and usage of metallic mordants and compliance with the eco regulatory limits of restricted heavy metals in dyed textiles has to be ensured. As some natural substances may also poisonous, toxicological evaluation of the new natural dye sources is necessary. Judicious harvesting of the dye plants needs to be ensured to prevent over exploitation and threat to the biodiversity.

As identification and characterisation aspects of natural dyes are not well established, there are authenticity and certification issues. Some vendors may try to pass off textiles dyed with synthetic dyes as natural dyed materials. To counter this, national and international standards organisations have formulated some Indian and ISO standards on identification of some natural dyes and some more are in pipeline. Establishment of a certification system similar to that followed for organic crop products can also ensure authenticity and quality.

To summarise, at the present textile production and natural dyes availability levels and primary requirement of land to provide food to ever increasing world population, these dyes can only complement synthetic dyes as an eco-friendly alternative for dyeing cotton and other natural textiles. Only some biotechnological breakthroughs leading to their mass production in laboratories can increase their availability to bring these into mainstream, but continued research efforts and policy support can definitely strengthen and expand this niche eco-friendly segment.

(The views expressed in this column are of the author and not that of Cotton Association of India)

Delegates led by Aid By Trade Foundation (ABTF), Germany Visit CAI

A group of 36 delegates led by Ms. Tina Stridde, Managing Director, Aid By Trade Foundation (ABTF), Germany visited Cotton Association of India, at Cotton Green on Wednesday, the 13th March 2024. ABTF owns Cotton Made in Africa (CMIA) Standard.

The delegation included representatives from Benin, Burkina Faso, Cameroon, Ivory Coast, Tanzania, Zambia and Europe and comprised Govt Bodies, Ginners, Brands and Certifying Bodies, etc.

Following a tour of the historic Cotton Exchange Building including CAI laboratory and Survey Room, the delegates met with CAI President, Mr. Atul S. Ganatra, CAI Office Bearers and Board of Directors.

Over a lively Q&A session, topics ranging from the Indian government policy on cotton MSP, the opportunities for cotton exports and imports in India and also cotton production-consumption-yield related issues were discussed.









Glimpses of Mahashivratri

Celebrated at Shree Bhid Bhanjan Mandir, Colaba, Mumbai on 8th March 2024

UPCOUNTRY SPOT RATES

(Rs./Qtl)

Standard Descriptions with Basic Grade & Staple in Millimetres based on Upper Half Mean Length [By law 66 (A) (a) (4)]								Spot Rate (Upcountry) 2022-23 Crop March 2024					
Sr. No.	Growth	Grade Standard	Grade	Staple	Micronaire	Gravimetric Trash	Strength /GPT	11th	12th	13th	14th	15th	16th
4	KAR	ICS-103	Fine	22mm	4.5 – 6.0	6%	21	15016 (53400)	15044 (53500)	15044 (53500)	14960 (53200)	14875 (52900)	14819 (52700)
								Spot Rate (Upcountry) 2023-24 Crop					
1	P/H/R	ICS-101	Fine	Below 22mm	5.0 – 7.0	4%	15	12513 (44500)	12654 (45000)	12738 (45300)	12738 (45300)	12738 (45300)	12738 (45300)
2	P/H/R (SG)	ICS-201	Fine	Below 22mm	5.0 – 7.0	4.5%	15	12682 (45100)	12823 (45600)	12907 (45900)	12907 (45900)	12907 (45900)	12907 (45900)
3	GUJ	ICS-102	Fine	22mm	4.0 – 6.0	13%	20	12092 (43000)	12120 (43100)	12120 (43100)	11979 (42600)	11810 (42000)	11670 (41500)
5	M/M (P)	ICS-104	Fine	23mm	4.5 – 7.0	4%	22	15803 (56200)	15888 (56500)	15888 (56500)	15803 (56200)	15719 (55900)	15663 (55700)
6	P/H/R (U) (SG)	ICS-202	Fine	27mm	3.5 – 4.9	4.5%	26	16000 (56900)	16085 (57200)	16197 (57600)	16197 (57600)	16197 (57600)	16141 (57400)
7	M/M(P)/ SA/TL	ICS-105	Fine	26mm	3.0 – 3.4	4%	25	- -	- -	- -	- -	- -	- -
8	P/H/R(U)	ICS-105	Fine	27mm	3.5 – 4.9	4%	26	16169 (57500)	16253 (57800)	16366 (58200)	16366 (58200)	16366 (58200)	16310 (58000)
9	M/M(P)/ SA/TL/G	ICS-105	Fine	27mm	3.0 – 3.4	4%	25	15044 (53500)	15129 (53800)	15129 (53800)	15044 (53500)	14904 (53000)	14904 (53000)
10	M/M(P)/ SA/TL	ICS-105	Fine	27mm	3.5 – 4.9	3.5%	26	15888 (56500)	16056 (57100)	16056 (57100)	15916 (56600)	15775 (56100)	15775 (56100)
11	P/H/R(U)	ICS-105	Fine	28mm	3.5 – 4.9	4%	27	16394 (58300)	16478 (58600)	16591 (59000)	16591 (59000)	16591 (59000)	16535 (58800)
12	M/M(P)	ICS-105	Fine	28mm	3.7 – 4.5	3.5%	27	16984 (60400)	17097 (60800)	17097 (60800)	17013 (60500)	16872 (60000)	16816 (59800)
13	SA/TL/K	ICS-105	Fine	28mm	3.7 – 4.5	3.5%	27	16956 (60300)	17153 (61000)	17153 (61000)	17069 (60700)	16928 (60200)	16872 (60000)
14	GUJ	ICS-105	Fine	28mm	3.7 – 4.5	3%	27	17069 (60700)	17097 (60800)	17125 (60900)	17069 (60700)	16984 (60400)	16928 (60200)
15	R(L)	ICS-105	Fine	29mm	3.7 – 4.5	3.5%	28	16816 (59800)	16900 (60100)	16956 (60300)	16956 (60300)	16956 (60300)	16900 (60100)
16	M/M(P)	ICS-105	Fine	29mm	3.7 – 4.5	3.5%	28	17294 (61500)	17406 (61900)	17434 (62000)	17350 (61700)	17266 (61400)	17209 (61200)
17	SA/TL/K	ICS-105	Fine	29mm	3.7 – 4.5	3%	28	17238 (61300)	17434 (62000)	17462 (62100)	17378 (61800)	17294 (61500)	17238 (61300)
18	GUJ	ICS-105	Fine	29mm	3.7 – 4.5	3%	28	17350 (61700)	17378 (61800)	17406 (61900)	17350 (61700)	17266 (61400)	17209 (61200)
19	M/M(P)	ICS-105	Fine	30mm	3.7 – 4.5	3.5%	29	17519 (62300)	17603 (62600)	17716 (63000)	17631 (62700)	17547 (62400)	17434 (62000)
20	SA/TL/K/O	ICS-105	Fine	30mm	3.7 – 4.5	3%	29	17462 (62100)	17631 (62700)	17744 (63100)	17659 (62800)	17575 (62500)	17462 (62100)
21	M/M(P)	ICS-105	Fine	31mm	3.7 – 4.5	3%	30	17716 (63000)	17856 (63500)	17912 (63700)	17912 (63700)	17912 (63700)	17856 (63500)
22	SA/TL/ K / TN/O	ICS-105	Fine	31mm	3.7 – 4.5	3%	30	17744 (63100)	17884 (63600)	17940 (63800)	17940 (63800)	17940 (63800)	17884 (63600)
23	SA/TL/K/ TN/O	ICS-106	Fine	32mm	3.5 – 4.2	3%	31	N.A. (N.A.)	N.A. (N.A.)	N.A. (N.A.)	N.A. (N.A.)	N.A. (N.A.)	N.A. (N.A.)
24	M/M(P)	ICS-107	Fine	34mm	2.8 - 3.7	4%	33	22496 (80000)	22496 (80000)	22496 (80000)	22496 (80000)	22496 (80000)	22496 (80000)
25	K/TN	ICS-107	Fine	34mm	2.8 - 3.7	3.5%	34	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)
26	M/M(P)	ICS-107	Fine	35mm	2.8 - 3.7	4%	35	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)	22918 (81500)
27	K/TN	ICS-107	Fine	35mm	2.8 - 3.7	3.5%	35	23340 (83000)	23340 (83000)	23340 (83000)	23340 (83000)	23340 (83000)	23340 (83000)

(Note: Figures in bracket indicate prices in Rs./Candy)