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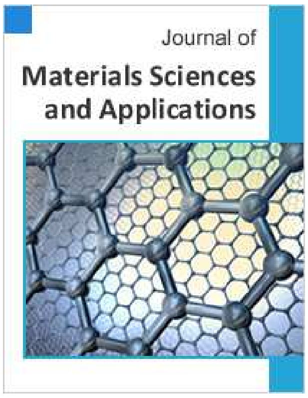

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Dyeing of Jute Fabric with Binary Mixtures of Catechu and Other Natural Dyes: Study on Colour Performance and Dye Compatibility

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Abstract
This paper constitutes extraction and characterization of catechu extracted colour component by UV-VIS spectral scan and studies on different colour interaction parameters and compatibility of different pairs of dyes for dyeing jute fabric with binary mixtures of selective natural dye pair [mixtures of catechu with Tesu (TESU), Manjistha (MJ), Babool (BL), Red Sandal Wood (RSW) and Pomegranate Rind (PGR)] to produce compound shades. This compatibility study was done by conventional plots of ΔC vs ΔL plots and K/S vs ΔL for two sets of progressive shade build up data for each pair of binary mixture of the said natural dyes, where pre-mordanted jute fabric samples were dyed with each pair of dyes taken in equal proportions (50:50). Also another newer method of Relative Compatibility Rating was applied using an empirical index (colour difference index i.e CDI value) as an alternative approach. Different shades of varying colour combinations were developed using binary mixtures of selective natural dyes and their colour strength (K/S value), total colour differences (ΔE), ΔL, Δa and Δb values, changes in hue (ΔH), brightness index (BI) and metamerism index (MI), along with colour different index (CDI) as well as their colour fastness behaviour to wash, light and rubbing have been evaluated and compared. Relative Compatibility Rating (RCR for 0 to 5 grade) for binary mixture of selective pair of natural dyes have also been assessed by analysis of differences of CDI values amongst dyed jute fabrics with different proportion of each pair of natural dyes and calculating RCR value accordingly by the said newer method. The results of this newer system of relative compatibility rating are found to be well in agreement with the results of above said conventional method of test of dye compatibility. Irrespective of proportions used, Catechu + Red sandal wood combination was found to be most compatible (having RCR-3-4). Colour fastness to wash may be improved ½ to 1 grade by treatment with selective cationic dye fixing agents like Cetyl Trimethyl Ammonium Bromide (CTAB) or Cetrimide or commercial Sandofix-HCF. Similarly colour fastness to light is found to be improved ½ to 1 grade by treatment with 1% Benztriazole (an UV- absorber).

1. Introduction

Dyeing with natural dyes has not achieved wide acceptability in organized sector due to their limited availability, variation from source to source, limited shades and lack of standard procedures of dyeing, difficulty in reproducibility and colour matching as per customer's choice of shade as well as lack of scientific knowledge on chemistry of many natural dyes except a few and lack of knowledge on compatibility of mixture of such natural dyes to produce compound shades. With worldwide growing consciousness of environmental and chemical hazards of some of the synthetic dyes, the use of ecofriendly natural dyes and its mixture particularly for natural fibre products like jute and cotton textiles is being preferred in the niche market. So, an attempt has been made in this part of the work to study compatibility of binary mixture of different natural dyes, to obtain scientific data on these issues for use of the jute dyers.

There are only a few and discrete studies available in literature[1-9] describing application of single and mixture of natural dyes on cotton and other textiles, reporting the colour interaction parameters, resultant colour strength and metameric effects and colour related issues in connection with development of compound shades with binary mixture of natural dyes. Chemistry of different natural dyes and their application method etc are briefed in a book by Gulrajani and Gupta[10]. Specific work on dyeing process variables for application of Catechu as natural dyes on jute is studied earlier from this laboratory by the present group of authors[11], as afirst part of their study on catechu. Present study is an extension of the same as a second part comprising study of colour performance and dye compatibility for use of binary mixtures of catechu and other natural dyes applied on jute. Some studies on compatibility of binary and ternary mixtures of synthetic dyes are also available in literature[3-9],whereas such studies with mixture of natural dyes on jute [12-14] or cotton[1,2]and other textiles [15-17]with other natural dyes are scanty and sporadic.

Compatibility of a binary pair of any dyes can be judged conventionally by different methods, such as

(i) Subjective visual assessment of degree of on-tone build up by a series of dyeing
(ii) Theoretical prediction of compatibility by comparison of rates of dyeing (time of half dyeing) and dyeing kinetics (diffusion coefficients) for each dye to derive V numbers or Z values, which are usually specific to the textile substrate and dyeing conditions,
(iii) Quantitative assessment of change in hue angle (ΔH),
(iv) Comparing and plotting ΔC *vs* ΔL or *K/S vs* ΔL values for two sets of progressive developed shades (1-5 % of Synthetic dyes or 10 - 50 % natural dyes in set –I and varying time and temperature profile at 10 point interval starting dyeing at 40/50^{0}Cto gradually raising temperature to 100^{0}C with 10 point increment of temperature per 10 min, i.e. 1^{0}C per minute raise of temperature)in Set-II, where these 2sets of progressive build up of shade obtained by dyeing with varying profile of dye concentration in set-I and varying dyeing time / temperature profile in Set-II.
(v) Quantitative compatibility rating for the mixtures of more than two dyes by colorimetric analysis of actual colour strength developed (not on the basis of dye absorbed). The method of plotting ΔC *vs* ΔL or *K/S vs*ΔL values has been used in the present study. A newer empirical index called colour difference index has also been proposed for the assessment of relative compatibility rating (RCR) to judge the degree of compatibility of different pairs of natural dyes applied on jute.

In the present work, compatability study of binary mixture of natural dyes like catechu with Tesu, Catechu with Red sandal wood, Catechu with Manjistha, Catechu with Babool and catechu with Pomogranate Rind were studied by conventional method as mentioned above in (iv) and non conventional method (Viz–Relative compatability rating method as mentioned above in (v). The said newer method of Relative compatability rating was carried out by calculating Colour Difference Index (CDI) values and annalysing differences in CDI values for different proportions of binary mixture of natural dyes used in binary mixture for compound shades. Before dyeing, all the natural dyes used were extracted in aqueous solution at their optimum extraction conditions for each dyeand used for dyeing at prescribed concentration level. After dyeing with different combinations of binary mixture of the said natural dyes, their colour value (surface colour strength i.e. K /S value) were measured and the observed K/S value and calculated K/S value were compared. For such comparison, purified natural dye powder for each natural dye was used for accuracy in data. In this part of the work. The major objectives of this part of work was to develop compound shades of varying colour combinations and to find out the compatible dye-pairs to control and monitor their colour interactions parameters for obtaining specific Compound shades with better colour matching formulations.

It has been established[11] earlier by the present group of authors that the pre-mordanting using 20% myrobolan followed 20% aluminiumsulphate is the most suitable for dyeing jute with catechu and hence all these dyeing were done on same mordantedbleached jute fabric adopting the same system of pre-mordanting of jute fabric also for this part of the study.

So, in the present part of study following selected binary pairs (50:50) of natural dyes were applied on the 20% harda and 20% $Al_2(SO_4)_3$double pre-mordanted (applied in sequence) jute fabrics using purified dye powder for obtaining overall 30% shade or varying shades of 10 - 50% shade (on the basis of weight of dry source material of respective natural dye) of the respective extracts for each natural dyes for following binary pairs of combination of selected natural dyes:

M1---Catechu +Tesu (CAT&TESU)
M2---Catechu + Manjistha (CAT & MJ)
M3---Catechu + Babool wood (CAT & BL)
M4---Catechu + Red Sandal wood (CAT & RSW)
M5---Catechu + Pomegranate Rind(CAT & PGR)

Most of the natural dyes show inadequate wash or light fastness behaviour and hence it may need to be after treated with suitable dye fixing agent or other additives to improve the corresponding colourfastness properties. In the present work, three types of cationic fixing agents and one specific UV absorber have been applied to improve colour fastness to washing and light respectively.

The present work in this part therefore finally deals with study related to compatibility of binary pairs of selected natural dyes and their colour interaction parameters for understanding (i) Colour strength and related colour parameters of compound shades developed (ii) Colour fastness for such binary mixture of natural dyed jute fabrics producing selected compound shades and (iii) Compatibility of selected natural dyes for selected binary pairs of such dyes.

2. Materials and Methods

2.1. Materials

2.1.1. Jute Fabric

Conventional 3% H_2O_2 bleached plain weave, fine hessian decorative variety jute fabric, (215tex warp, 285tex weft, 64 ends/dm, 58 picks/dm, 320g/m^2 fabric area density and 0.74 mm fabric thickness), obtained from M/s Golster Mills, Bowreah, Howrah, was used for the present study.

2.1.2. Chemicals, Dyes and Auxiliaries

Commercial grade acetic acid (CH_3COOH), hydrochloric acid (1N i.e. 3.6% HCl), sulphuric acid, common salt i.e. sodium chloride (NaCl) and sodium hydroxide (NaOH) obtained from local suppliers (M/S Lily & Co, Kolkata) were used in the present work.

L.R grade 1, 2, 3-benztriazole ($C_6H_5N_3$), CTAB (cetyl trimethyl ammonium bromide {$C_{19}H_{42}BrN$} as low molecular weight quartenary ammonium compound as dye fixing agent), Cetrimide obtained from M/S Loba-chem as well as textile auxillaries grade Commercial dye fixing agent Sando Fix-HCF (a querternary ammonium compound) and a non-ionic detergent (Sandozin NITI) obtained from M/S Clariant (India) were used in the present work.

2.1.3. Mordants

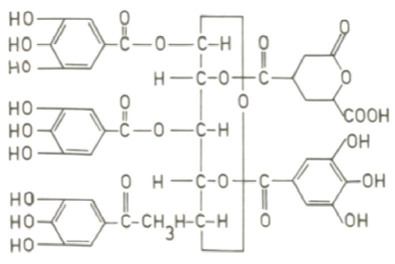


Fig. 1. Chemical structure of Chebulinic acid residue present in Harda obtained from myrobolan (Harda).

Laboratory reagent (LR) grade of Aluminium sulphate [$Al_2(SO_4)_3$, 18 H_2O], all obtained from E. Merck

(India) were used as chemical mordants.A natural mordant myrobolan (commonly known as haritaki or harda) and botanically known as *Terminalia chebula*[10]containing chebulinic acid as shown in Fig. 1, rich in tannic acid residue was also used in the present work.

2.1.4. Natural Dyes Used

Catechu, commonly known as cutch or khair or khadira is used in the present work. Catechu is botanically known as *acacia catechu*[10] and it belongs to family, Mimosaceae[10]. The major colour components of catechu are catechin and catechutannic acid. Catechu contains 2-12% catechins, 25-33% phlobatanin, 20-30% gummy matter, quercitrin, and quercitin. The manufacture of catechu is traditionally done by boiling the separated red heart wood, till all soluble portion exhausted. On cooling, it is converted to semisolid mass as cutch. Chemical structure of catechin is shown in Fig. 2.

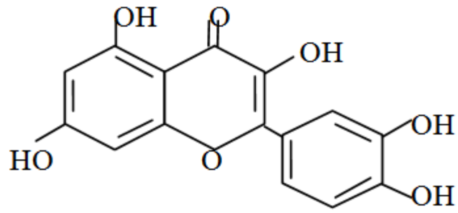


Fig. 2. Chemical structures of colour component of Catechu: Catechin.

The manufactureof catechu is traditionally done byboiling the separated red heart wood, till all soluble portion exhausted. On cooling, it is converted to semisolid mass as cutch.

Depending on the mordant and condition used, the colour range obtained on bleached jute with catechu extract varies from yellow / brown/ reddish brown to brownish red. There is adjacent hydroxyl groups in the above said colour component of catechu which accounts for the ability of these compounds to form complex with metal salts to fix those on jute by mordanting with metal salts. At the same time, there is immense possibility of hydrogen bonding with cellulosic –OH groups, utilizing the said –OH groups of the colour component of catechu.

Manjistha is commonly known as Indian Madder and is botanically known as *Rubia Cordifolia*[10]. The major colour components[10] of manjistha are purpurin (65%), manjistin (10%), purpuroxanthin (7-8%), pseudopurpurin and nordamncanthal (9-10%) (Structures in Fig. 3).

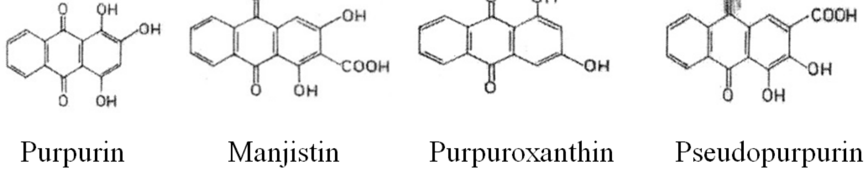


Fig. 3. Chemical Structure of Colour Components of Manjistha.

Tesuis commonly known aspalas /dhak /fire of forest and botanically known asbuteamonosperma / butea frondosa[3]and it belongs to family, Fabaceae. Main colour component of tesu is butein[10]and the chemical structure is shown in Fig. 4.

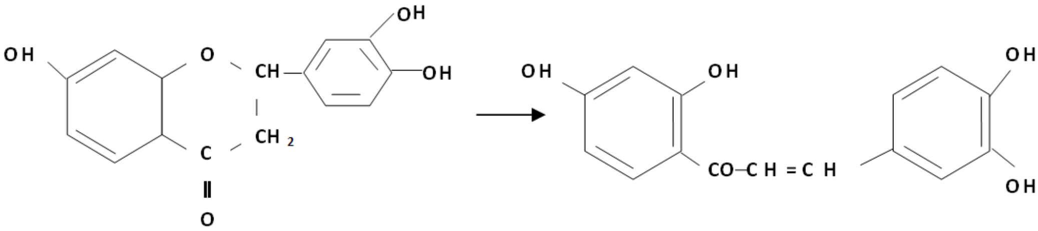
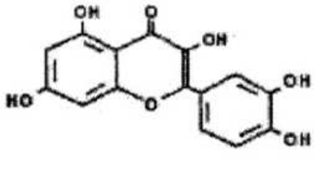
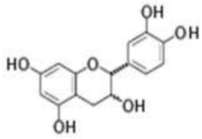


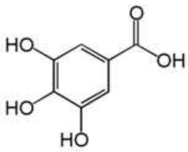
Fig. 4. *Chemical Structure of Butein from Petals of Tesu.*



F1. Catechin



F2. Epicatechin



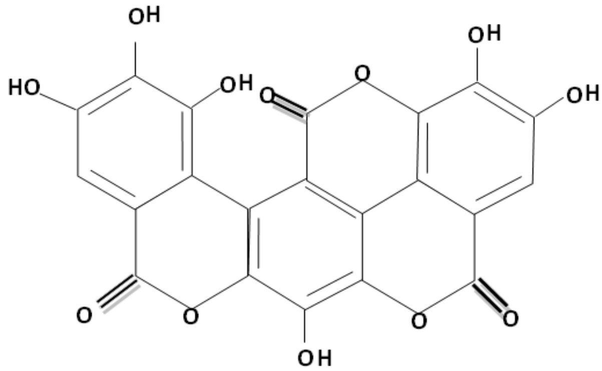
F3. Gallic Acid

Fig. 5. *(F1, F2 and F3) Chemical structure of colour components of Babool containing catechin, epicatechin and gallic acid.*

The colour range obtained on jute from tesu (Palas) extract varies from orange, ochre to brown depending on mordant used. In such hydroxy – flavone colour component, it is the hydroxyl and ketone group present in the pyrone ring which accounts for the ability of these natural dye compounds to form complex with metal salts. Also –OH groups of the benzene ring of the butein of the said natural dyes may account for mordanting with metal salts. At the same time, there is immense possibility of hydrogen bonding between cellulosic –OH groups, and the –OH groups of the butein colour component of tesu (palas).

Babool (BL); is botanically known as *Acacia Arabica*[10]. Several polyphenolic coloured components have been identified in the bark or woody part of babool tree and these are mainly catechin, epicatechin and gallic acid [(Structures-F_1, F_2 and F_3 in Fig. 5)] along with minor amount of decatechin, quercetin, and leucocyanidin gallate.

Pomegranate Rind(PR)is botanically known as punica granatum originated from the family Punicaceae. It contains flavogallolas main colour component obtained from its rind and the chemical structure1-2,10 is shown in Fig. 6.



Flavogallol

Fig. 6. *Chemical Structure of Colour Component of Pomegranate Rind.*

Red Sandal Wood (RSW) commonly known as rakta chandan and botanically known as *Pterocarpus Santalinius* ($C_{14}H_{14}O_7$) or *Adenanthera Paronina* is comprised of a mixture of few complex colouring compounds. Perkin and Everest have identified that there are at least two or more maroonish red colouring components in the red sandalwood, viz. Santalin A, Santalin B and Deoxysantalin, (as shown in Structures-A_1, A_2 and A_3 in Fig. 3.8respectively) of which Santalin A is considered as the main colouring component [10].

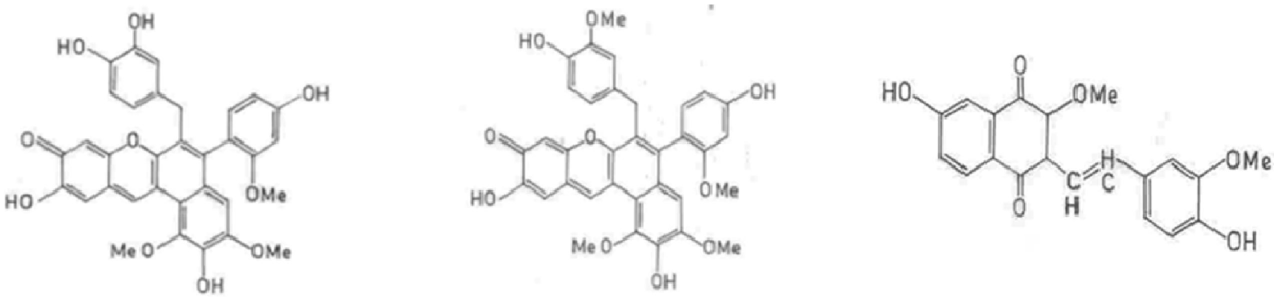


Fig. 7. *Chemical structures of colour components of Red sandal wood containing Santalin A, Santalin B and Deoxysantalin.*

2.2. Methods

2.2.1. Extraction of Dye Liquor from Different Natural Dyes Taken from Solid Source Materials

Catechu (Acacia Catechu): Catechu powder (as supplied) was boiled or heated in water with MLR 1:20 at pH 11, for 60 min, at 90°C for extraction. After the extraction of dye liquor from Catechu powder under specific conditions studied earlier by the present author [11],the slurry obtained was double filtered and the filtrate, the aqueous extract of dye liquor was used for dyeing.

Tesu: Pre-cut and dried chips of Tesu were initially crushed to powder and was subjected to aqueous extraction under the optimum condition for extraction [18]as follows:

Time – 60 min, temperature – 100°C Percentage of Tesu – 25% (w/w); pH-11.0, initial material to liquor ratio – 1:20.

Manjistha (Indian Madder): Pre-cut and dried branches of manjistha plant was initially crushed to powder form and then it was extracted in water using an optimsed conditions of extractions[19] using M.L.R- 1:20 (finally reduced to 1:5 by boiling and evaporation), temperature-90 °C and time -45 min and then it was filtered to obtain approximately 40% (w/w) clear extract of coloured aqueous solution of manjistha having pH 4.5.

Babool (Babla): Pre-cut and dried chips of Babool bark was initially crushed to powder form and then it was extracted in water using an optimised conditions of extractions[13], by boiling (100 °C) in water for 2hr and using M.L.R 1:20 (finally reduced to 1:5 by boiling and evaporation) and then it was filtered to obtain 40% (w/w) clear extract of coloured aqueous solution of Babool having pH 4.5.

Red Sandal Wood (RSW): Pre-cut and dried RSW wood pieces from branches of dried and chooped red sandal wood was initially crushed to powder form and then it was extracted in water using an optimsed conditions of extractions [20] as follows:

Time-90 min; temperature-80°C; Percentage of red sandal wood-40% (w/w); pH-4.5; initial material-to-liquor ratio- 1:20 (which was finally reduced to 1:5 by further boiling and evaporation technique).

Pomogrenate Rind (PGR): Pre-cut and dried Pomogrenate rind dried pieces were chooped and was initially crushed to powder in asuitable grinding cum pulveriser machine and then the powder was soaked in water and after overnight soaking, colour component was extracted in water boiling using an optimsed conditions of extractions [21] as follows:

M.L.R - 1:20, temperature-90 °C and time -45 min and then it was filtered to obtain approximately 40% (w/w) clear extract of coloured aqueous solution of pomegranate rind having pH 11.Time-45 min; temperature-90°C; Percentage of Pomogrenate rind - 40% (w/w); pH-11.0; initial material-to-liquor ratio - 1:20 (which was finally reduced to 1:5 by further boiling and evaporation technique).

Unless otherwise mentioned, in each case, the aqueous extract of dye liquor from all the above said extracted natural dye liquor based on % of solid source materials was prepared following the above said optimized conditions of extraction and was used as and when required,. To make the solution of dye extract concentrated to a desired level, the same was evaporated on a water bath, when required. for final application.All the above extracts were also purified to obtain corresponding pure colour components (dye) for each dye from those aqueous extracts of the dye liquor, for specific use and characterization.

2.2.2. Purification of Colour Componentof Extracted Natural Dyes

Catechu and other natural dyes taken in the present work (all the source of natural dyes used) were initially crushed to powder form in a mechanical pulverizer cum grinder. Catechu powder was then subjected to aqueous extraction under conditions: MLR 1:20; temperature 90°C; Time 60 minute and pH 11. Also Other dye powder were extracted at their optimized conditions of extraction. Aqueous extracts of Catechu and other natural Dyes used in each case was double filtered and then gradually concentrated by evaporation in water bath either to semi-dry solid mass or to a solution of desired concentration level required. Purification of colour components of Catechu and other natural dye extract were concentrated and that concentrated extract was were put in a piece of Blotting paper/Filter paper for soxhlet extraction of the semi-dry mass wrapped in filter paper, using 50:50 ethyl alcohol: toluene mixture for 10 cycles nearly for 2h at 70ºC in each case individually[13]. After soxhleting, the alcohol-toluene extract containing the soluble colour components of Catechu or any other natural dyes taken, was obtained by filtering and then filtrate was evaporated to semi dry mass under low temperature drying in vaccum oven. The dry residue was washed in acetone followed by washing with methyl alcohol and final drying in air to obtain the dry powder of the pure colour component of catechu or other natural dyes taken for purification.

2.2.3. Mordanting

(a) First Mordanting with Myrobolan for Double Mordanting (Harda)

The myrobolan (Harda/Haritaki) powder was soaked in 1:10 volume of water for overnight (12h) at room temperature before required volume of aqueous solution of the same is prepared. The said swelled myrobolan solution or ‘gel’was mixed with required volume of water to make an appropriate volume and was heated at 80ºC for 30 min [11]. This boiled solution of harda was then filtered in a 60 mesh nylon cloth and the filtrate was used as mordant solution for final application using MLR of 1:20. Pre-wetted conventional H_2O_2 bleached jute and cotton fabric samples were separately entered in the said mordant (harda) solution in separate bath at 40-50ºC and then the temperature of the harda solution was gradually raised to 80ºC and the mordanting was continued for 30 min[11]. After this, harda mordanting, the fabric samples were dried in air without washing to make it ready for either dyeing or for second mordanting as required.

(b) Second Mordanting with Metal Salt for Double Mordanting

The Myrobolan- treated (first mordanted) jute fabrics were then treated prior to dyeing using 10-40% $Al_2(SO_4)_3$, $KAl(SO_4)_2$as the case may be, at 80°C for 30 min using[11] MLR of 1:20. After the second mordanting, the fabric samples were finally dried in air without washing to make them ready for subsequent dyeing.

2.2.4. Dyeing of Pre-Mordanted Jute Fabrics with Extract of CATECHU and Other Natural Dyes

Dyeing of pre mordanted jute fabrics was done by using optimized dyeing conditions for catechu [11].using MLR 1:20; temperature 80°C; Time 90 minute, at pH 11, Salt 10gpl with 30 % application of Catechu dye liquor or 1 % purified colour components of catechu or other natural dye powder to obtain exactly comparable dosage (1%) of shade percentage for single shade or binary compound shade.

Thus, double pre-mordanted bleached jute fabric samples were dyed with aqueous extract of either single or selective pairs of binary mixture of selective natural dyes of varying proportions (100:0, 75:25, 50:50, 25:75 and 0:100 applying overall 30% (owf) extract of selective dyes (based on the weight of the dry source material of selective natural dye), at 80°C using MLR 1:20 for 90 min adding 10gpl sodium chloride as only additive.

However, in case of compatibility tests for different pair of binary mixture of natural dyes were carried out using 1% solution of purified natural dyes in each case from results of two sets of dyeing under different variations for progressive increase in depth of shade as described in the introduction part by conventional method obtaining plots of ΔC vs -ΔL, and plots of K/S vs - ΔL., as well as by a newer proposed method of relative compatability rating(RCR) based on earlier work. [12-14].

In each case, the dyed samples were repeatedly washed with hot and cold water and finally dried in air. Finally the dyed samples were subjected to soaping with 2g/l.soap solution at 60 °C for 15 min, followed by repeated water wash and atmospheric drying under sun.

2.3. Testing and Evaluation

2.3.1. Determination of Surface Colour Strength and Other Colour Interaction Parameters of Dyed Fabrics

K/S value is a measure of the surface colour strength of the dyed fabric samples. K/S values of dyed jute fabrics were determined by measuring surface reflectance of the dyed samples using a computer-aided Macbeth 2020 plus reflectance spectrophotometer followed by calculating the K/S values using Kubelka Munk[22] equation with the help of relevant software.

$$\frac{\mathrm{K}}{\mathrm{S}} = \frac{(I-R)^2}{2R} \text{ or } \frac{\mathrm{K}}{\mathrm{S}_{\lambda m}} = \frac{(1-R_{\lambda max})^2}{2R_{\lambda max}}$$

If not otherwise mentioned, only K/S value means $K/S_{\lambda max}$ value for corresponding sample, at any place mentioned in this thesis

Also coefficient of variation percentage (CV%) of K/S values was determined from the 10 point K/S data taken at 10 different points of the corresponding dyed fabric samples indicating the dye uniformity[23]. However the CV% of $(K/S)_{total}$ values, higher is the dye uniformity.

CV% is determined using the following expression:-

$$\text{SD (Standard Deviation)} = \sqrt{\frac{\sum(x_i-m)^2}{n-1}}$$

and $\text{CV\%} = \frac{S.D}{Mean} \times 100$

Standard colour difference parameters like Total colour difference (ΔE), ΔL (lightness / darkness), Δa (redness / greenness), Δb (yellowness / blueness), Δc (changes in chroma) and general metamerism index (MI) were calculated using standard CIE formulae for each[22]. Each of the standard colour difference parameters has its own characteristic to indicate a particular behavior of colour differing with respect to certain known standard parameter.

The total colour difference (ΔE) values were measured by measuring corresponding L*, a*, b* values before and after the treatments/ dyeing using the computer-aided Macbeth 2020-plus reflectance spectrophotometer along with associated Colour-Lab plus software employing following CIE-Lab equations [22], to compare the shade depth of one with other comparative standard samples:-

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$$

Where, $L^* = 116\,(Y/Y_o)^{1/3} - 16$ $\Delta L^* = L^*_1 - L^*_2$

$$a^* = 500\,[(X/X_o)^{1/3} - (Y/Y_o)^{1/3}] \quad \Delta a^* = a^*_1 - a^*_2$$

$$b^* = 200\,[(Y/Y_o)^{1/3} - (Z/Z_o)^{1/3}] \quad \Delta b^* = b^*_1 - b^*_2$$

Chroma, (psychometric chroma) values in CIELAB colour space was calculated as follows:-

$$C_{(ab)}^* = (a^{*2} + b^{*2})^{1/2}, \ \Delta C^* = C^*_{1(ab)} - C^*_{2(ab)}$$

where, $C^*_{1(ab)}$ and $C^*_{2(ab)}$ are the chroma values for standard sample and produced sample.

CIE 1976 metric Hue-Difference[19] (ΔH) for CIELAB system was calculated as follows:-

$$\Delta H_{ab} = [(\Delta E_{ab}^*)^2 - (\Delta L^*)^2 - (C_{ab}^*)^2)\,]^{1/2}$$

The Metamerism-Index (MI) will show the probability that two samples will show the same color difference under two different illuminants (represented by the first and second illuminant)

$$\text{MI} = \sqrt{(\Delta L_{a1} - \Delta L_{a2})^2 + (\Delta a_{a1} - \Delta a_{a2})^2 + (\Delta b_{a1} - \Delta b_{a2})^2}$$

•L^*_1•a^*_1•b^*_1 are the Delta CIELab* color coordinates between Standard and Sample for the first illuminant •

•L*$_2$•a*$_2$•b*$_2$ are the Delta CIELab* color coordinates between Standard and Sample for the second illuminant

Interpretation: • If MI is low the color difference between the sample pair is the same for both illuminants. This does not mean that the two samples match, it means, that the two samples show the same difference for both illuminants • If MI his high there is a different color difference between the two samples at two different illuminants. The samples might match under one illuminant, but not under the second. Or the sample 1 might to be red under illuminant 1 and to green under illuminant 2

Brightness Index (BI) was calculated as per ISO-2470-1977 method [24] using the following relationship.

$$\text{Brightness Index}=\frac{\text{Reflectance value of the substrate at 457nm}}{\text{Reflectance value of the standard}}\times 100$$

diffuser/white tile at 457nm

2.3.2. Study of Relative Colour Differences and Compatability Rating for pairs of Natural Dyes

However, no single index of colour parameters describing a perfect comparison of different sets of coloured samples dyed under different conditions, i.e., or using either different time and temperature profile or different dye concentration for single or mixture of dyes. Hence, a newer index called "colour difference index" (CDI) has been defined and used for this purpose. Magnitudes of the respective ΔE, ΔC, ΔH and MI values (irrespective of their sign and direction) for different sets of coloured fabrics dyed under different conditions of dyeing have been utilized to obtain the said newer 'colour difference Index' calculated by the following empirical relationship established from this laboratory [12-14] to understand the overall combined effects of different types of colour parameters by a simple comparative value in general.

$$\text{Colour difference Index (CDI)} = \frac{\Delta E \times \Delta H}{\Delta C \times MI}$$

2.3.3. Test of Compatibility of Binary Mixture of Selective Natural Dyes

Method –1 (Conventional):

For test of compatibility of the above said pair of natural dyes, bleached and pre-mordanted jute fabric samples were dyed in two different sets of progressive depth of shade for each pair of binary mixture of natural dyes as follows:-

Binary mixtures of natural dyes applied on jute fabric

-Mixture M1: Catechu + Tesu (CT &TESU)

-Mixture M2: Catechu + Manjistha (CT& MJ)

-Mixture M3: Catechu + Babool Wood (CT & BL)

-Mixture M4: Catechu + Redsandal wood (CT &RSW)

-Mixture M5: Catechu + Pomogrenate Rind (CT &PGR)

Binary mixtures of above said five different pairs of selective natural dyes were applied [applying general 1% shade depth with purified dyes and otherwise i.e. varying shade% in 20 to 100 parts of 1% shade. In some cases, where, direct of concentrated liquor of dye-extracts were used, overall application of 20% - 100% extract (on the basis of weight of dry source material) for selective natural dyes were also used] for build up of progressive shade depth on the double pre-mordanted bleached jute fabrics with varying temperature and time taking always-equal proportion (50:50) of each binary mixture profile or varying total dye concentration of the following pair of natural dyes and

Thus, bleached jute fabrics after double pre-mordanted with 20% harda (1st mordant) and 20% $Al_2(SO_4)_3$ (2nd mordant) applied in sequence, were dyed with the said binary mixtures of natural dye pair. In two sets as follows;

In Set I, (progressive depth of shade developed by varying dyeing time and temperature profile during dyeing), for each pair of dyes (M1-M5), five separate small pre-mordanted jute fabric samples were separately dyed for different dyeing period (10-60 min), by withdrawing from the dyebath at the intervals of 10 min from 60°C onwards maintaining the heating rate of 1-2°C/min. The penultimate sample was taken out after 30-50 min at 100°C and the last one at the end of the dyeing carried out for 60 min.

In Set II (progressive depth of shade developed by varying total concentrations of dye mixture using 20-100 parts of 1% shade depth using purified natural dye-stuff colourants) for each pair of binary mixture dyes, five separate small pre-mordanted jute fabric samples were separately dyed at increment of twenty percentage points by applying 20% -100% parts of 1% purified catechu and other natural dyes (on weight of fabric) for each pair of natural dye-mixture taken in equal proportion (50:50) at 100°C for 60 min.

For both Set I and Set II, after dyeing, all the dyed fabric samples were subjected to normal washing, soaping, and rinsing before final air-drying as mentioned earlier in this chapter of the thesis. In some cases, for general comparative purpose natural dyeing with their binary mixtures on jute and cotton fabric using the liquid dye extracts (20-100% on the weight of dry source material) was also used.

The differences in the CIELAB coordinates namely, ΔL, Δa, Δb and ΔC for all dyed fabric samples for Set I and II obtained indicate for the jute and cotton fabrics dyed with using purified natural dyes, as said above, the lightness/darkness, redness/greeness, yellowness/blueness and differences in saturation/chroma (ΔC) values with respect to the standard undyed fabric sample, which were measured and obtained from separate measurement of the same using the earlier said Macbeth 2020 plus reflectance spectrophotometer and associated software and computer.

The compatibility of a selective pairs of dyes can be judged[3-6, 12-14] from the degree of closeness overlapping of the two curves $\Delta C vs \Delta L or K/S vs \Delta L$ observed using the two sets of dyeing (Set I & Set II). Finally the compatibility of selected pair of natural dyes were judged from the nature of two sets of curves obtained from above said two sets of dyeing results for plots of $\Delta C vs \Delta L or K/S vs \Delta L$ for each binary mixture of the said natural dyes. The pattern of two curve (showing progressive depth of shade by two different way dyed as said above) for plot of ΔC vs -ΔL, and plot of K/S vs -ΔL obtained by such dyeing results in two sets of dyeing as said above for same pair mixture of natural dyes, indicate that whether that pair of natural dyes is compatible or not, but no quantitative rating is possible by this method.

Method-2 (Newer Developed method with comparative rating of compatibility):

An alternative method of judgement of relative compatibility rating of binary mixture of Dye in pairs of dyes for application of binary mixture of dyes may be predicted by a newer developed relative compatibility rating (RCR) system, that has been postulated here and applied in the present work, to prove its supremacy over conventional method of. After application of different proportions of binary mixture of selective pair of dyes (maintaining 1% (owf) overall shade percentage for each binary mixture/ pair of dyes using purified dye powder for each natural dye) on the same fabric, magnitudes of the respective ΔE, ΔC, ΔH and MI values irrespective of their sign and direction may be utilized to obtain colour difference Index values by the following proposed emperical relationship for CDI values as shown above.

The closer the CDI values for binary pairs of dyes, the higher is the compatibility rating(between 0 and 5, where rating 5 shows as the maximum or excellent compatibility, rating 1 indicates minimum or worst compatibility and rating 0 is considered as completely non-compatible). Lower is the values of Colour Difference Index (CDI), the more uniform is the dyeing results for single dye application. Higher is the value for dyeing process variable study, most important and critical is that parameter of dyeing need to control precisely. While, Closer are the Colour Difference Index (CDI) values for use of different proportions of binary mixtures of dyes applied on the same fabric under the comparable conditions of dyeing, the higher is the compatibility rating (between 0 to 5, where rating 5 is considered as the maximum or excellent compatibility and rating 1 is considered as the minimum or worst compatibility and rating 0 (zero) is considered as completely non-compatible). Proposed Relative Compatibility Rating (RCR) or compatibility grading system proposed here in this newer method of compatibility test based on numerous data for earlier work [12-14](done in this laboratory) for this may be represented here in Table 1:

Table 1. *Newer method of Relative Compatibility Rating.*

Compatibility Grade	**Relative Compatibility Rating (RCR)**	**Highest values of differences between maximum CDI values and individual CDI values for dyeing using different proportions of binary mixtures of selective dyes on the same fabric under the comparable dyeing conditions.**
Excellent	5	>0 but ≤ 0.05
Very good	4-5	>0.05 but ≤ 0.10
Good	4	>0.10 but ≤ 0.20
Moderate	3-4	>0.20 but ≤ 0.30
Average	3	>0.30but ≤ 0.40
Fair	2-3	>0.50 but ≤ 1.00
Poor	2	>1.00 but ≤ 5.00
Very poor	1-2	>5.00 but ≤ 10.0
Worst	1	> 10.0 but ≤15.0
Non-Compatible	0	>>15.00

The values shown above in the third column for corresponding relative compatibility rating have been arrived after a series of preliminary experiments carried out for different mixture of natural dyes applied on both pre-mordanted jute and cotton textiles and comparing the same with the compatibility grades for the corresponding pair of dyes by conventional test methods by plots of K/S vs -ΔL and ΔC vs -ΔL. between dyeing results of two sets (Set-I and Set-II) of dyeing for binary mixture of natural dyes, as said above.

2.3.4. Evaluation of Colour Fastness to Wash, Light and Rubbing

The wash fastness of dyed jute and cotton fabrics was evaluated according to IS: 3361-1979 method [25]. The light fastness of the bleached and dyed jute and cotton fabrics was evaluated as per IS: 2454-1967 method [25]. Dry and wet rubbing fastness of the dyed jute fabric was evaluated as per IS: 766-1956 method

3. Results and Discussion

3.1. Analysis of Colour Strength and Related ColourParameters for Dyeing Mordanted Jute with Selective Binary Mixture of Natural Dyes

Table 2 shows the observed (O) and calculated(C) surface colour strength (K/S values) for pre-mordanted jute fabrics dyed with binary pairs of dyes,whereD1 is Difference between observed and calculated *K/S*values.and D2 is Differences between two sets of observed *K/S* values at λ_{max}(DyeA) and at λ_{max} (DyeB) for pair of A and B Dyes.

$$[\lambda_{max} = CAT - 604\text{nm}, \text{MJ} - 540\text{nm}, \text{RSW} - 540\text{nm}, \text{BL} - 550\text{nm} and\ PGR - 520nm, \text{Tesu -490nm}]$$

**Proportion of binary pairs of dyes(m:n),; A-*K/S* at λ_{max} of dye A, B-*K/S* at λ_{max} of dye B,

O- Observed *K/S* value; C- Calculated *K/S* value;

D1=O_A-$C_A$or O_B-C_B =Difference between observed and calculated *K/S* values.; D2= O_A-O_Bi.e.Differences between two sets of observed *K/S* values at λ_{max}(A) and at λ_{max} (B)

It is found that the difference (D1) in the observed and calculated K/S values are minimum for CAT+BL irrespective of sign. The order of increase in the differences (D1) between the observed and calculated *K/S* for the various pairs of dyes applied are as follows irrespective of sign (Table 2):

CAT+BL <CAT+TESU < CAT+PGR <CAT+MJ<CAT +RSW

The metameric effect, considering the differences (D2) in the *K/S* values measured at λ_{max} (604 nm) for dye A and $at\ \lambda_{max}$ for dye B ($\mathrm{MJ-540nm, RSW-540nm, BL-550nm}$ $and\ PGR - 520nm$ and Tesu -490nm) for each pair of natural dyes taken for this part of the study, is also found to be minimum for the mixture of Catechu and babool (CAT& BL). The order of increasing differences between the two sets of observed *K/S* values at two differentλ_{max} values for each pair of natural dyes (D2=O_A-O_B) is as given below:

CAT+BL < CAT+MJ <CAT +RSW < CAT+PGR < CAT+TESU

Moreover, Data in Table 2 also indicate that with one exception all D2 values are found to be negative, indiacting that the K/S values at lower wave length are always higher than corresponding K/S at 604 nm (at λ_{max} for catechu extract). i.e the effect here are always predominatlyhypsochromic shift and in one case it is bathocromic.

Table 2. *Observed and Calculated K/S Values and Related Parameters of Pre-Mordanted Jute Fabrics Dyed with Selected Binary Pairs of Natural Dyes.*

Dye Combination	K/S Value									
	100:0a		**75.25a**		**50:50a**		**25:75a**		**0.100a**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
M1 (CAT:TESU)										
O	5.62	15.5	4.73	13.03	4.03	12.09	1.93	7.43	1.13	4.54
C	-	-	5.17	12.77	3.83	10.03	2.47	7.28	-	-
D1			-0.44	+0.26	+0.20	+2.06	-0.54	+0.19		
D2	-9.9		-8.3		-8.06		-5.54		-3.41	
M2(CAT+MJ)										
O	5.62	14.2	3.17	7.96	2.24	5.76	1.93	5.25	1.27	4.25
C			5.20	10.69	3.89	7.76	2.58	6.75		
D1			-2.03	-2.73	-.1.65	-2.00	-0.65	-1.50		
D2	-8.58		-4.79		-3.52		3.32		-2.98	
M3(CAT+BL)										
O	5.62	12.8	5.16	1.78	3.37	7.46	2.96	6.06	2.25	3.65
C			5.45	10.51	4.38	8.22	3.32	5.94		
D1			-0.29	+0.27	-1.01	-0.76	-0.36	0.12		
D2	-7.18		-5.62		-4.09		-3.10		-1.40	

Dye Combination	K/S Value									
	100:0a		**75.25a**		**50:50a**		**25:75a**		**0.100a**	
M4(CAT:RSW)										
O	5.62	14.26	6.32	14.42	2.00	6.05	1.44	4.47	1.25	4.14
C			5.20	11.72	3.89	9.20	2.57	11.72		
D1			+1.12	+2.70	-1.89	-3.15	-1.13	-7.25		
D2	-8.64		-8.10		-4.05		-3.03		2.89	
M5(CAT:PGR)										
O	5.62	15.49	3.96	11.61	3.04	10.94	2.09	6.45	1.17	2.23
C			5.18	12.17	3.84	8.85	2.51	5.54		
D1			-1.22	-0.56	-0.8	+2.09	-0.47	0.91		
D2	-9.87		-7.65		-7.90		-4.41		-1.06	

However, considering all the colour parameters i.e$\Delta E, \Delta H, \Delta C$ and MI, for dyeing of all selected binary pair of mixture of natural dyes, the Colour difference index (i.e. CDI value) are found to be in the following increasing order (Table 3):

CAT+PGR < CAT +RSW <CAT+TESU < CAT+MJ < CAT+BL

Thus, it is understood from the colour interaction parameters along with K/S data as shown in both Table 2 and 3, that the different proportions of mixture of selected binary pairs of Natural dyes do not follow the same trend, proabaly due to combination of dual effect of (i) Hypsochromic/bathochromic shift for two colours used in each pair of natural dyes and (ii) competitive varying mordanting power of two dyes in each pair of selected mixture of natural dyes affecting absorption of slower member than the rate of absorption of faster member between the two. Hence there is no specific trend in colour difference index (CDI), Table. 3, for dyeing with different proportion s of eacgh pair of selected natural dye mixture.

Data in Table 3 shows the K/Svalues, total colour differences (ΔE), changes in hue (ΔH), changes in chroma (ΔC), metamerism index (MI) and brightness index (BI).at a common wavelength ($\lambda_{max} = 604$ nm- for Catechu used as common member for all pair of binary mixture studied) for double pre-mordanted jute fabrics dyed with selected binary pairs of selected natural dyes in different proportions (75: 25, 50:50 and 25:75). The data for total colour difference (ΔEvalues) for different combination though do not follow any trend but MI values are found to be minimum for M3 (CAT: BL), irrespective of the proportions of the mixture of each selected pairs of dyes.

Comparison of the values for change in chromaΔC and ΔHshows that the changes in the chroma and Hue values for the different combination though not follow any particular trend, but as compared to other pairs, M3

(CAT+BL) are always found to be at lower side for that particular proportions. Of binary mixtures of this pair of natural dye, while the for other pairs the same are observed to be some time much higher and some time marginally higher for all the proportions of different pairs of binary mixture of natural dyes studied.

Brightness index (BI) is another important colour parameter of dyed fabrics, being considerably dependent on the surface luster and specular reflectance. Brightness index(BI) values are found to decrease initially for all natural dyed fabric than the corresponding BI value of Bleached and mordanted Jute fabric, Moreover, it is observed from data in Table 3 that Brightness index values for all these binary pairs of dyes taken in different proportions are found to increase with decrease in Catechu % and the total BI values are always lower than corresponding BI values of 100% individual dyed jute fabric.

Another interesting observation on K/S value is, with decrease in catechu concentration in each pair of binary mixture of natural dye, the K/S value reduces to some extent, but BI values are found to be increased to some extent with decrease concentration of catechu. These two opposing phenomenon may be viewed under two opposing influences (i) K/S value of comparable % application of catechu individually is highest amongst the other individual dyes applied in same concentration on the same fabric, showing proportionate reduction of K/S value for % decrease in catechu concentration(K/S values are additive and linear with dye concentration) and (ii) two different types of colour component of natural dyes having different scattering property probably more and more increasing the total surface covering by combination of two types of dye materials one being complimentary to other to increase the regular reflection to a small extent and still below their BI for 100% application of any of these individual dyes taken.

Table 3. *Colour strength, brightness index and related parameters of pre-mordanted jute fabrics dyed with selected single and binary pairs of natural dyes in different proportionsof PURIFIED NATURAL DYES.*

Dye combination	K/S λ_{max}604, nm	ΔE	ΔC	ΔH	MI	BI	CDI
(A)Nil (Control Bleached Jute Fabric)	0.81(at 420nm) 0.25 (at 604nm)	-	-	-	-	48.04	-
(B)Control fabric + Mordant *	2.82	1.77	-	-	-	45.85	
	For 100% single dye for each						
B+ 30% CAT	5.62	-	-	-	1.96	7.07	-
B+ 30% MANJISTHA	1.27	13.75	11.24	5.03	2.65	7.21	2.32
B + 30% BABOOL	2.25	5.93	10.31	5.45	0.94	7.27	3.33
B + 30% RSW	1.25	14.95	11.92	5.72	2.60	7.00	2.76
B+ 30% PGR	1.17	14.12	14.40	17.69	4.19	7.16	4.14
B+ 30% TESU	1.13	17.62	10.96	10.30	2.46	7.99	6.73
	For 75:25 proportion						
M1(CAT:TESU)	4.73	2.61	2.05	1.27	0.59	3.65	2.73
M2(CAT:MJ)	3.17	7.34	5.33	3.84	1.28	4.13	4.13
M3(CAT:BL)	5.16	11.54	1.50	0.32	0.57	3.48	4.31
M4(CAT:RSW)	6.32	1.53	1.28	0.87	0.43	2.95	2.42
M5(CAT:PGR)	3.96	5.37	4.33	2.15	1.12	3.66	2.38
	For 50:50 proportion						
M1(CAT:TESU)	4.03	5.51	3.92	2.89	0.83	3.74	4.89
M2(CAT:MJ)	2.24	8.09	5.77	4.31	1.47	5.54	4.11
M3(CAT:BL)	3.37	16.49	5.30	2.51	1.40	4.14	5.58
M4(CAT:RSW)	2.00	10.32	8.50	3.75	2.14	5.59	2.13
M5(CAT:PGR)	3.04	10.60	8.92	3.54	2.05	3.77	2.05
	For 25:75 proportion						
M1(CAT:TESU)	1.93	12.83	9.12	6.25	1.71	5.50	5.14
M2(CAT:MJ)	1.93	7.88	5.82	3.87	1.53	6.44	3.42
M3(CAT:BL)	2.96	7.02	4.72	3.90	1.08	4.74	5.37
M4(CAT:RSW)	1.44	10.77	8.69	4.22	2.15	7.26	2.43
M5(CAT:PGR)	2.04	16.19	10.87	8.13	1.57	4.80	7.71

*Moradnt meant Double mordanted with 20% Harda(myrobolan) and 20% aluminiumsulphate applied in sequence. Moreover all samples having code M1 to M5 are Double mordanted as above before corresponding dyeing with single or binary mixture of natural dyes.

3.2. Colour Fastness

Table 4 shows the colour fastness data for selected binary pairs of natural dyes applied in different proportions (75:25, 50:50, 25:75) on double pre-mordanted jute fabrics and also for post treated with Dyefixing agent or UV absorber or other after treatment chemicals using one of the three types of cationic dye fixing agents or one specific type of UV absorber (to improve /wash fastness / light fastness. of these materials.

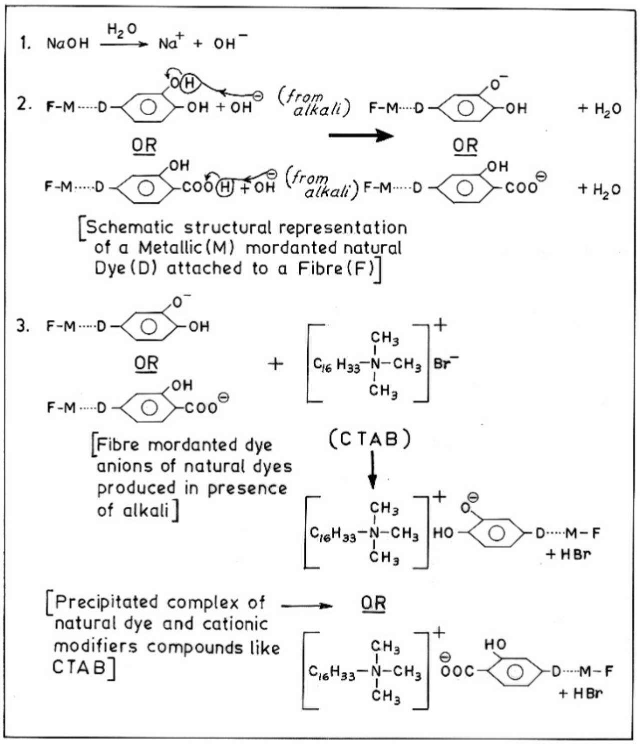


Fig. 8. Complex formation between Fibre-Mordant –dye system and cationic dye fixer.

This is observed that with decrease in catechu concentration; for all selected pair of mixture of natural dyes taken, the colour fastness to washing is found to be reduced to a marginal scale i.e. ½ unit to 1 unit. It is also found that whenever Red Sandal Wood is used in the combination of binary mixture i.e. for CAT + RSW, the overall washing and other fastness properties are overall better and is about ½ to 1 unit higher than any other combination irrespective of the proportions of mixtures for different pairs of dyes used to produce combine shades. Thus presence of higher amount of Catechu or any amount of RSW show up higher or better colour fastness to washing or light than others may be due to higher mordanting power of both Catechu and RSW due to more number of adjacent ortho OH groups present in colour component of these two dyes.

It is also mentioned worthy that post treatment of these dyed fabrics with any one of the three cationic dye fixing agents used here, lead to improvement of the wash fastness almost ½ unit or more for all the pairs i.e. M1 to M5. The mechanism for complex formation between the anoinisable / modarntable anionic natural dye and cationic dye fixing agents is shown in Fig. 8:

Improvement of light fastness to 1 unit or more by post treatment with 1% Benztriazole (as UV absorber) on all these dyed fabrics may also be explained by preferential UV light absorption by Benztriazole than that by the dye used or by the fibre itself (jute) or even both. The mechanism of fixing Benztriazole to jute may be explained in Fig. 9, it is postulated by earlier workers [12,14]that in presence of alkali, jute aldehyde attracts benztriazole to donate its nitrogenous lone pair to be anchored with Jute aldehyde group and get fixed and does the job of an inherent uv absorber permanently protecting both early fading of jute fibre and the natural dye for dyed and benztriazole after treated jute fabric. by the above said mechanism (Fig. 9),. Thus, benztriazole applied on dyed jute protect early fading of dyed jute improving the light fastness of dyed jute fabric to ½ to one grade.

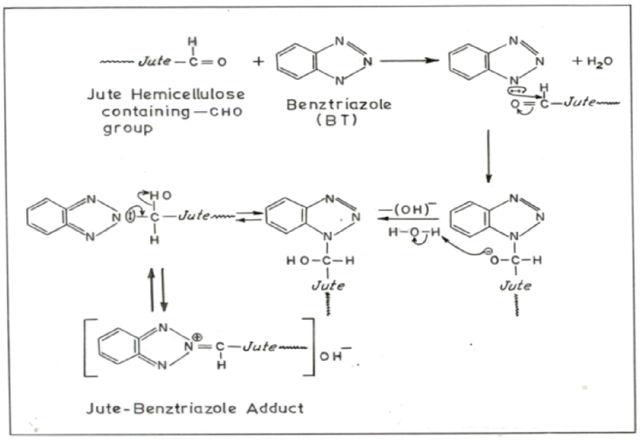


Fig. 9. Schematic Reaction mechanism between Jute-aldehyde and Benztriazole.

Both dry and wet rubbing fastness are very good i.e. 4 or 4-5. Hence no after treatment / post treatment is found necessary. Astonishingly good to excellent both dry and wet rubbing fastness observed for all these pairs of dyes irrespective of proportions or type of dyes used, may be viewed as an effect of less or no loose dye molecules present on the surface of the fibre, because of their common features of good to excellent mordanting power for all single or binary mixtures of the selected natural dyes used. However, as already mentioned earlier, amongst these 6 dyes used in different combinations, relatively

Highermordanting / anionisable capacity of RSW and Catechu than the others are well established from these results. The results of good to excellent rubbing fastness for all the pairs of natural dyes used, indicate that there are no unfixed dyes left on the fibre surface after soaping and washing and that these dyes have penetrated well inside the fibre voids and probably got fixed well by ionic interaction or hydrogen bonding or coordinate complex formation with the mordants or with the functional groups of jute fibre, as the case may be.

Table 4. *Colour fastness data for pre-mordanted jute fabrics dyed with selected binary pairs of natural dyes in different proportions and after treated with one of three cationic fixing agent and a UV absorber.*

Dye combination	ColourFatness to											
	Washing								Light		Rubbing	
	Untreated Control fabric		2% CTAB treated		2% Cetrimide Treated		2% Sandofix-HCF treated		Un-treated	1% Ben treated	Untreated Control fabric	
	LOD	ST	LOD	ST	LOD	ST	LOD	ST			Dry	Wet
For 75:25 Proportion												
M1(CAT:TESU)	3	4	4	4-5	4	4-5	4	4-5	3	4-5	5	4-5
M2(CAT:MJ)	4	4-5	4	4-5	4	4-5	4	4-5	3	4	5	4-5
M3(CAT:BL)	3	3-4	4	4-5	3-4	4	3-4	4	3	4	4-5	4
M4(CAT:RSW)	4	4-5	4	4-5	4	4-5	4	4-5	3	4	5	4-5
M5(CAT:PGR)	4	4-5	3-4	4-5	3-4	3-4	4	4-5	3	4	5	4-5
For 50:50 Proportion												
M1(CAT:TESU)	3	3-4	4	4-5	4	4-5	4	4-5	3	4-5	4-5	4
M2(CAT:MJ)	4	4-5	4	4-5	4	4-5	4	4-5	3	4	5	4-5
M3(CAT:BL)	3	3-4	3-4	4	3	3-4	3-4	4	2-3	3-4	4-5	4
M4(CAT:RSW)	4	4-5	4	4-5	4	4-5	4	4-5	3	4	5	4-5
M5(CAT:PGR)	3	3-4	3-4	4-5	3-4	3-4	4	4-5	3	4	5	4-5
For 25:75 Proportion												
M1(CAT:TESU)	3-4	3-4	3-4	4	3-4	4	4	4-5	3	4-5	4-5	4
M2(CAT:MJ)	3	2-3	3-4	4	4	4-5	4-5	5	2-3	3	5	4-5
M3(CAT:BL)	2-3	3	3	3-4	3	3-4	3-4	4	2-3	3	4-5	4
M4(CAT:RSW)	4	4-5	4	4-5	4	4-5	4	4-5	3	4	5	4-5
M5(CAT:PGR)	3	3-4	3-4	4	3	3-4	4	4-5	3	3-4	4-5	4

CTAB-n-cety1 trimethyl ammonium bromide, Ben-benztrizole, LOD-loss of depth of shade,
ST – staining on adjacent bleached jute.

3.3. Compatibility Tests

Selected pairs of binary mixture ofnatural dyes taken in different proportion vary considerably in their response to shade depth and colour differences parameters including CDI values for dyeing under comparable conditions. A given pair of dyes may exhibit compatibility under one set of dyeing conditions but may be prove to be incompatible under another set of conditions of dyeing. Regular build-up of the individual dye on a particular fibre or fabric dose not always guarantee similar behaviour when applied together. One conventional method and one newer method of test for compatibility of selected binary pairs of dyes have been used in the present work. In the conventional method, the similarity and closeness and degree of overlap have been compared between two sets of curves in the plots ΔC vs ΔL or K/S vs ΔL for two sets of dyeing results of progressive depth of shade [12-14,] produced using the Set I (by varying time and temperature profile) and Set II (by varying dye concentrations) dyeing methods. Corresponding data for Set-I and SET-II dyeing results of K/S values and colour difference parameters like ΔE, ΔL, Δa, Δb, ΔC, ΔH, BI, MI, and CDIare shown below in Tables 5A to 9A for SET-I dyeing conditions for five different selected pair of binary mixture of Natural dyes (in 50:50 proportions) and in Tables 5B to 9B for SET-II dyeing conditions for the same Five different selected pair of binary mixture of Natural dyes (in 50:50 proportions). The Standard methods [22] of CIE-Lab Colour measurement for determining K/S, ΔE, ΔL, Δa, Δb, ΔC, ΔH, BI, MI, are followed and CDI values are calculated as per newer method reported from this laboratory in earlier literature [12-14].

Table 5A. *Data for Build upof Progressive shade with Variation of Time and Temperature profile for 50: 50 Mixture of total 30% application of CAT + TESU binary mixture of natural dyes for study of compatibilty. (SET-I) [30% Shade of Cat + Tesu (50:50) Temp. 50ºC to Gradually - 10ºC increase in Time 10 Min., Measurement of colour data at604 nm λ_{max} for catechu extract.].*

Temp Profile	Time Profile	K/S	ΔE	ΔL	Δa	Δb	ΔC	ΔH	BI	MI	CDI
Bleached Jute		**5.62**	-	-	-	-	-	-	**48.04**	-	-
50 ºC	10 min	1.39	10.72	-1.65	1.02	10.54	7.86	7.09	6.25	1.93	5.01
60 ºC	20 min	1.88	8.66	-1.57	1.80	8.32	6.61	5.26	5.50	1.91	3.60
70 ºC	30 min	1.80	10.19	-1.90	2.90	9.58	8.36	5.50	5.16	2.36	2.84
80ºC	40 min	1.81	6.91	-1.53	1.60	6.55	5.29	4.18	6.45	1.68	3.25
90ºC	50 min	1.96	8.38	-2.08	3.45	7.36	7.19	3.18	5.32	2.31	1.60
100 ºC	60 min	1.22	7.69	-1.55	8.83	7.49	5.41	5.24	8.59	1.58	4.71

Table 5B. *Data for Build upof Progressive shade with Variation of Dye Concentration profile for 50: 50 Mixture of 10% to -50% application of CAT + TESU binary mixture of natural dyes for study of compatibilty.(SET-II)[10 to 50 % Shade for Cat + Tesu (50:50) and Temp. 90°C, Time 60 Min., Measurement of colourdata at604 nm λ_{max} for catechu extract.].*

Dye Concn (%)	Time Profile	K/S	ΔE	ΔL	Δa	ΔB	ΔC	ΔH	BI	MI	CDI
Bleached Jute		**6.52**	-	-	-	-	-	-	**48.04**	-	
10	60 min	0.81	9.97	-0.60	-2.67	9.59	4.94	8.64	11.66	1.35	12.9
20	60 min	1.08	10.59	-1.26	-0.36	10.50	6.99	7.84	8.23	1.59	7.47
30	60 min	1.63	6.93	-1.48	1.37	6.62	5.18	4.35	6.93	1.66	3.50
40	60 min	2.95	5.68	-1.57	2.56	4.85	4.85	2.51	4.49	1.64	1.79
50	60 min	3.49	4.39	-1.21	2.05	3.69	3.77	1.90	4.26	1.28	1.73

Table 6A. *Data for Build upof Progressive shade with Variation of Time and Temperature profile for %0: 50 Mixture of total 30% application of CAT + BL binary mixture of natural dyesfor study of compatibilty (SET-I). [30% Shade for Cat + BL (50:50) Temp. 50℃ to Gradually - 10°C increase in Time 10 Min., Measurement of colour data at604 nm λ_{max} for catechu extract.].*

Temp Profile	Time Profile	K/S	ΔE	ΔL	ΔA	ΔB	ΔC	ΔH	BI	MI	CDI
50 ºC	10 min	1.94	5.57	-0.97	0.53	5.54	3.76	3.99	6.79	1.25	4.73
60 ºC	20 min	2.65	5.76	-1.57	3.20	4.52	5.19	1.93	5.11	1.83	1.17
70 ºC	30 min	1.68	5.80	-1.33	1.44	5.46	4.43	3.50	7.58	1.50	3.05
80ºC	40 min	1.68	4.73	-0.95	0.86	4.55	3.39	3.15	7.86	1.32	3.32
90ºC	50 min	2.39	4.18	-0.93	1.13	3.91	3.18	2.54	6.22	1.21	2.75
100 ºC	60 min	2.12	3.52	-0.61	-0.22	3.45	1.85	2.92	7.21	0.88	6.31

Table 6B. *Data for Build upof Progressive shade with Variation of Dye Concentration profile for 50: 50 Mixture of 10% to -50% application of CAT + BL binary mixture of natural dyes for study of compatibility(Set-II). [10 to 50 % Shade for Cat + BL (50:50) and Temp. 90°C, Time 60 Min., Measurement of colourdata at604 nm λ_{max} for catechu extract.].*

Dye Concn (%)	Time Profile	K/S	ΔE	ΔL	Δa	ΔB	ΔC	ΔH	BI	MI	CDI
10	60 min	7.24	0.01	-3.51	6.33	1.77	7.02	16.75	1.96	14.60	0.68
20	60 min	4.56	-0.62	-0.44	4.50	2.39	3.83	9.40	1.10	6.64	1.45
30	60 min	3.79	-0.82	0.84	3.61	2.77	2.45	6.65	1.14	2.94	2.21
40	60 min	3.14	-0.78	0.80	2.94	2.32	1.97	5.16	0.94	2.84	2.98
50	60 min	3.39	-1.19	2.20	2.28	3.08	0.75	4.73	1.28	0.64	3.37

Table 7A. *Data for Build upof Progressive shade with Variation of Time and Temperature profile for %0: 50 Mixture of total 30% application of CAT + MJ binary mixture of natural dyesfor study of compatibilty(SET-I). [30% Shade ofCat + MJ (50:50) Temp. 50℃ to Gradually - 10°C increase in Time 10 Min., Measurement of colour data at604 nm λ_{max} for catechu extract.].*

Temp Profile	Time Profile	K/S	ΔE	ΔL	ΔA	ΔB	ΔC	ΔH	BI	MI	CDI
50 ºC	10 min	1.15	8.70	-2.40	3.74	7.48	7.49	3.72	8.56	2.58	1.67
60 ºC	20 min	1.54	9.08	-2.46	4.78	7.32	8.17	3.10	6.62	2.77	1.24
70 ºC	30 min	1.27	6.33	-1.60	2.10	5.57	5.11	3.36	9.13	1.73	2.40
80ºC	40 min	1.44	7.39	-2.33	4.19	5.62	6.65	2.23	7.49	2.65	0.93
90ºC	50 min	1.05	8.07	-2.65	4.42	6.21	7.19	2.54	9.50	2.75	1.04
100 ºC	60 min	1.17	6.93	-2.37	3.39	5.55	5.98	2.58	9.30	2.27	1.32

Table 7B. *Data for Build upof Progressive shade with Variation of Dye Concentration profile for 50: 50 Mixture of 10% to -50% application of CAT + MJ binary mixture of natural dyes for study of compatibilty(Set-II). [10 to 50 % Shade for Cat + MJ (50:50) and Temp. 90°C, Time 60 Min., Measurement of colourdata at604 nm λ_{max} for catechu extract.].*

Dye Concn (%)	Time Profile	K/S	ΔE	ΔL	Δa	ΔB	ΔC	ΔH	BI	MI	CDI
10	60 min	6.76	-1.38	0.08	6.62	4.27	5.06	15.10	1.14	7.02	0.67
20	60 min	7.14	-1.79	1.98	6.63	5.62	4.03	8.04	1.83	2.80	1.36
30	60 min	7.64	-2.35	3.52	6.36	6.59	3.07	8.03	2.41	1.47	1.31
40	60 min	5.79	-1.99	3.32	4.30	5.16	1.71	6.01	2.13	0.90	2.15
50	60 min	2.68	-1.06	1.70	1.77	2.39	0.59	3.90	1.01	0.66	4.12

Table 8A. *Data for Build upof Progressive shade with Variation of Time and Temperature profile for %0: 50 Mixture of total 30% application of CAT + RSW binary mixture of natural dyesfor study of compatibilty(SET-I). [30% Shade of Cat + RSW(50:50) Temp. 50℃ to Gradually - 10°C increase in Time 10 Min., Measurement of colour data at604 nm λ_{max} for catechu extract.].*

Temp Profile	Time Profile	K/S	ΔE	ΔL	ΔA	ΔB	ΔC	ΔH	BI	MI	CDI
50 ºC	10 min	1.37	8.52	-2.07	3.37	7.54	7.26	3.94	7.43	2.37	1.95
60 ºC	20 min	1.34	8.72	-2.44	4.00	7.35	7.60	3.50	7.49	2.65	1.51
70 ºC	30 min	1.81	7.43	-2.09	3.86	5.99	6.62	2.65	6.35	2.34	1.27
80ºC	40 min	1.13	7.91	-2.59	4.32	6.10	7.04	2.50	9.1	2.71	1.03
90ºC	50 min	1.29	8.84	-2.85	4.96	6.74	7.94	2.64	7.85	2.91	1.01
100 ºC	60 min	2.84	5.07	-0.77	-0.18	5.00	2.93	4.06	5.06	0.82	8.56

Table 8B. *Data for Build upof Progressive shade with Variation of Dye Concentration profile for 50: 50 Mixture of 10% to -50% application of CAT + RSW binary mixture of natural dyes for study of compatibility (SET-II). [10 to 50 % Shade for Cat + RSW (50:50) and Temp. 90ºC, Time 60 Min., Measurement of colourdata at604 nm λ_{max} for catechu extract.].*

Dye Concn (%)	Time Profile	K/S	ΔE	ΔL	Δa	ΔB	ΔC	ΔH	BI	MI	CDI
10	60 min	7.45	-1.98	1.91	6.93	5.77	4.28	12.41	1.66	3.33	0.80
20	60 min	6.56	-1.67	1.04	6.25	4.68	4.27	10.82	1.50	3.99	1.00
30	60 min	6.90	-2.27	3.26	5.65	5.93	2.70	8.32	2.28	1.38	1.35
40	60 min	3.97	-1.37	2.33	2.90	3.54	1.17	5.60	1.57	0.83	2.60
50	60 min	4.03	-1.30	2.52	2.86	3.67	1.04	4.30	1.45	0.79	3.51

Table 9A. *Data for Build upof Progressive shade with Variation of Time and Temperature profile for %0: 50 Mixture of total 30% application of CAT + PGR binary mixture of natural dyesfor study of compatibility (SET-I). [30% Shade Cat + PGR (50:50) Temp. 50℃ to Gradually - 10ºC increase in Time 10 Min., Measurement of colour data at604 nm λ_{max} for catechu extract.].*

Temp Profile	Time Profile	K/S	ΔE	ΔL	ΔA	ΔB	ΔC	ΔH	BI	MI	CDI
50 ºC	10 min	1.50	9.86	-0.93	-0.89	9.77	6.09	7.69	6.78	1.52	8.19
60 ºC	20 min	1.91	8.55	-1.56	1.34	8.30	6.36	5.50	5.61	1.66	4.45
70 ºC	30 min	2.37	7.07	-1.03	0.20	6.99	4.62	5.24	5.29	1.21	6.63
80ºC	40 min	2.19	7.09	-1.22	0.65	6.96	4.91	4.97	5.39	1.37	5.24
90ºC	50 min	2.65	6.61	-1.55	1.77	6.17	5.16	3.83	4.87	1.45	3.38
100 ºC	60 min	1.37	6.24	-2.10	2.57	5.28	5.16	2.79	8.43	1.99	1.70

Table 9B. *Data for Build upof Progressive shade with Variation of Dye Concentration profile for 50: 50 Mixture of 10% to -50% application of CAT + PGR binary mixture of natural dyes for study of compatibility (SET-II). [10 to 50 % Shade for Cat + PGR (50:50) and Temp. 90ºC, Time 60 Min., Measurement of colourdata at604 nm λ_{max} for catechu extract.].*

Dye Concn (%)	Time Profile	K/S	ΔE	ΔL	Δa	ΔB	ΔC	ΔH	BI	MI	CDI
10	60 min	5.75	-0.58	-1.09	5.61	2.73	5.02	9.33	1.21	8.74	1.41
20	60 min	5.35	-0.13	-2.20	4.88	1.45	5.15	6.62	0.88	21.60	2.23
30	60 min	6.99	-0.36	-1.89	6.73	3.06	6.28	5.32	0.94	15.26	2.47
40	60 min	5.98	-1.18	1.14	5.75	4.41	3.87	4.15	1.17	4.48	3.19
50	60 min	6.13	-1.45	2.04	5.59	4.97	3.28	3.98	1.57	2.57	3.28

The above data for K/S vs ΔL and ΔC vs ΔL for each pair of five different pairs of binary mixture of natural dyes taken were plotted and are shown here as Fig 10 as the plots of K/S vs ΔL (plots a – e) and ΔC vs ΔL (plots a' – e') for two sets (Set I and Set II) of dyed materials for five separate pairs (M1-M5) of natural dyes.

In the conventional method, the plots of K/S vs ΔL and ΔC vs ΔL for each pair binary mixture of natural dye, the similarity and closeness and degree of overlap have been assesed between two sets of curves in the plots ΔC vs ΔL or K/S vs ΔL for two sets of dyeing results of progressive depth of shade produced using the Set I (by varying time and temperature profile) and Set II (by varying dye concentrations) dyeing methods and higher the closeness or similarity in pattern /path of progressive shade build up, higher is the compatibility between that two individual natural dye of that particular pair.

Accordingly from the two sets of plots of Fig. 10 (a-e & a' –e'), for plots K/S vs ΔL and ΔC vs ΔL for each pair of selected binary mixture of the natural dyes, it was understood /revealed the subjective results of compatibility by assessing closeness of two sets of plots of both plots K/S vs ΔL and ΔC vs ΔL for each pair of selected binary mixture of the natural dyes.

From Fig. 10 (a & a') and data in Table 5A and 5B, it was therefore revealed from two sets of plots for M1, that the M1 pair (Catechu +Tesu) may be poor i.e less compatible, as the plots of two sets do not flow similarly for bothplots K/S vs ΔL and ΔC vs ΔL:

From Fig. 10(b & b') and data in Table 6A and 6B, it was also understood from two sets of plots for M2, that the M2 pair (catechu +manjishtha) may be partly compatible at medium concentration of dyes or at a particular temp zone, as initially these two sets of plots do not follow same pattern, but for ΔC vs ΔL plots in some zone it follow same pattern partly and hence may be fairly compatible,

From Fig. 10(c & c') and data in Table 7A and 7B, it was also understood from two sets of plots for M3, that M3 pair (Catechu +Babool) may be considered as moderate or average compatible, as in this case also, the two sets of ΔC vs ΔL plots for a considerable part/ zone for M3 follow same pattern partly.

Similarly, from Fig. 10(d & d') and data in Table 8A and 8B, it was also clear from two sets of plots for M4, that M4 pair (Catechu +Red Sandal wood) may be considered as moderate to good compatible, as both the two sets of plots K/S vs ΔL and ΔC vs ΔL follow a similar pattern except a very small zone of initial part or end part, and hence may be moderate or good compatible.

Also from Fig. 10(e & e')and data in Table 9A and 9B, it was revealed from two sets of plots for M5, that the M5 pair (Catechu +Pomogrenate Rind) may be Very poor or worst compatible, as the plots of two sets do not flow any similarly for bothplots K/S vs ΔL and ΔC vs ΔL:

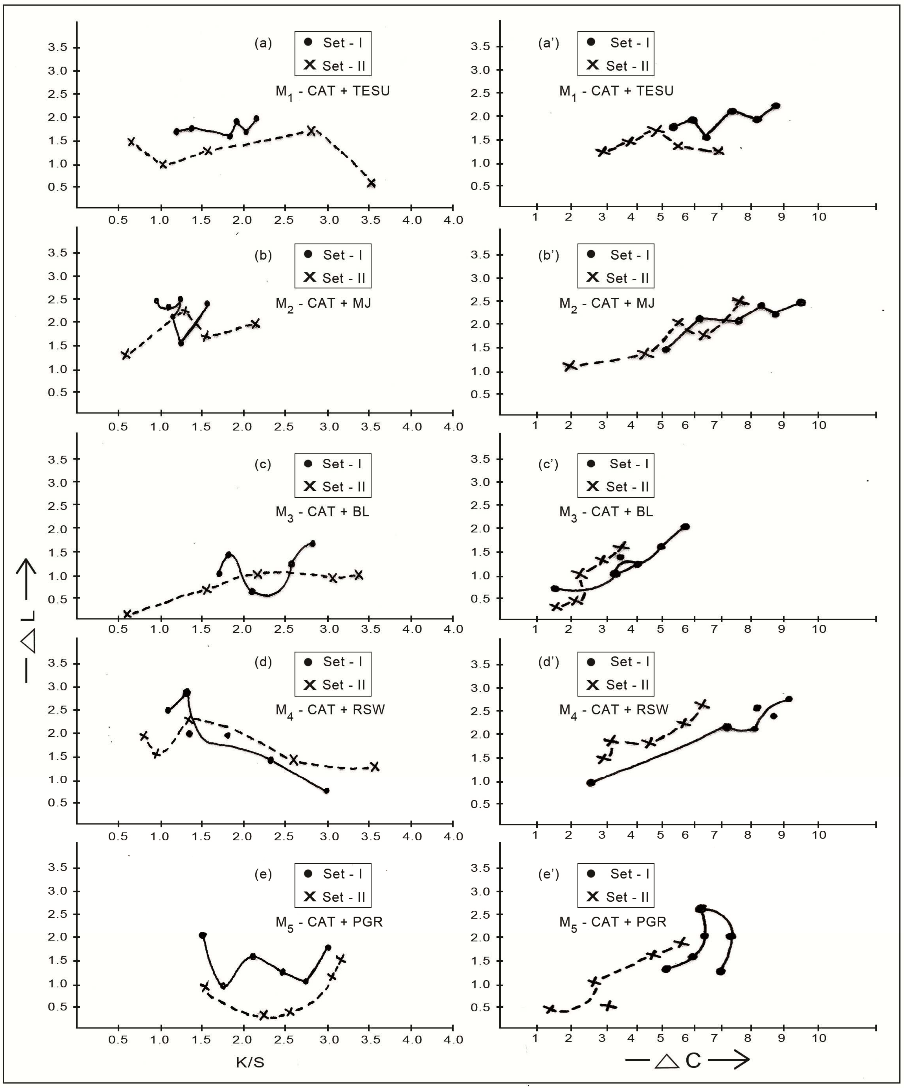


Fig. 10. *a-e & a'–e': Plots of K/S vs ΔL and ΔC vs ΔL for each pair of selected binary mixtures of natural dyes applied under two different sets of variation- Set I – Variation of time and temperature profile and Set II- variation of dye concentration for progressive shade build-upfor Study of compatibility in conventional method.*

As this process of finding compatibility by the above method involved in separate dyeing of two sets with variation of temperature and time profile in one set and variation of dye concentration in another set and then measurement of required colour parameters for plotting of two sets for K/S vs ΔL and ΔC vs ΔL and then finally assessing closeness of two sets of curves from those plots for each pair of dyes taken for subjective assessing of degree of compatibility by this conventional method. This conventional method being too lengthy and need lot of time to arrive at decision. Hence,it was felt highly essential to test the compatibility of different pairs of natural dyes by some easy process and also form of quantitative term expressed as relative compatibility rating for the selective pair of natural dyes, that will help the dyers and Lab chemists by providing some easy options for selecting dyes to match a target shade. Therefore, an easy method of determining relative compatibility rating between any pair of natural dyes has been proposed by postulating a new colour difference index method as mentioned in material and method, chapter -3, sub-section no 3.3.9 and also mentioned in introductionpart of the present section briefly.

The said newer method of assessing compatibility test of selected pair of natural dyes is based on assessing the closeness of the CDI values for dyeing selective textile substrate with different proportions (75:25, 50:50, 25:75) of the binary mixture of selective pair of natural dyes under the same dyeing conditions, where, the higher is the closeness of CDI values (Comparing the difference between highest CDI value and other CDI values for dyeing of different proportions i.e75:25, 50:50, 25:75 ratio of the binary mixture of selective pair of natural dyes, higher or better is the compatibility rating for that pair of dyes.

For the present cases of assessing compatibility for M1 to M5 pairs of natural dyes by the proposed newer and simpler method, the relative compatability rating (RCR) in quantitative grading from 0-5,is shown in Table-10. Finally, to test the degree of fitness of this proposed newer method, the results of the compatibility obtained by the two methods (conventional and proposed newer method) have compared and analyzed below.

Table 10. *Colour difference index (CDI) for dyeing of different proportion of Binary mixture of natural dyes and Relative Compatibility Rating (RCR) for application of selected binary pairs of natural dyes on double pre-mordanted jute fabrics.*

Dye combination	CDI			Difference between highest CDI and Individual CDI			Highest Diff in CDI	RCR	Compa-tibility grade
	75:25a	50:50a	25:75a	75:25a	50:50a	25:75a			
M1(CAT:TESU)	2.73	4.89	5.14	2.41	0.25	-	2.41	2	Poor
M2(CAT:MJ)	4.13	4.11	3.42	-	0.02	0.71	0.71	2-3	Fair
M3(CAT:BL)	4.31	5.58	5.37	1.27	-	0.21	1.27	2	Poor
M4(CAT:RSW)	2.42	2.13	2.43	0.01	0.30	-	0.30	3-4	Moderate
M5(CAT:PGR)	2.38	2.05	7.71	5.33	5.66	-		1-2	Very Poor

[a] Proportion of binary pair of dyes.

In case of binary pair M1 (CAT+TESU),two sets of plots for Set-I and Set-II for K/S vs ΔL and ΔC vs ΔL plots show that the two curves for Sets I and Set II do not run similarly and show wide separation, and do not approach one another indicating fair to poor compatibilty. In the proposed Newer RCR system of compatibility test, the M1 pair of dyes exhibitGrade 2 (Poor) relative compatibility rating (Table 10), showing similarity between the compatibility grade assessed by this newer method and the assessment of compatibility of this M1 pair of dyes from the K/S vs ΔL and ΔC vs ΔLplots as per conventional method. Thus the compatibility test results by these two methods are well in agreement.

Similarly, in case of binary pair M2 (CAT+MJ), the two curves for Sets I and II do not show similar build-up behaviour in both the plots (b and b') initially for these two sets of plots do not follow same pattern,but for ΔC vs ΔL plots in some particular zone it follow same pattern partly and hence may be Fairly to Moderate compatible, as per conventional method of compatibility test. In the proposed Newer RCR system of compatibility test, this M2 binary pair of dyes also exhibits Grade 2-3 (Fair) relative compatibility rating (Table 10). Thus, in this case also, the conventional and the proposed methods show very similar results.

In case of binary pair M3 (CAT+BL), the plots K/S vs ΔL show that the two curves for Sets I and II do not overlap or run similarly showing worst compatible, but for ΔC vs ΔL plots, it follow similar pattern partially in some zone it follow other pattern initially,showing fair compatible and hence may be worst to poor tofairly compatible, indicating a low degree (fair to poor) of compatibility between these dyesi.e finally poor compatible, as per conventional method of compatibility test. While, in the proposed newer RCR system of compatibility test, this M3 binary pair of dyes exhibits Grade 2 (Fair) relative compatibility rating (Table 10). In this case also the results of compatibility test by two different methods are similar.

In case of binary pair M4 (CAT+RSW), the two sets of plots K/S vs ΔL and ΔC vs ΔL show that the two curves for Sets I and II both follow a similar pattern except a very small zone of initial part or end part partially with only slight deviation, indicating a moderate to good compatibility, as per conventional method of compatibility test. The same M4 pair of dyes, as per the newer proposed RCR method of compatibility test, exhibits Grade 3-4 (moderate) relative compatibility rating (Table 10). So, The Results of compatibility test by the two different method are found to be similar.

In case of binary pair M5 (CAT:PGR), the two curves for Sets I and II of plots K/S vs ΔL and ΔC vs ΔL, in both the plots show a wide separation without any systematic build-up behavior with either increasing concentrations of dyes (Set II) or increasing dyeing time and temperature profile (Set I) where these plots of two sets do not flow similarly. Thus, these two dyes are found to be totally incompatible with one anotheri,e Very poor to worst compatible. Also. in the proposed newer RCR system of compatibility test, this M5 pair exhibits the Grade 1-2 (Very Poor compatible) relative comparibility rating (Table 10). Thus, in this case also, results of compatibility test by the two different methods are found to be matching with each other.

Thus it is indicated that compatibility of test can also be assessed by proposed Newer RCR methods successfully, indicating a good degree of agreement between results of compatibility test by these two methods and thus the results of compatibility test obtained by both the methods (Conventional method and newer RCR method) are expected to match. Hence this RCR method of compatibility test gives option to eliminate the separate dyeing for progressive shade build up under variation of two different types of dyeing process parameters in conventional method and also eliminate further need of plotting two sets of curves for Sets I and II for plotingK/S vs ΔL and ΔC vs ΔL, for two sets of variations. Moreover, this RCR method render a quantitative grade of compatibility between 0-5, while the results of compatibility test in conventional method is fully subjective only.

4. Conclusions

The followings may therefore be concluded from the present study:

It is found that the difference (D1) in the observed and calculated K/S values are minimum for CATECHU +BABOOL irrespective of sign. The order of increase in the differences (D1) between the observed and calculated *K/S* for the various pairs of dyes applied are as follows irrespective of sign:

CAT+BL <CAT+TESU < CAT+PGR <CAT+MJ<CAT +RSW

This indicate that the order of increase of observed and calculated *K/S* values for the various pairs of dyes applied lead to Dye uniformity in the same order for combined mixture dyeing for compound shade.

The order of increasing differences between the two sets of observed *K/S* values at two different λ_{max} values for each pair of natural dyes for different mixture of dyes used are as given below:

CAT+BL < CAT+MJ <CAT +RSW < CAT+PGR < CAT+TESU

This indicate that order of increasing differences between the two sets of observed *K/S* values at two different λ_{max} values for each pair of natural dyes lead to the Metamerism index in the same order for combined mixture dyeing for compound shade.

The Colour difference index (i.e. CDI value) are found to be in the following increasing order

CAT+PGR < CAT +RSW <CAT+TESU < CAT+MJ < CAT+BL, indicating the overall dyeing non-uniformity with variation of brightness and metamerism leading to higher shade depth in the same order for combined mixture dyeing for compound shade.

This is observed that with decrease in catechu concentration, for all selected pair of mixture of natural dyes taken, the colour fastness to washing is found to be reduced to a marginal scale i.e. ½ unit to 1 unit. It is also found that whenever Red Sandal Wood is used in the combination of binary mixture i.e. for CAT + RSW, the overall washing and other fastness properties are overall better and is about ½ to 1 unit higher than any other combination irrespective of the proportions of mixtures for different pairs of dyes used to produce combine shades. Thus presence of higher amount of Catechu or any amount of RSW show up higher or better colour fastness to washing or light than others may be due to higher mordanting power of both Catechu and RSW due to more number of adjacent ortho -OH groups present in colour component of these two dyes. It is also mentioned worthy that post treatment of these dyed fabrics with any one of the three cationic dye fixing agents used here, lead to improvement of the wash fastness and treatment with Benztriazole also improves light fastness grade to almost ½ unit or more for all the pairs of dyes used.

Both dry and wet rubbing fastness are found to be very good i.e. 4 or 4-5 and hence no after treatment / post treatment was found necessary.

It is indicated that compatibility test by two different methods (conventional method of ploting K/S vs ΔL and ΔC vs ΔL for two sets of variations for progressive shade build up for Binary pairs of dyes and Newer RCR method) show a good degree of agreement between results of compatibility test by these two methods as shown in Table 11 below:

Table 11. *Final Compatibility Results by newer method of Relative Compatibility Rating.*

Dye combination	Compatibility result as per Conventional method of plotting of two sets for K/S vs ΔL and ΔC vs ΔL	Relative Compatibility rating (RCR) as per Newer CDI method	Final Compatibility Results
M1(CAT:TESU)	Fair to Poor	2	Poor
M2(CAT:MJ)	Fair to Moderate	2-3	Fair
M3(CAT:BL)	Poor to Fair	2	Poor
M4(CAT:RSW)	Moderate to Good	3-4	Moderate
M5(CAT:PGR)	Very Poor to Worst	1-2	Very Poor

*As per plots of two sets for K/S vs ΔL and ΔC vs ΔL and then finally assessing closeness of two sets of curves from those plots.

Hence, the said newer RCR method of compatibility test gives option to eliminate the separate dyeing for progressive shade build up under variation of two different types of dyeing process parameters in conventional method and also eliminate further need of plotting two sets of curves for Sets I and II for plottingK/S vs ΔL and ΔC vs ΔL, for two sets of variations. Moreover, this RCR method render a quantitative grade of compatibility between 0-5, while the results of compatibility test in conventional method is fully subjective only.

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