CHAPTER - 5

SUMMARY AND CONCLUSIONS
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Colour is a vital and vibrant ingredient of our existence, and is one of the elements of nature that made the human living more aesthetic and fascinating in the world. An urge in human beings to experiment resulted in producing beautiful colours from certain plants and animal extracts. It is evident from the history of various civilizations that the use of natural dyes for various purposes like dyeing, printing and painting was a common practice since prehistoric period. The tradition continued till the discovery of Perkin’s purple in 1856, which marked the beginning of endless synthesis of dyes. At the same time natural dyeing techniques were suffering from lack of further experimentation and openness of the persons engaged in the dyeing industry. On the other hand synthetic dyes were easier to obtain, were brighter and companies were not at all secretive about the techniques of using the dye. This inevitably resulted in steady decline of natural dyes.

After independence, one of the policies of the Government of India was the revival and development of dyeing and printing with natural dyes was covered under priorities. Government institution such as the National Handloom Development Corporation, Weavers Service Centres, and individual environmentalists are making several efforts to revive the ancient natural dye industry.

Environmental pollution is increasing day by day due to increasing industrialization and urbanization. Dyeing effluent from textile industries contain unabsorbed dyes, surfactants, auxiliary chemicals, which may increase pollution load; which if untreated, pose serious ecological problems.

The Bureau of Indian Standards formulated a comprehensive standard for pollution treatment. However scientists and environmentalists propose not to pollute rather than pollute and treat. Emerging environmental awareness has compelled the colourists to go back to natural dyes.

The natural dyes have been classified on the basis of sources like plant, mineral and of animal origin. Hummel classified the colouring matter as monogenetic.
and polygenetic. In the colour index, dyes are classified according to chemical constitution as well as major application classes. The natural organic dyes and pigments cover a wide range of chemical constitution.

*Carissa carandas* Linn is an indigenous evergreen shrub or a small crooked tree up to 30 meter in height with dichotomous branches armed with simple or forked 2.4 cm long auxiliary thorns, found throughout India. Berries are ellipsoid, purple or pink and white normally are 8 seeded. Dye pigments of *Carissa carandas* fruits could not be traced from the secondary data; only an unknown alkaloid from the fruits is reported (Kirtikar and Basu 1996).

*Holarrhena antidysenterica* Linn is a small to medium size deciduous tree, attaining a height of forty feet. Tall shrub bearing fairly large, opposite, short petioled membranous ovate oblong, prominently veined leaves. Chemotaxonomical studies on Apocynaceae by Daniel and Sabnis, (1977) reported that flavonoids such as quercetin and Leuco anthocyanins and phenolic acids such as vanillic, syringic and p-hydroxy benzoic acid are present in the leaves of *Holarrhena antidysenterica.* Another study by Daniel et al., (1978) detected 2.3% of tannins in the leaves of *Holarrhena antidysenterica.* Dutta et al., (1950) studied the seasonal variation of the alkaloidal content in the plant and reported that the leaf contains highest amount in June (1.56%). Both these plants are the members of Apocynaceae and can be successfully grown in marginal and wasteland and hence considered vital to explore them as a dye source. The dye sources were finalized after carried out the exploratory survey.

Natural dyes are either substantive, needing no mordants, or adjective, requiring one. The majority of natural dyes need a chemical in the form of metal salt to create an affinity between the fibre and the pigment. These chemicals are known as ‘Mordants’. Besides metallic mordants, tannins are also used as mordants. Tannins being natural mordants are considered as important ingredients in the dyeing with natural dyes.
The restrictions to the use of metal salts have been put by the famous ‘German Ban’. Accordingly the indicative maximum permissible quantities of different metals in the ultimate products are specified as follow.

As (1.0 ppm), Pb (1.0 ppm), Cd (2.0 ppm), Cr (2.0 ppm), Co (4.0 ppm), Cu (50 ppm), Zn (20 ppm).

The upper limits of the presence of metals vary from product to product and are different for different Eco-marks. However, there is no upper limit on Aluminium, Iron and Tin. The upper limit on copper is also fairly high. Hence one can safely use these salts for complexing and mordanting. One has to, of course optimise the quantities so as to minimise the pollution load. Alum has been proposed (Anonymous 1995) for its low environmental toxicity.

Therefore it was considered important to select Alum as a sole mordant for the present study. Tin and Iron were also selected, as they are not banned according to the eco-norms. Most of the studies revealed that mordants provide specific colours as well as improved fastness properties irrespective of the type of mordant, mordant concentrations, mordanting time and the method of mordanting. Very few studies revealed the use of natural vegetable mordants.

Most of the reports in the literature on natural dyes highlights that the number of shades obtained from natural dyes are limited. However very few attempts have been made on printing with newer sources of natural dyes.

Therefore an attempt has been made to explore the new dye sources. On the other hand emerging environmental awareness forced the researcher to use natural vegetable mordants, such as pomegranate rind and babool bark.

Use of natural mordants in the process of natural dyeing and printing will help to create healthy as well as balanced environment, both for human population and flora and fauna of the region.

With due considerations, the present study was directed towards the following objectives.
Objective of the study

Literature search has brought to light that not a single study has been carried out in the Vidarbha region to explore the regional flora for dye yielding plants. However the ‘Melghat Forest’ of Vidarbha region is known for its natural wealth. There are several species of trees and shrubs, which do give excellent dye sources, which were not tapped as a potential of dye source, therefore it has become a primary objective to do the survey of ‘Melghat forest’.

The specific Objectives

• To optimise the dyeing parameters of selected natural dyes on cotton and silk fabrics.
• To undertake the dyeing study for control and experimental group with each selected dye.
• To evaluate the effect of alum as a single mordant and alum in binary combination with metal and natural mordants at three ratios in terms of colours, shade variation and fastness properties.
• To evaluate the colour value of dyed samples with each selected dye in terms of L* a* b* c* h* values.
• To assess the fastness properties of dyed fabrics in terms of control and experimental group.
• To estimate the cost for dyeing per kg of fabric for each selected dye.
• To assess the viability of printing cotton and silk with selected dye sources.
• To assess the fastness properties of printed fabrics in terms of alum as a single mordant and alum in combination with metal and natural mordant with only one ratio.
• To estimate the cost for printing cotton and silk with selected dye sources.

Methodology

The present study comprised of the following stages.

• 100% Grey cotton and Tussar silk being natural fibres are biodegradable in nature and hence preferred safe route of using natural dyes on natural fibres.
The fabrics selected for the present study were tested for understanding the various physical parameters so that the effect of dye can be generated for the selected fabrics. With known specifications, selected fabrics were prepared for the dyeing.

In order to make the fabric absorbent and to obtain level dyeing, penetration of dyestuffs scouring of cotton fabric and degumming of silk fabric was done.

- Exploratory survey of the ‘Melghat Forest’ was carried out with the help of the taxonomist. During the survey it was observed that the variety of trees/plant species, available in Melghat Forest of Vidarbha region, have not been explored as dye sources, though these trees are abundantly available in forest. *Carissa carandas* Linn and *Holarrhena antidysenterica* Linn are the members of Apocynaceae. Both these plants are phytochemically rich which have not been tapped for the extractions of dyes were selected for the present study. The other phytochemically rich plant *Tagetes erecta* (Marigold), the member of Asteraceae is a most commonly used dye source was also selected for the study. Collection of *Carissa carandas* matured fruits and leaves, of *Holarrhena antidysenterica* was arranged from forest and the Marigold flower heads were collected from the nearby gardens.

- Pilot study was the third stage, which was carried out to optimise the dyeing conditions separately for each dye source for dye material concentration, extraction time and pH using fresh and dried dye materials.

- In the fourth stage of this study dyeing for controlled and experimental group with each dye was carried out with optimised conditions. Mordanting with alum as a single mordant and its combination with other mordants at three different ratios was carried out for cotton as well as silk, followed by dyeing with each selected dye for control group.

- Pre-treatment with Harda tannin was given to cotton and silk for the experimental group. Mordanting and dyeing procedure was repeated as that of control group followed by after treatments as rinsing, soaping and washing.
Evaluation of the dyed samples in terms of \( L^* \ a^* \ b^* \ c^* \ h^* \) values was done for each sample of cotton and silk of control and experimental group with each selected dye separately with data colour spectrophotometer.

Samples were also subjected for various fastness tests (laid by ISO standards) to assess the fastness properties.

Printing was the fifth stage, which was confined to only one ratio of mordant combination. Printing was started with pre-treatment of cotton and silk with Harda tannin. Printing was done with black outlines and filling with mordant pastes. After printing the samples were allowed for ageing, followed by steaming and washing in running water.

Dyeing was carried out with each selected dye for samples printed with alum as a single mordant and alum with two metal and two natural mordants.

Printed samples were assessed for washing, perspiration, rubbing and sunlight, fastness tests.

Cost Estimation was done for dyeing and printing of cotton and silk with selected natural dyes separately.

Results

Fabrics i.e. Grey cotton and Natural tussar silk which were tested for their physical parameters were found to be light weight with 60gm/sq.mt. for cotton and 45gm/sq.mt. for silk with fine count and plain weave.

Fabrics with above specifications were used for dyeing and printing for the present study.

Alum has been proposed for dyeing with natural dyes due to its low toxicity. It was decided to take alum as a sole mordant for the study. But the extension of colour palette may not be possible with the single mordant.

Hence in the present study an attempt has been made to use alum as a single mordant and alum with two metal mordants i.e. Tin and Iron, which are not red listed according to the eco norms (There is no upper lit on use of them). Attempt was also
made to partially reduce the quantity of alum by using its combination with natural mordants like Pomegranate rind and Babool bark.

Binary system of mordanting was used to dye cotton and silk with three selected dyes; namely *Carissa carandas* Linn, *Holarrhena antidysenterica* Linn and *Tagetes erecta* Linn separately.

**Results of *Carissa carandas** dyed cotton and silk**

Total 52 samples were dyed with *Carissa carandas* out of which 26 were of cotton and 26 of silk.

The L* a* b* c* h* values and fastness of the dyed cotton and silk fabrics of control and experimental group have been evaluated and discussed.

The colour gamut for *Carissa carandas* was obtained by joining the extreme values of a* b* on the plot.

It was observed from the colour gamut obtained by the samples dyed with *Carissa carandas* that yellow red region covers a larger area followed by blue red, yellow green and green blue.

It has been observed that L* values of all the dyed samples of control group are higher compared to cotton samples of experimental group. On the contrary c* values of experimental group of alum and (A+T) mordant combination found to be higher.

Results also revealed the highest a* and b* values for the sample CTTCT2 with maximum red and blue component.

Range of cream and purple colour was obtained on cotton samples dyed with *Carissa carandas*.

Further it has been concluded that all CNT cotton and CTT cotton pre-mordanted with all the ratios of (Alum + Tin) predominantly falls within the Blue-purple region, where as all the samples of other binary mordant combination falls within a yellow region.

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In terms of silk dyed with *Carissa carandas* it is observed that sample CNTST1 has the highest \( a^* \) \( b^* \) \( c^* \) values where \( b^* \) value (-17.10) shows the maximum blue component.

Effect of alum as single mordant and alum with other mordant as binary combination on colours

- On cotton fabric Reddish cream colour was obtained with 10% alum and dyed with *Carissa carandas*.
- Extreme change in hue was observed when mordanted with \((A+T)\) combination ranging from light to dark purple.
- Range of Reddish, Orangish to Brownish cream colour was imparted when \((A+I)\), \((A+P)\) and \((A+B)\) binary mordant combinations were used.

In general, it may be inferred that tannin treatment does not play any effective role in dyeing of *Carissa carandas* for producing shade variations on cotton.

On the contrary exciting colours were produced on tussar silk when dyed with *Carissa carandas*.

Purplish grey hue was produced when mordanted with alum as a single mordant.

Very interesting change was noted for \((A+T)\) mordant combination.

Purple to deep purples were produced with varying ratios of \((A+T)\) combination.

Range of Purplish to, Olivish grey was produced with varying tonal values, when mordanted with \((A+I)\) binary mordant combination. Citreenish greys, Greyish yellows were produced on tussar silk using \((A+P)\) binary mordant combination.

On mordanting with \((A+B)\) combination, Bluish grey to Brownish grey hues were imparted on silk when dyed with *Carissa Carandas*.

- Thus a fascinating range of purples and greys can be possible on dyeing on carissa with each binary mordant combination with varying ratios of alum with other mordant.
• Tannin treatment proved to be significant in obtaining colours and shade variations in terms of dyeing tussar silk with *Carissa Carandas*.

**Washing fastness of *Carissa carandas* dyed Cotton and Silk**

- The 10% Alum used as a sole mordant showed excellent fastness towards washing. Wash fastness of all the cotton samples of controlled and experimental groups produced very good to excellent (4/5 to 5) results. Where as (A+T) combination used was found to be less effective in terms of fastness of dyed cotton samples. Natural mordants, Pomegranate rind and Babool bark when used in binary combination with alum for the dyeing of carissa on cotton showed excellent wash fastness and thus makes the system eco-friendly.

- The results concluded that all the silk samples of control and experimental group on dyeing of *Carissa carandas* when mordanted with alum in combination with natural mordants exhibited good washing fastness followed by alum as a sole mordant with fair to good wash fastness and alum with Iron showed acceptable range of fastness. Where as (alum + tin) combination used exhibited comparatively low fastness towards washing.

**Acidic perspiration fastness of *Carissa carandas* dyed Cotton and Silk**

- The results obtained towards the dyed cotton samples of control and experimental group for alum as a single mordant and alum with other mordants with varying ratios showed excellent performance towards acidic perspiration with negligible staining on adjacent fabric. Except the one binary combination (A+T), which indicated poor to fair results for colour change with slight, to no staining on adjacent fabrics.

- To see the overall performance towards acidic perspiration it can be concluded that dyeing of cotton with *Carissa Carandas* does not require tannin treatment except for the demand of change in hue.

- In case of *Carissa Carandas* dyed silk when mordanted with alum as a single mordant showed moderate fastness towards acidic perspiration. Similar results were obtained for (Alum + Tin) binary combination. Where as (Alum + Iron)
combination in terms of acidic perspiration was ranging between poor to excellent. All the dyed silk samples of control group showed negligible staining on adjacent fabric.

The results also highlight the good to excellent performance of Pomegranate rind and Babool bark as natural mordants when used in combination with alum as a binary combination. All the ratios of mordant concentration fixed at 10% (owf) exhibited equal performance towards acidic perspiration of *Carissa Carandas* dyed silk samples.

It has been also concluded that pre-treatment with tannin showed decrease in performance towards acidic perspiration.

**Alkaline perspiration fastness of *Carissa Carandas* dyed Cotton and Silk**

- Almost all cotton samples of control group exhibited excellent alkaline perspiration fastness with negligible staining on adjacent fabric. (Alum + Babool) binary mordant combination was found to be good in terms of alkaline perspiration; but it was observed excellent for the tannin treated group.

- Alkaline perspiration fastness of the silk samples dyed with *Carissa Carandas* mordanted with alum as a single mordant and (Alum + Tin) and (Alum + Iron) binary combination was ranging between moderate to excellent with negligible staining. Significant effect was observed in tannin treated samples. Encouraging results were seen in terms of natural mordants along with alum for most of the samples of control as well as experimental group ranging between good to excellent for colour change and extent of staining. Moreover the colours were seen improved in sheen when subjected to alkaline test in some of the samples.

Foregoing results pointed out that dyeing of Carissa on silk is possible without metal mordants, there by making the process more eco-friendly.

**Dry and Wet rubbing Fastness of *Carissa carandas* Dyed Cotton and Silk**

It is apparent from the results that cotton and silk samples of both control and experimental group showed good to excellent dry rubbing fastness.
Wet rubbing fastness was also ranged between good to excellent in terms of dyed cotton and silk samples of both control and experimental group.

It may be stated that alum and its combination with two metal mordants and two natural mordants as binary system of mordanting found to be effective in raising the level of fastness towards dry and wet rubbing.

Natural and metal mordants along with alum are found to be almost similar in terms of dry and wet rubbing fastness of cotton and silk samples.

No significant effect was observed in tannin treated cotton and silk.

Sunlight fastness of Carissa Carandas dyed Cotton and Silk

All the dyed cotton samples of experimental group exhibited fairly good light fastness compared to dyed samples of control group.

It has been emphasized that no significant effect was observed towards tannin treated group (experimental). Results were almost similar for control and experimental group.

Natural mordants along with alum showed synergistic effect on the sunlight fastness of Carissa Carandas dyed silk samples.

Results of the Dyeing study of Holarrhena antidysentrica

The dyeing with Holarrhena antidysentrica was carried out on cotton and tussar silk. Total 52 samples were dyed with Holarrhena antidysentrica out of which 26 were of cotton and 26 of silk.

The colour gamut was obtained by joining the extreme points of (Values) of a* b* on the plot. Colour values of Holarrhena predominantly fall within the yellow red region.

This may be because of the presence of flavanols (Quercetin and Kaempferol) and flavonoids in the leaves of Holarrhena.

So it can be stated here that use of other mordants preferably natural in origin may impart different colours and shades, which can expand the boundary of colour gamut.
The highest L* value was observed for sample HNTCT3. It has also been concluded from the results that increase in percentage of tin with lowering of alum as a binary system of mordanting showed increase in L* values of both HNT and HTT cotton.

The sample HNTCO was noticed for its maximum a* b* values for maximum red and yellow component, where as the lowest b* value was observed for sample HTTCI3. (Sample treated with (A+I) binary mordant combination of experimental group). The same sample also denote the lowest c* value.

On the contrary the highest c* value was observed for the sample HNTCP3.

During evaluation of L* a* b* c* h* values of Holarrhena antidysenterica dyed silk for control and experimental group showed the maximum L* values of (Alum+Tin) combination were found to be higher compared to other mordant combination.

Maximum a* value was observed for the sample HNTST1 with maximum redness. The highest b* value was noted for sample HTTST3; where as lowest b* value was noticed for HTTS13.

C* values (chromatic) were found to be decreased in the pre-treated silk samples which decreases the intensity of the colours. Slight increase in h* values for tannin treated samples shifted them towards the yellower region.

Effect of Alum as a single mordant and alum with other mordants as a binary combination on colours

- Range of orangish brown, orangish cream to brownish cream colour with shade variation was produced on cotton depending on the alum and alum with other mordants with varying ratios. It has been further stated that added red colour was produced with increase in Babool bark with lowering the concentration of alum.

Pre-treatment with tannin proved to be significant in darkening the brown colours for (A+B) combination in dyeing of cotton with Holarrhena.

- It can be seen from the Colour Catalogue 2 that silk imparted Golden brown, Golden yellow to Orangish brown colours using alum as a single mordant and alum with other mordants as binary mordant combinations with varying ratios.
Here it can also be concluded that pre-treatment with tannin plays an important role in imparting shade variations on silk with *Holarrhena antidysentrica*.

**Washing fastness of Holarrhena antidysentrica dyed cotton and silk fabrics**

- Washing fastness of the control cotton sample for all combinations of mordants with varying ratios was ranged between 1 to 5 i.e. it was found poor to excellent with no staining on adjacent fabric of all the dyed cotton. Pre-treatment with tannin prior to mordanting and dyeing was found to have profound effect on wash fastness of Holarrhena dye, which was further graded as good to excellent.

- Wash fastness of control silk samples with (A+T), (A+I) and (A+B) combinations with varying ratios showed good fastness. Where as all ratios of (A+P) combinations were found to be excellent for wash fastness. Improvement in the wash fastness of all the silk samples was seen due to pre-treatment with tannin and graded excellent.

Wash fastness of control and experimental silk samples showed that samples had good to excellent fastness when alum was used along with natural mordants. It is therefore suggested that natural mordants can be used successfully along with alum as a binary system of mordanting for the dyeing of *Holarrhena antidysentrica* on silk to make the process more environment friendly.

**Acidic perspiration fastness of Holarrhena antidysentrica dyed Cotton and Silk fabrics**

- The grades allotted for acidic perspiration fastness for all the cotton samples of control group of (A+T), (A+P) and (A+B) binary mordant combination and alum as a single mordant observed to be excellent. The fastness of (A+I) combination which was found to be moderate to good but pre-treatment with tannin exhibited excellent fastness properties for cotton specifically for this binary mordant combinations.
Contrary to above acidic perspiration fastness of (A+P) and (A+B) binary combination showed slight change in colour of few samples when pre-treated with tannin. Expectedly no staining was observed on undyed adjacent piece, which rated 5 for almost all the samples of control and experimental group.

- Acidic perspiration of almost all the silk samples exhibited excellent performance. Therefore it can be stated here that dyeing of silk with *Holarrhena antidysenterica* by using alum as a single mordant and alum along with metal as well as natural mordants as a binary system of mordanting found to be beneficial; where no pre-treatment of tannin is required. No change in hue was noticed after the testing but more pronounced effect was seen in bringing lustre.

Alkaline perspiration fastness of *Holarrhena antidysenterica* dyed Cotton and Silk

- Alkaline perspiration of control cotton samples also showed the encouraging results, which ranged from (2 to 5) i.e. poor to excellent. It has been observed further that pre-treatment with tannin has brought the results down with slight staining on almost all samples when the cotton samples were subjected for the alkaline perspiration test.
- Almost all silk samples of control group showed excellent performance during alkaline perspiration test with negligible staining on undyed piece. It is of immense importance that (A+I) binary combination of mordant showed sharp decrease in alkaline perspiration fastness which was found to be very poor with regard to colour change with noticeable staining on undyed test specimen.

Dry and Wet rubbing fastness of *Holarrhena antidysenterica* dyed Cotton and Silk

- It has came to notice from the results that dry rubbing fastness of all control and treated cotton samples was found to be excellent when graded in terms of staining. Moreover with slight staining on undyed adjacent fabric except on cotton sample, there was no colour change in dyed samples even after wet crocking.
The result of the wet rubbing fastness of control and experimental silk samples revealed that slight to negligible staining was observed against dry crocking. Whereas noticeable to slight staining was observed against wet crocking. To see the similar results of control and experimental group, it can be stated that tannin does not play any significant role in improving dry and wet rubbing fastness of cotton as well as silk.

Sunlight fastness of *Holarrhena antidysenterica* dyed Cotton and Silk

- In case of sunlight fastness of cotton samples it has been noted that pre-treatment with tannin showed improvement in samples mordanted with alum as a single mordant and (Alum + Tin) combination from moderate to excellent. On the contrary decrease in sunlight fastness was observed for the treated cotton samples of (A+1) combination. Binary combination of alum with natural mordants, Pomegranate rind and Babool bark showed fairly good to very good results in terms of control group whereas pre-treated group showed that (7:3) ratio had optimum sunlight fastness which was found to be very good.

- From the results it would be fair to say that the silk samples of control and experimental group dyed with *Holarrhena antidysenterica* are proved to be fast with or without pre-treatment as very good when exposed to sunlight.

Results of the Dyeing study of *Tagetes erecta* Linn (Marigold)

Total 52 samples were dyed with *Tagetes erecta* out of which 26 were of cotton and 26 were of silk. The L* a* b* c* h* values of the dyed cotton and silk fabrics of control and experimental group have been evaluated and discussed. The colour gamut for *Tagetes erecta* was obtained by joining the extreme a* b* values of the dyed samples. The basic colours, namely Yellow, Red, Blue and Green decide the contours of the gamut. It has been observed from the colour gamut obtained that the
colour values of *Tagetes erecta* conspicuously cover the larger area of yellow red region. This may be due to the presence of Flavonol.

- The sample MTTCT2 denotes the maximum L* value on the contrary to the above the lowest value of L* was observed for sample MTTCI3.
- Evaluation of L* a* b* c* h* values also revealed that the mordants induce a change in hue and hue angle. Where (Alum + Tin) mordant combination distinctly made the sample yellower with increase in b* values. The maximum a* b* values were observed for sample MNTCT3.

On the contrary to the above discussion a set of (A+I) combination depicts the lower a* and b* values. Least values of a* and b* were observed for MTTCI3. Highest hue angle was observed for the sample MTTCP3 that shifted the sample towards yellower region.

- It is clear from the colour coordinates that the values of L* for the silk samples of MNT and MTT silk (Control and experimental) were found lower as compared to MNT and MTT cotton samples. The maximum L* value of dyed silk samples was observed for the sample MNTST3, and the lowest for the sample MTTSI3.

Sample MTTST3 denotes the highest a* value and MTTST2 depicts the maximum b* value. Expectedly the least values of a*, b* and c* were observed for the samples of A+I combination of MNT and MTT silk. Colour coordinates of silk also indicates that the samples of (A+P) and (A+B) combination had fairly good a* b* c* values which falls within the average range of yellow red region. Hence, it can be inferred that alum along with natural mordants Pomegranate rind and Babool bark as binary mordant combination can be used successfully for the dyeing of *Tagetes erecta* on cotton and silk to impart a good range of yellow colours.
Effect of alum as a single mordant and alum with other mordants as a binary combination on colours

- Orangish yellows, Brilliant yellows, tonal yellows were produced on cotton when dyed with *Tagetes erecta* (Marigold).

Thus, in dyeing with *Tagetes erecta* on cotton not much variation was found with respect to hue but the shade variation is prominent with changing ratios of binary mordant combination and tannin treatment.

- Colour Catalogue-5 exhibits the colours produced on silk dyed with *Tagetes erecta*.

Deep yellows, bright yellows, Tonal yellows, Blackish yellows to soothing tones of yellows were offered by the alum as a sole mordant and alum along with two metal mordants and two natural mordants as a binary system of mordanting.

Washing fastness of Marigold dyed Cotton and Silk

- Control and Experimental group showed good to very good performance towards washing for all the dyed samples except the samples of (A+I) combination, which found to produce poor performance. Pre-treatments helped to improve the wash fastness of these samples. Negligible staining was observed on almost all the undyed adjacent samples of the pre-treated and control group.

- Almost all the silk samples of control and experimental group exhibited excellent wash fastness except it was observed good for (A+I) combination of control group. Decrease in wash fastness was seen towards pre-treated group of (A+I) combination, which was found to be moderate with negligible staining on undyed piece.

Acidic perspiration fastness of Marigold dyed Cotton and Silk

- Pre-treatment with tannin helped to improve the acidic perspiration fastness of cotton samples of (A+T) and (A+B) combination and graded excellent with negligible staining on undyed piece. Where as only one ratio of (A+I) i.e. (9:1)
exhibited excellent performance towards acidic perspiration. (A+P) combination showed similar results i.e. very good performance with or without pre-treatment with tannin on cotton in terms of acidic perspiration fastness.

- The entire Marigold dyed silk samples exhibited good to excellent performance with or without the pre-treatment with tannin in terms of acidic perspiration fastness. Thus, it can be said that pre-treatment with tannin does not play any significant role in improving the acidic perspiration fastness of dyed silk samples.

Alkaline perspiration fastness of Marigold dyed Cotton and Silk

- Alkaline perspiration fastness of control cotton samples was found to be good, except the samples of (A+T) combination, which was observed excellent. Fastness was seen improved on tannin treatment from good to excellent for (A+P) and (A+B) binary mordant combination. On the contrary fastness was seen reduced for the samples of (A+I) combination. Negligible staining was observed on undyed piece for all the cotton samples of control and experimental group.

- The whole set of cotton and silk samples of control and treated group showed good to excellent performance when subjected to alkaline perspiration fastness. However, better results were obtained for alum with natural mordants i.e. Pomegranate rind and Babool bark as binary mordant combination.

Dry and Wet Rubbing fastness of Marigold dyed Cotton and Silk

- Dry rubbing fastness of control and treated cotton samples was found to be very good with slight to negligible staining when rubbed against undyed piece. Wet rubbing fastness of control cotton samples ranged between fair to good. Decrease in wet rubbing was observed for samples of treated (experimental) group, which was found to be poor to good.

- Similar results for silk samples of control and treated group were observed for both dry and wt rubbing fastness when rubbed against undyed test specimens.
Dry rubbing was found to be good with slight staining and wet rubbing as a moderate, with noticeable staining.

Sunlight fastness of Marigold dyed Cotton and Silk

- Sunlight fastness of marigold dyed control cotton samples was ranging between fair to fairly good. Pre-treatment with tannin helped to improve the fastness.
- Moderate to fairly good results were obtained towards sunlight fastness in terms of control silk samples where as it was seen improved up to very good sunlight fastness with pre-treatment of tannin.

(A+I), (A+P) and (A+B) binary mordant combinations were found to be more effective in case of sunlight fastness. Thus, the process will find more eco-friendly if the dye will be applied along with these binary combinations.

Printing

Fastness properties of cotton and silk printed with 10% alum and alum with other mordant at (9:1) ratio as binary mordant combination dyed with Carissa carandas.

- Satisfactory results were obtained towards various agencies with fair washing fastness and no staining on adjacent fabric. Fair to fairly good results were obtained for alkaline and acidic perspiration fastness with no staining at all. Sunlight and wet rubbing fastness was also found fairly good with noticeable to slight staining where as dry rubbing was found good with slight staining on adjacent fabric for printed cotton samples.
- Similar satisfactory results were obtained for the printed silk samples towards various fastness agencies.
- It can be noticed from print catalogue that colour impression are more prominent in cotton and silk samples printed with A+T and A+I binary mordant combination.

Fastness properties of Cotton and Silk printed with 10% alum and alum with other mordant at (9:1) ratio as binary mordant combination dyed with Marigold

- Washing fastness of printed cotton samples was found to be good with negligible staining on adjacent test specimen. Alkaline fastness was also found
good with no staining. Where as in acidic perspiration test noticeable staining was seen on adjacent fabric. This may be due to the background colour of the printed portion. Most of the cotton samples exhibited very good dry rubbing fastness with slight to negligible staining on adjacent fabric. On the contrary noticeable to slight staining was observed on adjacent white fabric with moderate to good performance towards wet rubbing. Impressing results were noted for the sunlight fastness.

Fastness properties of Cotton and Silk printed with 10% alum and alum with other mordant at (9:1) ratio as binary mordant combination dyed with Holarrhena

- Good to excellent performance towards washing was seen. Acidic perspiration was also found good compared to alkaline perspiration which was observed moderate to fairly good with no staining. Impressive results were noted when subjected to wet and dry rubbing. Wonderful sunlight fastness was observed for both cotton and silk printed with Holarrhena antidysentrica dye. Thus all the binary combinations of mordants showed synergistic effect in printing.

Colours produced within the design due to the complex formation between mordant and fibre were found satisfactory for cotton, where as in case of silk (A+T) and (A+I) combinations were found effective in producing colours within the design area but less worthy colour effect has been noted for (A+P) and (A+B) combination.

Cost estimation for dyeing and printing

- Cost was found to be reasonably low for dyeing and printing

Conclusions

Natural dyes are again getting importance due to harmful effects caused by synthetic dyes during their production and use. Thus, it is of immense importance to explore the sources of natural dyes particularly of the plant material, which do not destruct the plant growth in any way. Aqueous extraction of dyes provides scope for eco-friendly dyeing process with less investment costs. Mordants used herein are safe causing minimum pollution and having less risk to human health. There is currently a demand for natural dyes in a niche market that could be expanded through the use of...
natural mordants such as Harda, Pomegranate rind and Babool bark to have Eco labels for the green-minded consumer.

The present study indicate that

- *Carissa carandas* fruits of matured stage in fresh form can be exploited as a good source of natural dye for cotton and silk dyeing. It can be utilized more specifically for silk in producing exciting colour range from light to bright and deep purples to amazing greys using binary mordant combinations of alum with two metal mordants, which are not red, listed according to the eco norms such as Tin and Iron and, the natural mordants such as Pomegranate rind and Babool bark. Pre-treatment with tannin proved to be significant in obtaining colours and shade variations.

It is evident from the result that *Carissa carandas* imparts satisfactory colourfastness to cotton and silk. Dyeing of silk can be possible with the use of natural mordants and without pre-treatment with tannin there by making the process more eco-friendly and economically viable.

- It can be concluded that printing is also possible using binary mordant combination with acceptable range of fastness. Thus, (*Carissa carandas* find its place in textile dyeing as a natural colourant in the coarse of time) or (hopefully *Carissa carandas* fruits aqueous dye extract will definitely find great use in silk industry especially in purple and grey colour range dyeing.

- The present study indicates that the season and climatic conditions definitely affects the colour value. The leaves of *Holarrhena antidysenterica* which were collected in the month of September for pilot study obtained better results than the leaves collected in February (cenasing leaves) for the actual experiment.

- *Holarrhena antidysenterica* leaves in fresh form show good to excellent fastness properties on cotton and silk with alum as a sole mordant and alum in binary combination with other mordants. Tannin treatment is not required to improve the fastness. A fascinating range of brown can be imparted on Cotton and Silk.
• Colour effect was prominent on cotton than on silk printed with alum as a single mordant and alum with binary mordant combination using (9:1) ratio. Printing is viable with good performance towards various fastness agencies. Therefore, *Holarrhena antidysenterica* leaves dye can be used as a good source of natural dye for dyeing and printing of cotton and silk.

• A detailed study of the Marigold dye was carried out with aqueous extraction and dyeing at neutral pH. *Tagetes erecta* flowerheads can be utilized as good source of natural dye for cotton and silk dyeing. Orangish yellows deep yellows tonal and blackish yellows can be imparted depending upon the choice of mordant combination with varying ratios. Shade variation is possible with tannin treatment prior to mordanting and dyeing. Fair to excellent fastness towards various agencies can be imparted using alum as a single mordant and alum with other metal and natural mordants. It has also been concluded that pre-treatment with harda tannin helped to improve the fastness in most of the cases. It is worthy to know that alum as a single mordant and alum with metal mordants exhibited very good printing effect on cotton and silk. Further natural mordants, Pomegranate rind and Babool bark along with alum can impart excellent colours within the line of design on cotton and silk. Thus the process of printing will find more environmental friendly. Its use on these fabrics will certainly satisfy the consumer in terms of serviceability, value addition and cheaper price.