CHAPTER IV

RESULTS AND DISCUSSION

The research was aimed at exploring suitable pre-treatments for obtaining improved dyeing properties of jute using natural dyes. Two sources of natural dyes i.e. root and leaves were purposively selected for the study. The root sources were Turmeric and Madder while the leave sources were Eucalyptus Leaves and Indian Almond leaves. The results of the above investigations are discussed under the following heads.

4.1 Specifications of the fabric

Table 4.1: Results of physical properties of the standard sample

Sr. No.	Testing Properties		Standard Sample
1.	Count (warp/weft)		30/15
2.	GSM		632.33 gms/sqmt
3.	Absorbency		23 sec
4.	Weight loss after scouring		5%
5.	Bending Length (Stiffness)	Warpwise	3.8 cm
		Weftwise	4.03 cm
6.	Tensile Strength		
	Maximum Load	Warpwise	226.05 kg
		Weftwise	137.58 kg

	Maximum Extension	Warpwise	33.44 mm
		Weftwise	20.79 mm
	Breaking Load	Warpwise	182.64 kg
		Weftwise	107.65 kg
	Breaking Extension	Warpwise	33.47 mm
		Weftwise	23.51 mm
7.	Whiteness Index		37.7
8.	Yellowness Index		51.8

4.2 Phase- I: Pilot work

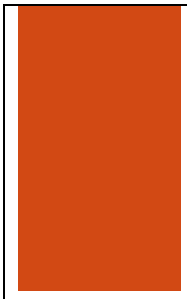
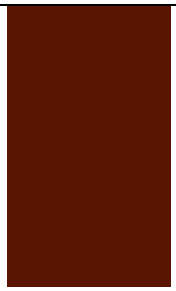
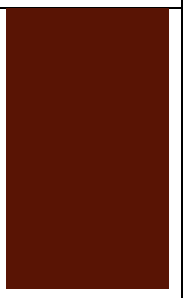
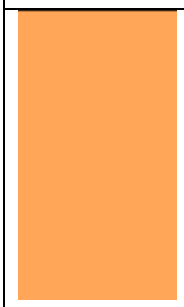
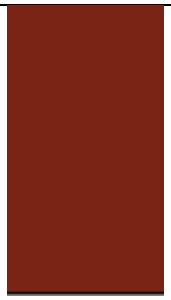
Mordants and bleaching agents play a key role in natural dyes. Hence, pilot study was carried out to finalize the mordants, mordanting techniques for the selected natural dyes and different bleaching treatments for the study. Four natural dyes namely Madder, Turmeric, Eucalyptus leaves and Indian Almond leaves and three metal mordants – alum, copper sulphate and ferrous sulphate were purposively selected for this study. Colour palatte was developed using these dyes and mordants on the bleached jute fabric. Two aspects were studied: one the shade and extent of colour obtained on jute fabric and second the effect of mordants on dyeability of the jute fabric with selected mordants and dyes.

4.2.1 Development of colour palatte

Colour palatte was developed using four natural dyes and mordants on the bleached jute fabric. The number of shades developed for samples bleached with three bleaching agents namely sodium hypochlorite, hydrogen peroxide and peracetic acid were 72 (four dyes, three mordants, three bleaching agents and two mordanting techniques). The colour ranged from bright yellow to dark brown for turmeric, maroon to dark coffee for madder, olive green to dirty dark green and dark grey for eucalyptus and Indian almond leaves.

- Plate 4.1 indicates the shades obtained from Madder dye
- Plate 4.2 indicates the shades obtained from Turmeric dye
- Plate 4.3 indicates the shades obtained from Eucalyptus leaves dye
- Plate 4.4 indicates the shades obtained from Indian Almond leaves dye

I) Madder Dye

					
Alum pre	Alum post	Cu pre	Cu post	Fe pre	Fe post
Bleaching Agent- Sodium Hypochloride					
					
Alum pre	Alum post	Cu pre	Cu post	Fe pre	Fe post
Bleaching Agent- Hydrogen Peroxide					
					
Alum pre	Alum post	Cu pre	Cu post	Fe pre	Fe post
Bleaching Agent- Peracetic Acid					

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

Plate 4.1: Shades of Madder on Jute bleached with three bleaching agents using pre-mordanting and post mordanting techniques

DL^*, Da^*, Db^*, Dc^* and K/S show the colour property indices of the dyed samples pre-bleached with different bleaching agents. Colours obtained from madder dye ranged

from light coffee colour to brown to dark brown colour which is shown in Plate 4.1. Tables 4.2, 4.3 and 4.4 show the results of colour parameters for shades obtained from madder dye using three mordants viz alum, copper sulphate and ferrous sulphate for the sample bleached with sodium hypochlorite, hydrogen peroxide and peracetic acid.

Table 4.2: Colour Parameters for sample dyed with Madder using Alum as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	11.4	10.7	8.5	13.1	18.7	18.6
Da^*	6.9	4.0	2.8	7.9	8.1	0.9
Db^*	13.6	7.7	7.2	12.2	11.4	11.4
Dc^*	13.0	7.7	6.5	13.6	13.2	6.9
K/S	9.3	9.0	10.3	10.3	9.3	9.0

Note: Pr- Samples pre-mordanted with alum,
Po- Samples post mordanted with alum,

It was observed from the DL^* values (Table 4.2) that the high score in terms of luminance, the samples were light in shade. This was also supported by the fact that the K/S values of all samples ranged from 9.0 to 10.4. The Da^* and Db^* values indicates that the colour obtained ranged in between red and blue. The sample bleached with peracetic acid pre-mordanted with alum showed the brightest sample. Among the three bleaching agents, the highest DL^* value and K/S was obtained for peracetic acid, followed by hydrogen peroxide and sodium hypochlorite indicating that peracetic bleached samples were best amongst the three.

Table 4.3: Colour Parameters for sample dyed with Madder using Copper Sulphate as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	14.5	10.4	8.5	13.6	0.7	0.5
Da^*	0.7	-8.8	2.8	7.9	0.4	-3.3
Db^*	11.4	15.2	7.2	12.2	2.1	-2.8
Dc^*	8.3	5.5	6.5	13.6	1.7	-4.3
K/S	7.6	5.8	7.6	8.0	8.2	8.6

Note: Pr- Samples pre-mordanted with copper sulphate,
Po- Samples post mordanted with copper sulphate

Table 4.3 showed that all the DL^* values were positive which indicated high luminance. High luminance means light in shade. Luminance is inversely proportion

to the shade. Thus the samples obtained were of lighter shade. The positive Da^* values indicated that the samples were more redder except for the samples bleached with peracetic acid and sodium hypochlorite post mordanted with copper sulphate. The K/S values ranged between 5.8 to 8.6 indicated that the colour yield was brighter. The highest K/S was observed for peracetic acid bleached sample dyed using post mordanting technique (8.6), followed by peracetic acid bleached sample dyed using pre-mordanting technique (8.2). The least K/S value was observed in post mordanted sample bleached with sodium hypochlorite dyed using post mordanting technique (5.8). Thus colours obtained were light and brighter in shade.

Table 4.4: Colour Parameters for sample dyed with Madder using Ferrous Sulphate as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	-7.2	-4.6	8.5	13.2	2.8	-4.1
Da^*	3.8	-18.5	2.7	7.8	-1.1	-12.2
Db^*	0.9	0.4	7.2	12.1	0.1	-8.9
Dc^*	3.6	-12.2	6.8	13.2	-0.8	-15.2
K/S	7.5	6.4	7.6	7.9	7.5	8.2

Note: Pr- Samples pre-mordanted with ferrous sulphate and
Po- Samples post mordanted with ferrous sulphate

It was seen from the Table 4.4 that the readings of all the samples mordanted with ferrous sulphate were positive except for post mordanted sample bleached with peracetic acid and pre and post mordanted samples bleached with sodium hypochlorite, concluding that the samples were dark and dull in appearance. The positive Da*and Db* values of the samples indicates that the samples were redder in colour except for the post mordanted sample of peracetic acid which showed negative value of Da*and Db* indicating that the samples were greenish-blue in colour. The highest K/S value among all the samples was observed in post mordanted sample of peracetic acid and the lowest K/S value in post mordanted sample bleached with sodium hypochlorite.

Tables 4.5, 4.6, 4.7 gives values for the effect of various mordants for bleaching agents used during the dyeing process of jute with madder dyes. Tables 4.5, 4.6, 4.7 and Graphs 4.1, 4.2, and 4.3 shows the data regarding the reflectance values obtained from the spectrophotometric analysis of jute sample dyed with madder dye mordanted

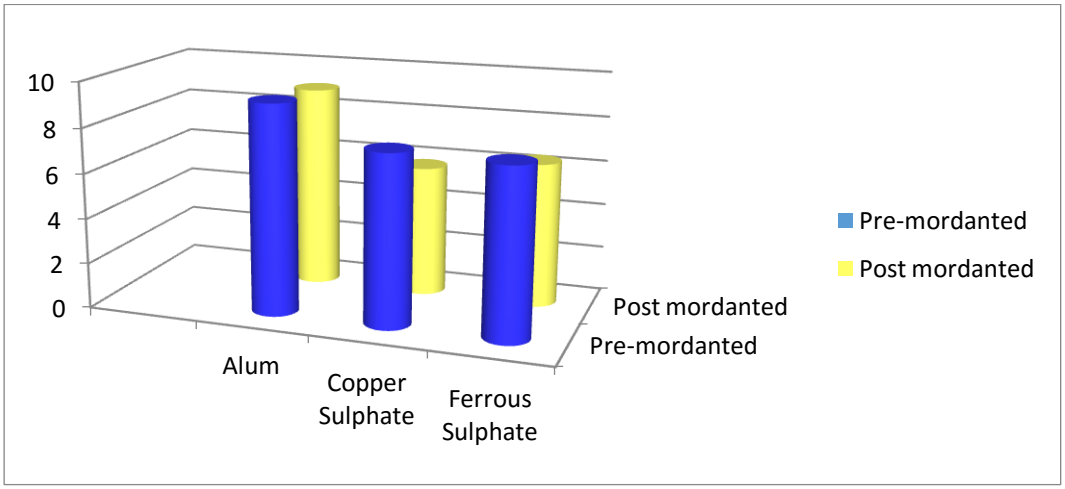
with alum, copper sulphate and ferrous sulphate for bleaching agent namely sodium hypochlorite, hydrogen peroxide and peracetic acid respectively.

Table 4.5: Colour Parameters of samples bleached with Sodium Hypochlorite dyed with Madder using different mordants

Colour Parameters	Samples bleached with NaOCl					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL*	11.4	10.7	10.5	10.4	-7.2	-4.5
Da*	6.9	4.0	0.7	-8.8	3.8	-18.4
Db*	13.6	7.7	11.4	15.2	0.9	0.4
Dc*	13.7	7.7	8.3	5.4	3.6	-12.1
K/S	9.3	9.0	7.6	5.8	7.5	6.4

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

The DL* values were positive except for samples mordanted with ferrous sulphate; hence these samples were darker in colour. The samples post mordanted using copper sulphate and ferrous sulphate had negative Da* values indicating the greenish tone of the sample. The Db* values showed high positive value indicating the presence of yellowness. The samples bleached with sodium hypochlorite when dyed in madder showed the highest K/S value in case of alum pre-mordanted (9.3) and post mordanted (9.0) followed by the other two mordants. It was concluded that the colour strength was more in case of alum compared to copper sulphate and ferrous sulphate.



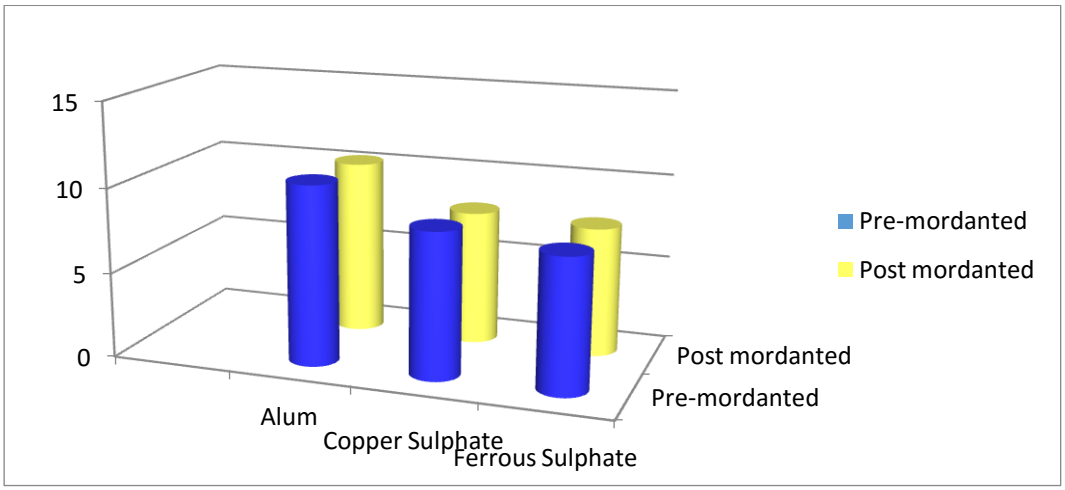
Graph 4.1: K/S values of samples bleached with Sodium Hypochlorite and dyed with madder using different mordants

Table 4.6 Colour Parameters of samples bleached with Hydrogen Peroxide dyed with Madder using different mordants

Colour parameters	Samples bleached with H_2O_2					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL*	8.5	13.1	8.5	13.6	8.5	13.1
Da*	2.8	7.9	2.8	7.9	2.7	7.7
Db*	7.2	12.2	7.2	12.2	7.2	12.1
Dc*	6.4	13.6	6.4	13.6	6.8	13.1
K/S	10.3	10.3	8.6	8.0	7.9	7.6

Note : Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

From the Table 4.6 and graph 4.2, the highest K/S was seen in alum whereas copper sulphate and ferrous sulphate showed almost similar results. The DL* values for the above samples were positive. The positive Da*and Db* values of the samples indicated that the colour obtained ranged in between red and dark brown.



Graph 4.2: K/S values of samples bleached with Hydrogen peroxide and dyed with madder using different mordants

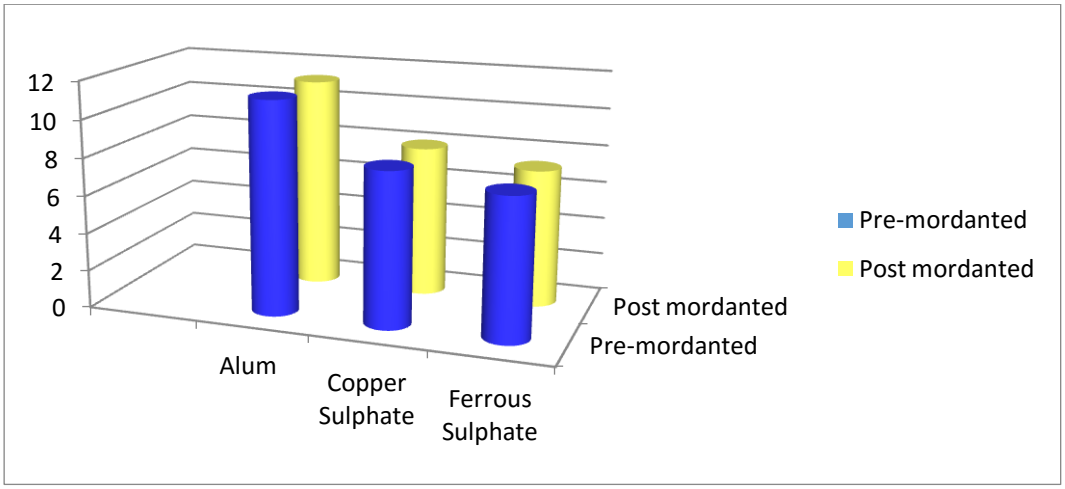
From the table 4.7 it was observed that the DL* values were positive except for post mordanted sample in ferrous sulphate bleached with peracetic acid. The lightest sample was observed in case of post mordanted alum and the darkest sample was of post mordanted ferrous sulphate. In case of peracetic acid bleached samples, most of the Da* values where negative indicating the presence of green in the samples. The Db* values were mostly positive except for post mordanted copper sulphate and ferrous sulphate samples which indicated the blueish tone into it. Alum mordanted

samples (pre and post) showed highest K/S values with readings of 11.3 and 11.2 respectively.

Table 4.7: Colour Parameters of samples bleached with Peracetic Acid dyed with Madder using different mordants

Colour parameters	Samples bleached with CH_3COOH					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	11.7	18.6	0.7	0.5	2.8	-4.0
Da^*	8.1	-0.9	0.4	-3.3	-1.1	-12.2
Db^*	11.4	11.4	2.1	-2.8	0.1	-8.9
Dc^*	13.2	6.8	1.7	-4.3	-0.8	-15.1
K/S	11.3	11.2	8.2	8.0	7.5	7.3

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



Graph 4.3: K/S values of samples bleached with Peracetic acid and dyed with madder using different mordants

Graph 4.3 shows the comparison of pre and post mordanting techniques for the samples bleached with peracetic acid, dyed with madder using different mordants. It was seen from the graph that post mordanting technique resulted higher colour depth compared to the pre mordanting method of mordanting. But the difference was very less. Amongst the three mordants used alum gave highest K/S values. Shades obtained from madder dye using alum ranged from sherbet orange to orangutan orange. Copper sulphate mordanted samples ranged from ginger orange to amber orange and ferrous sulphate mordanted samples ranged between rust to mahogany orange.

II) Turmeric

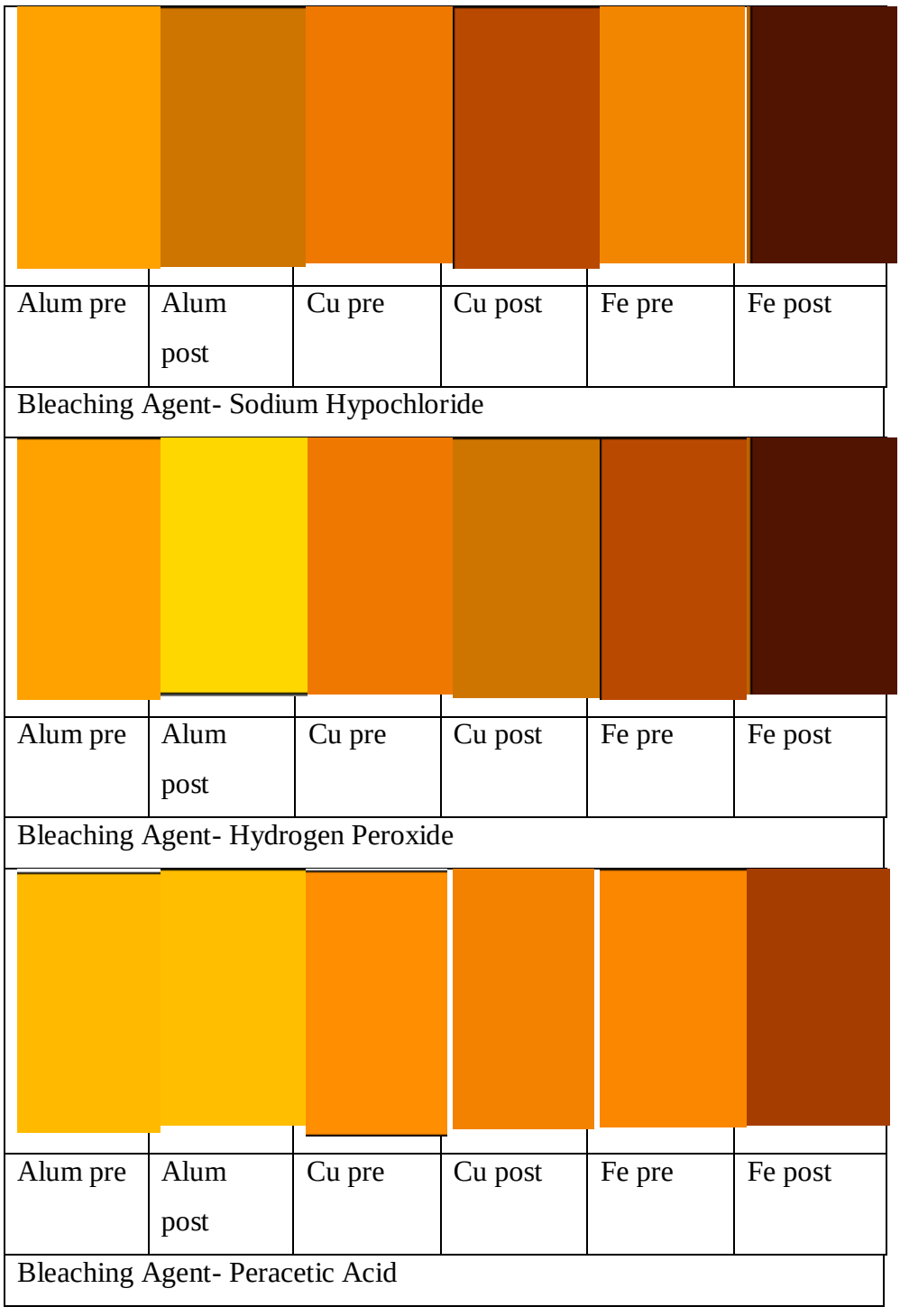


Plate 4.2: Shades of Turmeric on Jute bleached using three Bleaching Agents

Colours obtained for turmeric dye ranged from bright lemon yellow to dark brown colour with yellow ochre and brown as intermediate. It was observed from Plate 4.2

that for the samples dyed using alum of mordant produced lemon yellow colour whereas for samples dyed using copper sulphate produced yellow ochre to brown shade while samples dyed using ferrous sulphate produced dark brown colours. Effect of bleaching agents on mordants was studied. Tables 4.8, 4.9 and 4.10 showed the reflectance of shades obtained from turmeric dye using various mordants for bleaching agents sodium hypochlorite, hydrogen peroxide and peracetic acid.

Table 4.8 Colour Parameters for sample dyed with Turmeric using Alum as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	9.0	8.1	19.4	14.4	11.5	17.4
Da^*	5.0	4.3	4.4	5.5	5.7	4.3
Db^*	16.7	13.3	15.7	24.6	18.5	23.9
Dc^*	17.4	14.0	16.3	25.1	19.4	24.1
K/S	11.5	11.3	12.4	12.3	13.4	13.2

Note: Pr- Samples pre-mordanted with alum and
Po- Samples post mordanted with alum

The colour depth in terms of K/S and colour differences of the bleached samples dyed with turmeric using alum as mordant is shown in Table 4.8. It was observed from the table that the samples bleached with peracetic acid showed the highest value of K/S followed by hydrogen peroxide and sodium hypochlorite. The pre mordanted alum sample bleached with peracetic acid had the highest value (13.4) and the lowest value (11.3) was shown by post mordanted alum bleached with sodium hypochlorite. The DL^* values indicating the lightness and darkness of colour showed that the colours obtained were light as they all had positive values which ranged from 8.1 to 19.4. The positive Da*and Db* values of the samples indicated that the colours were towards yellow with little presence of red into it.

It was observed from Table 4.9 that the K/S values of copper sulphate mordanted samples dyed with turmeric dye ranged from 7.5 to 8.7. The highest K/S was observed in post mordanted sample bleached with peracetic acid while the lowest value was of post mordanted sample bleached with sodium hypochlorite. Also the DL* values showed positive values (27.1 – 6.5) except for post mordanted sample bleached with sodium hypochlorite (-4.5). The Da*and Db* values showed a positive result. Db* values showed the strong presence of yellow. The highest Db* value was

shown by pre mordanted sample bleached with peracetic acid while the lowest value was of post mordanted sample bleached with sodium hypochlorite.

Table 4.9: Colour Parameters for sample dyed with Turmeric with Copper Sulphate as Mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	7.1	-4.5	7.6	13.6	10.3	7.9
Da^*	5.7	8.8	2.9	7.9	4.9	5.5
Db^*	24.5	13.5	17.3	13.3	30.9	25.3
Dc^*	34.9	14.1	6.5	13.6	31.2	25.8
K/S	8.2	8.0	8.5	8.2	8.5	8.6

Note: Pr- Samples pre-mordanted with copper sulphate and
Po- Samples post mordanted with copper sulphate

For the samples mordanted with copper sulphate, the results are given in Table 4.10. From the table, it was observed that all the Da*and Db* values obtained were positive and thus showing that the colour lie in red-yellow quadrants, where the presence of yellow is stronger compared to red. The DL^* values were positive except for post mordanted samples bleached with peracetic acid and sodium hypochlorite. These two samples were darker compared to the others. The K/S values ranged from 6.4 (post mordanted samples bleached with sodium hypochlorite) to 8.9 (post mordanted samples bleached with peracetic acid).

Table 4.10: Colour Parameters for sample dyed with Turmeric with Ferrous Sulphate as Mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	9.3	-2.5	7.5	13.5	9.5	-8.3
Da^*	2.5	7.9	3.8	7.5	4.7	9.1
Db^*	18.6	30.1	16.2	13.2	27.7	20.7
Dc^*	18.8	-27.1	7.4	12.4	28.1	2.2
K/S	7.9	6.4	7.6	8.2	8.7	8.9

Note: Pr- Samples pre-mordanted with ferrous sulphate and
Po- Samples post mordanted with ferrous sulphate

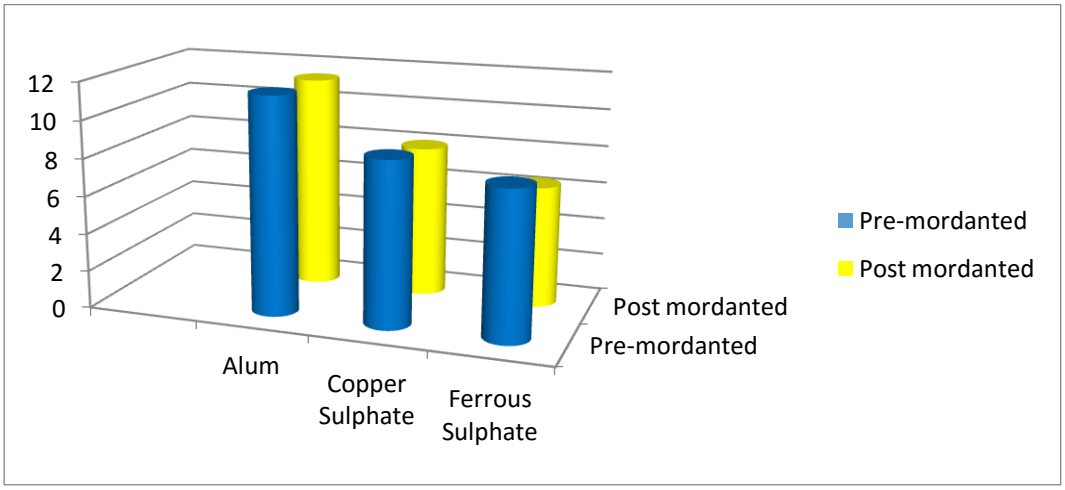
Tables 4.11, 4.12, 4.13 discussed the effect of various mordants for bleaching agent used during the dyeing process of jute with turmeric dyes. Tables 4.11, 4.12, 4.13 and Graphs 4.4, 4.5, and 4.6 contains the data regarding the reflectance values obtained

from the spectro photometric analysis of jute sample dyed with turmeric dye mordanted with alum, copper sulphate and ferrous sulphate for bleaching agent namely sodium hypochlorite, hydrogen peroxide and peracetic acid respectively.

Table 4.11: Colour Parameters of samples bleached with Sodium Hypochlorite dyed with Turmeric using different mordants

Colour Parameters	Samples bleached with NaOCl					
	Al -Pr	Al -Po	Cu- Pr	Cu-Po	Fe- Pr	Fe-Po
DL*	9.0	8.1	7.1	-4.5	9.3	-2.5
Da*	5.0	4.3	5.7	8.8	2.5	7.9
Db*	16.7	13.3	34.5	13.4	18.7	30.2
Dc*	17.4	14.0	34.9	14.0	18.8	-27.1
K/S	11.5	11.3	8.8	8.0	7.9	6.4

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



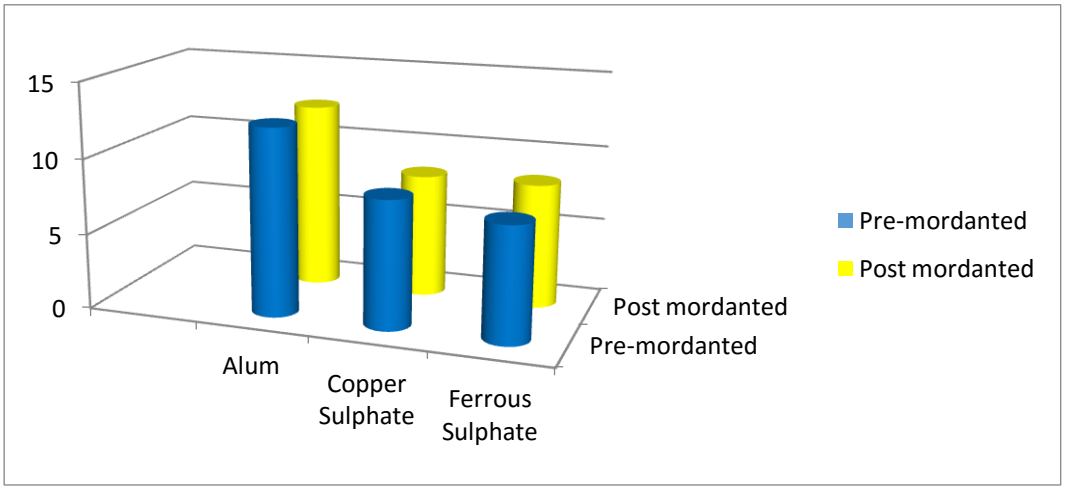
Graph 4.4: K/S values of samples bleached with Sodium Hypochlorite dyed with turmeric using different mordant

Graph 4.4 showed that the alum mordanted samples showed the higher K/S values compared to the others. This was observed from Table 4.11 that pre-mordanted alum sample showed the highest K/S value (11.5), followed by post mordanted alum sample (11.3) and then by pre-mordanted copper sulphate sample (8.8). The positive Da*and Db* values of the samples indicated that the samples were more yellow in colour with little presence of red into it.

Table 4.12: Colour Parameters of samples bleached with Hydrogen Peroxide dyed with Turmeric using different mordants

Colour Parameters	Samples bleached with H_2O_2					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	19.4	14.4	17.6	13.6	17.5	13.5
Da^*	4.4	5.5	2.9	7.9	3.8	7.5
Db^*	15.7	24.6	17.3	13.3	6.2	13.2
Dc^*	16.3	25.1	6.5	13.6	17.4	12.4
K/S	12.4	12.3	8.5	8.2	7.6	8.2

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



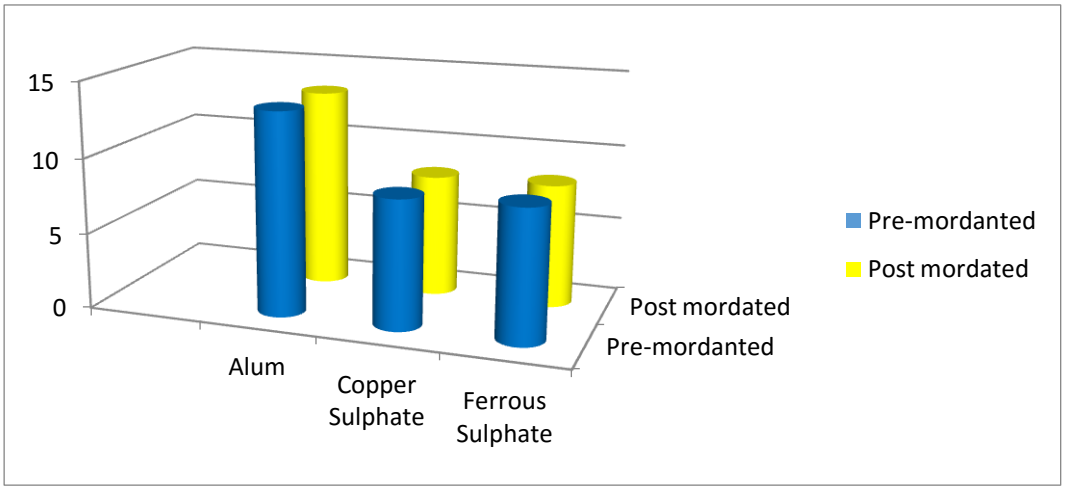
Graph 4.5: K/S values of samples bleached with Hydrogen peroxide dyed with turmeric using different mordant

Table 4.12 showed the results of dyeing with turmeric with various mordants when bleached with hydrogen peroxide. From the Table 4.12 and Graph 4.4, the highest K/S value was observed in case of pre-mordanted alum sample (12.4) and the lowest K/S was observed in case of pre-mordanted ferrous sulphate sample (7.6). All the DL^* values were positive ranging from 13.5 to 19.4. The lightest sample observed was pre-mordanted alum sample and the darkest was post mordanted ferrous sulphate sample. The Da*and Db* values were positive. High Db*values indicated strong yellow colour.

Table 4.13: Colour Parameters of samples bleached with Peracetic Acid dyed with Turmeric using different mordants

Colour Parameters	Samples bleached with CH_3COOH					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL*	11.5	17.4	10.3	7.9	9.5	-8.3
Da*	5.7	4.3	4.9	5.5	4.7	9.1
Db*	18.5	23.9	30.8	25.3	27.7	0.7
Dc*	19.4	24.1	31.2	25.8	28.1	2.2
K/S	13.4	13.2	8.5	8.1	8.7	8.2

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



Graph 4.6: K/S values of samples bleached with Peracetic acid dyed with turmeric using different mordant

It was observed from the Table 4.12 that the only darkest sample with a negative value of DL* was for the sample which was post mordanted with ferrous sulphate (-8.3). All the other values were positive indicating the lighter shade of colour. It also gave the high Db* values indicating strong yellow colour. The K/S values of peracetic acid ranged from 8.2 to 13.4. The alum mordanted samples showed higher K/S values compared to the others which was shown in the graph 4.6.

From the above Tables 4.8, 4.9, 4.10, 4.11, 4.12, 4.13 and Graphs 4.4, 4.5, 4.6 for the jute dyed with turmeric, the following conclusions were made. Among the three bleaching agents, samples treated with peracetic acid showed the best result in terms of colour strength compared to sodium hypochlorite and hydrogen peroxide. Alum

was the best mordant which gave the highest K/S value among the three mordants. Also pre-mordanting technique was better than post mordanting technique in all bleaching agent and for all mordants. Turmeric dyed and alum mordanted samples produced the shade of yellow ranging from yellow to yellow ochre. For copper mordanted samples the shade obtained were Russian orange to light brown. The shades for ferrous mordanted samples for turmeric dye ranged from pumpkin yellow to dark chocolate in colour.

III) Eucalyptus Leaves

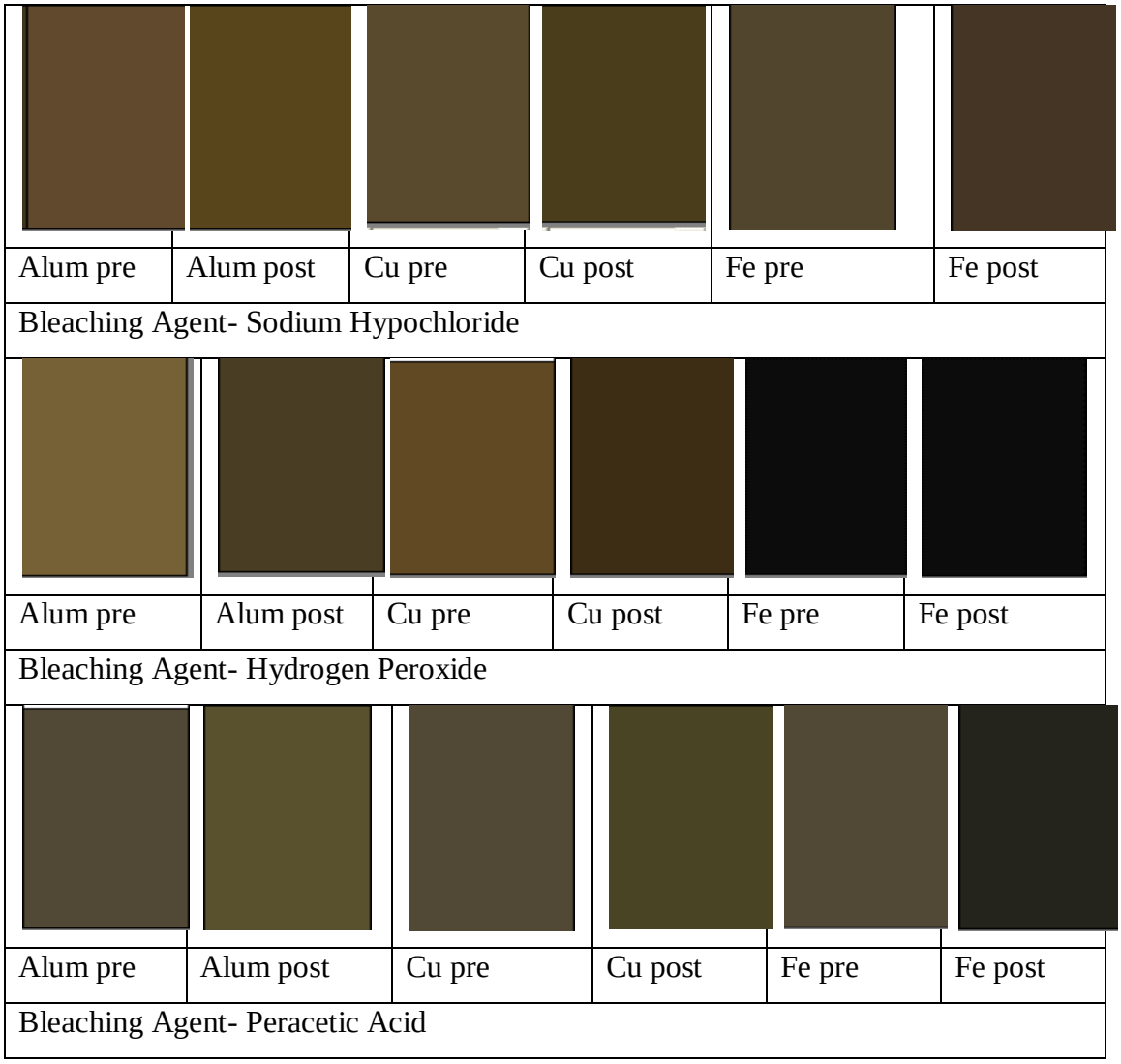


Plate 4.3: Shades of Eucalyptus Leaves on Jute with Various Bleaching Agents

Table 4.14: Colour Parameters for sample dyed with Eucalyptus Leaves with Alum as Mordant

	Samples bleached with		
Colour	NaOCl	H_2O_2	CH_3COOH

Parameters	Pr	Po	Pr	Po	Pr	Po
DL^*	5.6	5.6	14.1	3.3	7.5	8.5
Da^*	1.2	1.0	-3.2	-0.4	-2.5	-4.7
Db^*	2.9	2.4	9.6	1.6	-1.4	4.7
Dc^*	3.1	3.2	8.9	1.4	-1.9	4.0
K/S	6.3	6.1	6.3	6.0	7.7	7.5

Note: Pr- Samples pre-mordanted with alum and
Po- Samples post mordanted with alum

Table 4.14 showed the reflectance values of eucalyptus leaves with alum bleached with three different bleaching agents. The positive DL^* values indicates that all the samples were light in shade. The negative Da* values indicated that the samples were greener and positive Db* values showed that the samples had little bit of yellow. Hence, the samples fall in the green-yellow quadrants. The highest K/S values were shown by peracetic acid, followed by hydrogen peroxide and sodium hypochlorite which ranged from 6.0 to 7.7.

Table 4.15: Colour Parameters for sample dyed with Eucalyptus Leaves with Copper Sulphate as mordant

Colour Parameters	Samples bleached with					
	NaOCl			H_2O_2	CH_3COOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	7.7	2.5	8.3	-0.6	7.5	5.7
Da^*	-1.1	-0.1	-0.2	-2.2	-2.2	-4.0
Db^*	0.9	5.2	7.2	2.9	-1.2	1.5
Dc^*	0.5	5.1	7.0	2.4	-1.7	0.8
K/S	7.6	7.6	7.6	8.0	7.2	7.6

Note: Pr- Samples pre-mordanted with copper sulphate and
Po- Samples post mordanted with copper sulphate

It was observed from the Table 4.15, the samples were light in shade with all the positive DL^* values. The negative Da* values and positive Db* values indicated that the samples lie in green-yellow quadrant. Hence, the samples appear to be dull green in colour with the range of K/S value from 7.2 to 8.0. The highest K/S value was seen in case of post mordanted sample bleached with hydrogen peroxide.

Table 4.16: Colour Parameters for sample dyed with Eucalyptus Leaves with Ferrous Sulphate

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		CH_3COOH	
	Pr	Po	Pr	Po	Pr	Po
DL^*	6.2	1.9	-16.0	-15.4	6.4	-4.7
Da^*	-1.0	-0.9	-3.4	-4.0	-2.7	-4.5
Db^*	0.8	-0.1	-12.7	-9.9	-2.2	-9.6
Dc^*	0.5	-0.3	-13.2	-10.6	-2.7	-10.0
K/S	17.5	16.8	17.9	17.3	18.7	17.5

Note: Pr- Samples pre-mordanted with ferrous sulphate and
Po- Samples post mordanted with ferrous sulphate

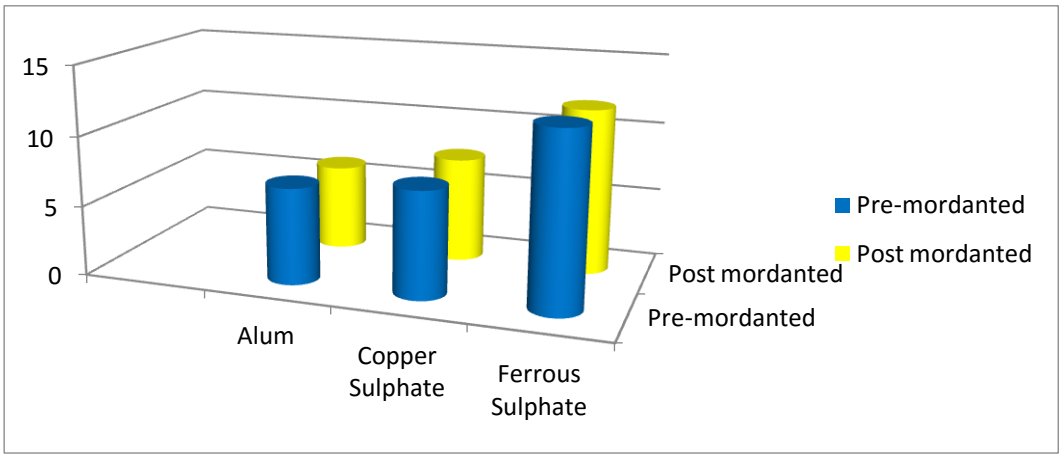
As observed from the Table 4.16, the DL^* readings indicated that all the samples were dark in appearance. The post mordanted samples bleached with hydrogen peroxide and peracetic acid were found to produce very dark shades than sodium hypochloride bleached samples. The pre mordanted samples were darker than post mordanted sample. The highest K/S value was observed in case of pre-mordanted sample bleached with peracetic acid (18.7) followed by pre-mordanted sample bleached with hydrogen peroxide. The negative Da* values of all the dyed samples indicated that the samples had greenish tone.

Table 4.17: Colour Parameters of samples bleached with Sodium Hypochlorite dyed with Eucalyptus leaves using different mordants

Colour Parameters	Samples bleached with NaOCl					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	8.3	5.1	7.7	2.5	6.1	1.9
Da^*	-0.4	-0.4	-1.1	-0.1	-1.0	-0.9
Db^*	3.7	7.9	0.9	5.2	0.8	-0.1
Dc^*	3.5	7.8	0.5	5.1	0.5	-0.3
K/S	6.9	6.1	7.6	7.5	12.5	11.8

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

From the Table 4.19 and the graph 4.9, it was observed that ferrous sulphate mordanted samples had highest K/S value, followed by copper sulphate and alum. The positive DL^* readings indicated lighter shade of the samples. Also the negative Da* values indicated presence of green into the samples and positive Db* value showed the presence of yellow. Hence the colours obtained in case of sodium hypochlorite bleached samples ranged between pale brown to khaki colour.

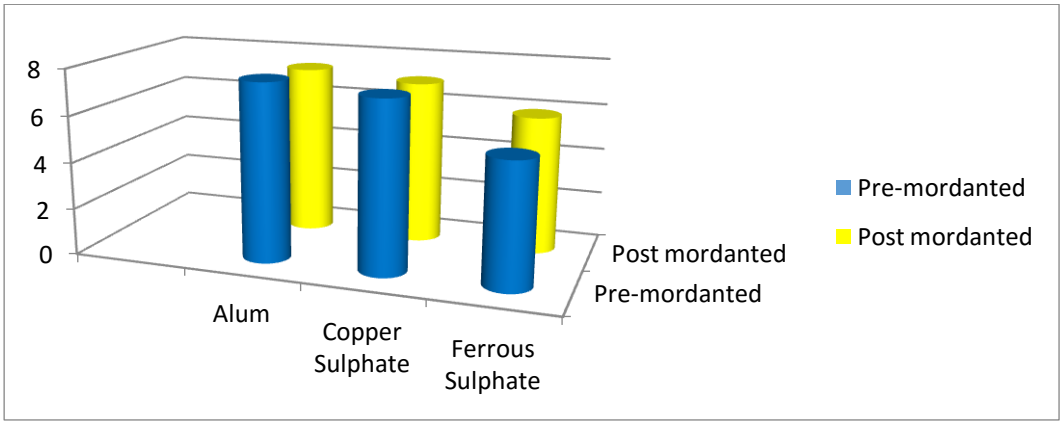


Graph 4.7: K/S values of samples bleached with Sodium Hypochlorite dyed with Eucalyptus Leaves using different mordants

Table 4.18: Colour Parameters of samples bleached with Hydrogen Peroxide dyed with Eucalyptus leaves using different mordants

Colour Parameters	Samples bleached with H_2O_2					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL*	14.1	3.8	8.3	-0.6	-16.0	-15.4
Da*	-3.2	-0.4	-0.2	-2.2	-3.4	-4.0
Db*	9.6	1.6	7.2	2.9	-12.8	-9.9
Dc*	8.9	1.5	7.0	2.4	-13.2	-10.6
K/S	7.3	7.1	7.6	7.0	5.3	5.9

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



Graph 4.8: K/S values of samples bleached with Hydrogen Peroxide dyed using Eucalyptus Leaves using different mordants

It was observed from the Table 4.17 that the post mordanted copper sulphate sample and both the ferrous sulphate samples i.e. pre and post mordanted samples were dark

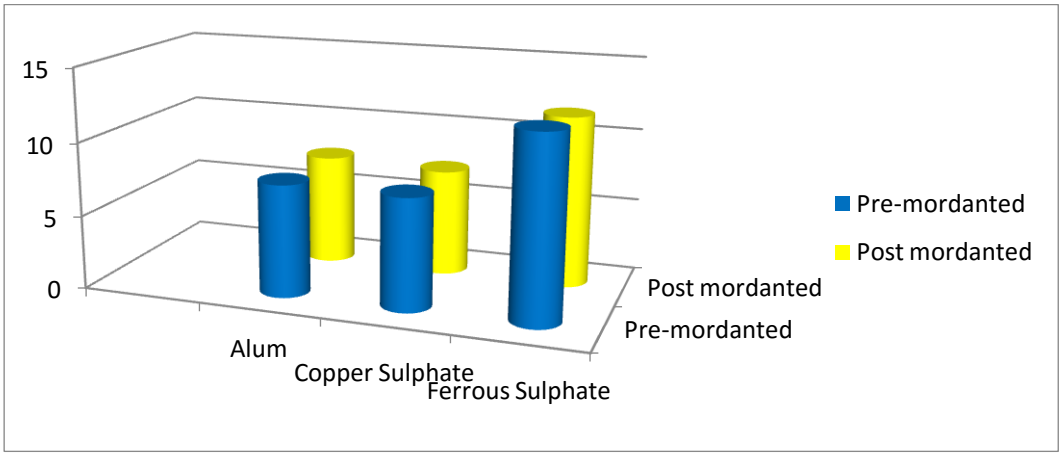
in shade, while the other samples were lighter in shade indicated by negative DL^* readings. The pre-mordanted alum sample had the highest K/S value, followed by post mordanted alum sample and followed by pre- mordanted copper sulphate.

Table 4.19: Colour Parameters of samples bleached with Peracetic Acid dyed with Eucalyptus leaves using different mordants

Colour Parameters	Samples bleached with CH_3COOH					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	7.5	8.5	7.5	5.6	6.4	-4.7
Da^*	-2.5	-4.7	-2.2	-4.0	-2.7	-4.5
Db^*	-1.4	4.7	-1.2	1.5	-2.2	-9.6
Dc^*	-1.9	4.0	-1.7	0.8	-2.7	-10.0
K/S	7.6	7.5	7.6	7.2	12.4	11.6

Note: Std- Standard sample bleached with respected bleaching agent and dyed without mordant,
Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

It was reflected from the Graph 4.9 that the highest K/S value obtained in case of peracetic acid bleached samples was of ferrous sulphate. Also from the Table 4.18, the negative DL^* readings proved that these samples were darker compared to the rest of the samples. Most of the samples fell in the green-blue quadrant as per their negative Da* and Db* values. The colours obtained were more of pale green to greyish green to dark brownish colour.



Graph 4.9: K/S values of samples bleached with Peracetic acid dyed with Eucalyptus Leaves using different mordant

From the Tables 4.15, 4.16, 4.17, 4.18, 4.19 and Graphs 4.7, 4.8 and 4.9 for jute dyed with Eucalyptus Leaves, the following conclusions were derived. Alum was the best mordant which gave the highest K/S value among the three mordants. Also pre-

mordanting technique was better than post mordanting technique in all bleaching agent and for all mordants. Among the three bleaching agents, samples treated with peracetic acid showed the best result in terms of colour strength compared to sodium hypochlorite and hydrogen peroxide.

Shades obtained from Eucalyptus leaves dye using alum as mordant ranged from olive to khaki. Copper sulphate as mordant gave the shades of camel brown to rich brown and ferrous sulphate mordanted samples produced the shade ranged between khaki colour to dark brown.

IV) Indian Almond Leaves

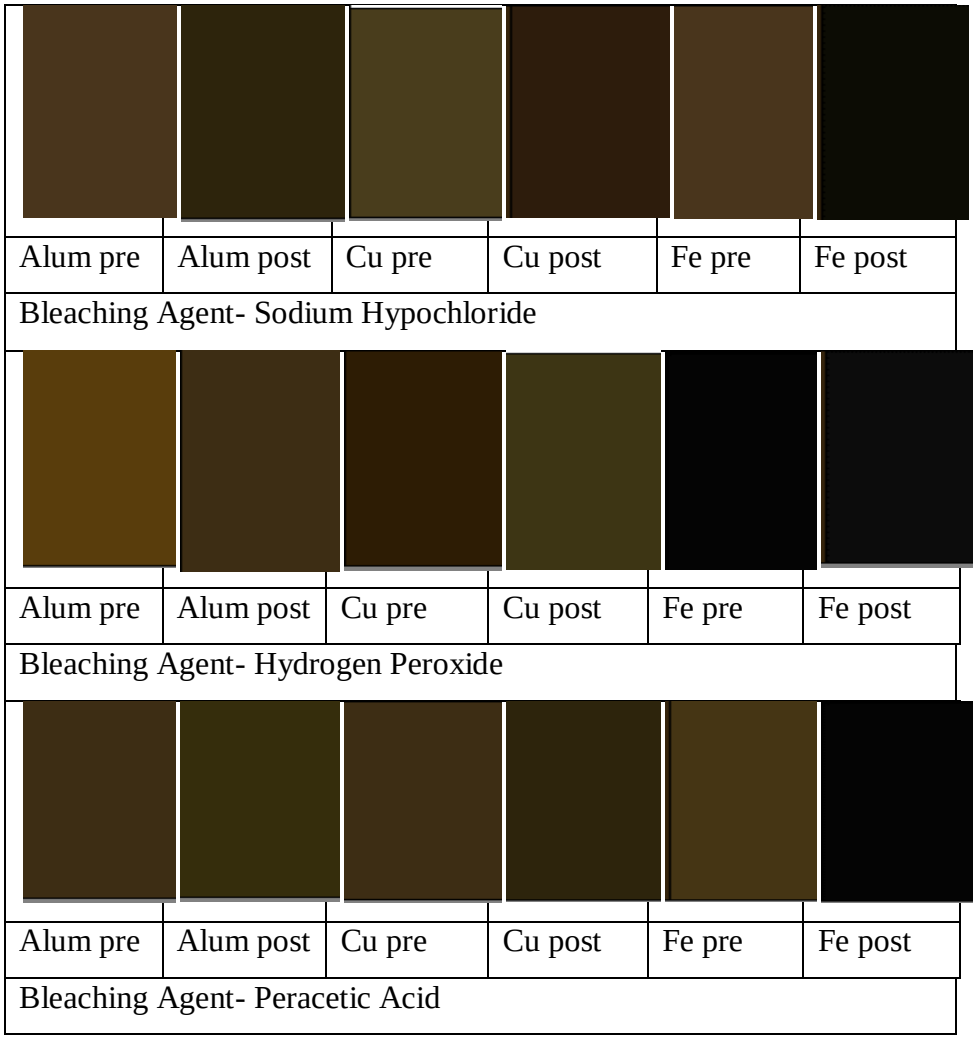


Plate 4.4: Shades of Indian Almond Leaves on Jute with Various Bleaching Agents

Indian almond leaves dyed samples showed higher K/S values when mordanted with alum as seen from the Table 4.20. The highest K/S value was observed in case of

peracetic acid bleached samples, followed by hydrogen peroxide and then sodium hypochlorite. The negative DL^* readings indicated that the samples were darker in shade. The negative Da* values indicated presence of green into the samples and positive Db* value showed the presence of yellow.

Table 4.20: Colour Parameters for sample dyed with Indian Almond Leaves with Alum as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		PAA	
	Pr	Po	Pr	Po	Pr	Po
DL^*	7.7	-0.4	8.5	6.3	5.4	3.6
Da^*	-1.5	-2.9	-1.8	-2.2	-2.7	-6.7
Db^*	1.3	-1.2	15.6	3.6	0.7	3.9
Dc^*	0.8	-1.9	2.7	2.8	1.0	2.8
K/S	25.1	25.0	25.7	25.5	27.7	27.8

Note: Pr- Samples pre-mordanted with copper sulphate and
Po- Samples post mordanted with copper sulphate

Table 4.21: Colour Parameters for sample dyed with Indian Almond Leaves with Copper Sulphate as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		PAA	
	Pr	Po	Pr	Po	Pr	Po
DL^*	9.5	-0.9	-0.9	6.1	3.8	1.2
Da^*	-2.8	-2.7	-1.6	-3.1	-2.4	-4.7
Db^*	1.3	-1.1	4.5	-0.8	-0.7	1.6
Dc^*	0.6	-1.8	3.9	-1.6	-1.9	0.7
K/S	17.6	16.4	18.6	17.0	18.7	18.6

Note: Pr- Samples pre-mordanted with copper sulphate and
Po- Samples post mordanted with copper sulphate

It was observed from the table 4.21 that the samples mordanted with copper sulphate were lighter as indicated by positive DL^* values. The negative Da* values proved that the samples were greener in colour along with yellow and blue. The samples post mordanted with copper sulphate were bluer compared to the others. The K/S values ranged from 16.4 to 18.7.

Table 4.22: Colour Parameters for sample dyed with Indian Almond Leaves with Ferrous Sulphate as mordant

Colour Parameters	Samples bleached with					
	NaOCl		H_2O_2		PAA	
	Pr	Po	Pr	Po	Pr	Po
DL^*	7.8	-11.6	-18.1	-10.9	6.1	-15.7
Da^*	-2.7	-6.6	-6.0	-6.8	-2.5	-8.1
Db^*	0.4	-12.7	-17.8	-16.5	1.3	-18.2
Dc^*	-0.3	-13.8	-18.8	-17.6	0.6	-19.2
K/S	27.4	25.4	27.7	28.3	24.6	25.3

Note: Pr- Samples pre-mordanted with copper sulphate and
Po- Samples post mordanted with copper sulphate

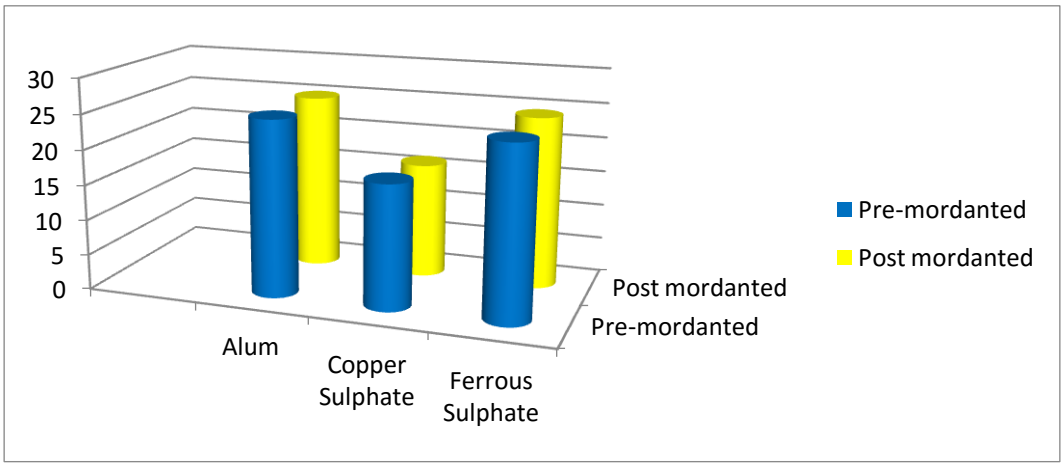
The ferrous sulphate mordanted samples showed high K/S values ranging from 24.5 to 28.3 as shown in Table 4.22. The highest K/S value was observed in case of post mordanted bleached with hydrogen peroxide sample followed by pre-mordanted bleached with hydrogen peroxide sample. The negative Da* and Db* values indicated that the samples fall into the green-blue quadrant thus giving the shades of greenish-blue.

Table 4.23: Colour Parameters of samples bleached with Sodium Hypochlorite dyed with Indian Almond leaves using different mordants

Colour Parameters	Samples bleached with NaOCl					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	7.7	-0.4	9.5	-0.9	7.8	-11.6
Da^*	-1.5	-2.9	-2.8	-2.7	-2.7	-6.6
Db^*	1.3	-1.2	-1.3	-1.1	-0.4	-12.8
Dc^*	0.8	-1.9	0.6	-1.8	-0.2	-13.8
K/S	25.1	25.0	17.6	16.4	24.4	24.5

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

From the Table 4.23 and the Graph 4.10, the highest K/S value was observed in case of alum mordanted samples, followed by ferrous sulphate mordanted samples. The K/S values ranged from 25.1 to 16.4. The negative Da* and Db* values showed that the samples fell into green-blue quadrant. From the Table 4.25, the negative DL^* readings indicated that the post mordanted samples for all the three mordants were darker compared to the pre-mordanted samples. The colours obtained were khaki to grayish brown to dark chocolate brown.

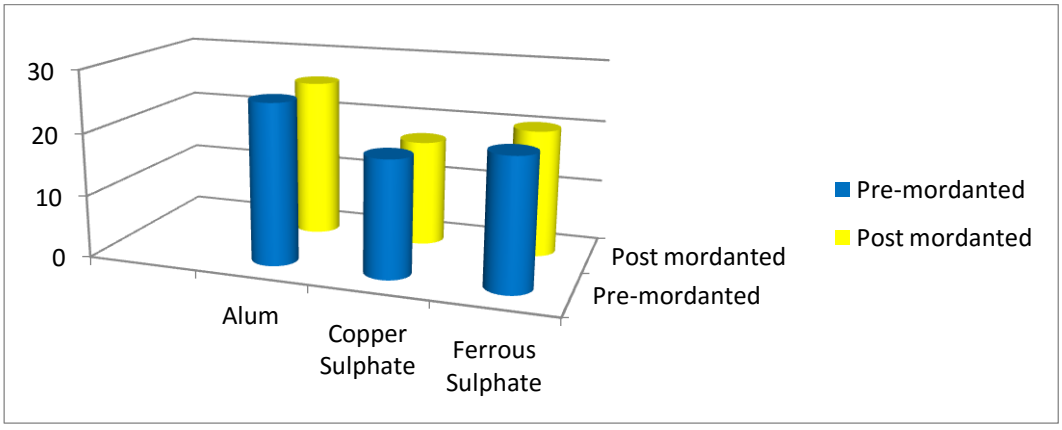


Graph 4.10: K/S values of samples bleached with Sodium Hypochlorite dyed with Indian Almond Leaves using different mordants

Table 4.24: Colour Parameters of samples bleached with Hydrogen Peroxide dyed with Indian Almond leaves using different mordants

Colour Parameters	Samples bleached with H_2O_2					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL*	8.5	6.3	-0.9	6.1	-18.2	-10.9
Da*	-1.8	-2.2	-1.6	-3.8	-6.0	-6.8
Db*	15.6	3.6	4.5	-0.8	-17.8	-16.5
Dc*	2.7	2.8	3.9	-1.6	-18.8	-17.6
K/S	25.7	25.5	18.6	17.0	20.7	20.3

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate



Graph 4.11: K/S values of samples bleached with Hydrogen Peroxide dyed with Indian Almond Leaves using different mordants

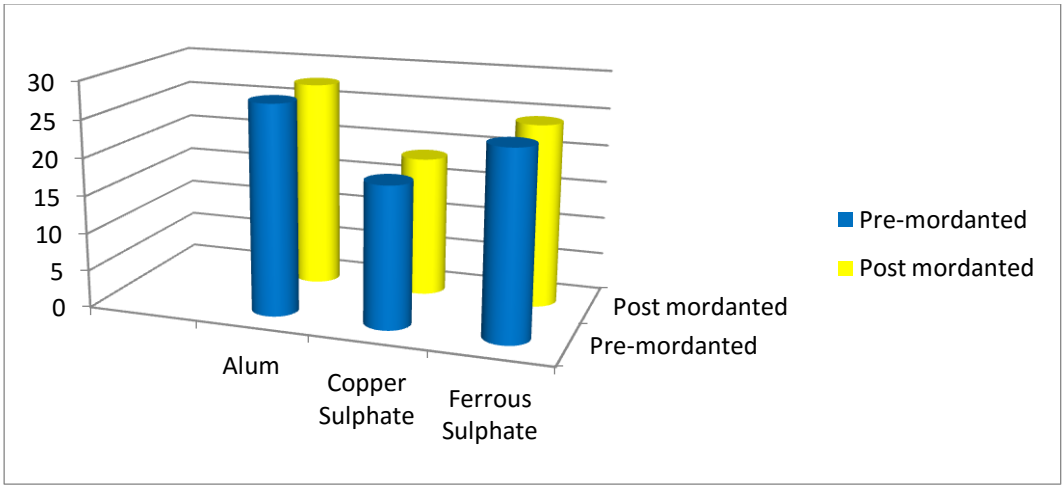
The K/S values of the samples dyed with Indian almond leaves ranged from 17.0 to 25.7 as shown in Table 4.24. The alum mordanted samples showed high K/S value (pre-25.6, post – 25.5), followed by ferrous sulphate mordanted samples (pre- 20.7, post – 20.3) then copper sulphate (pre- 18.6, post 17.0).

Table 4.25: Colour Parameters of samples bleached with Peracetic Acid dyed with Indian Almond leaves using different mordants

Colour Parameters	Samples bleached with PAA					
	Al Pr	Al Po	Cu Pr	Cu Po	Fe Pr	Fe Po
DL^*	5.4	3.6	3.8	1.3	6.1	-15.7
Da^*	-2.7	-6.7	-2.4	-4.7	-2.5	-8.1
Db^*	0.7	3.9	-0.7	1.6	1.3	18.1
Dc^*	1.0	2.8	-1.4	0.7	0.6	-19.1
K/S	27.8	27.6	18.7	18.6	24.6	24.3

Note: Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

It was reflected from the Graph 4.12 that the highest K/S value obtained in case of peracetic acid bleached samples was of alum. Also from the Table 4.24, the positive DL^* readings proved that these samples were lighter compared to the rest of the samples. Most of the samples fell in the green-yellow quandrant as per their negative Da* and positive Db* values. The colours obtained were more of brown to greyish-green to brownish- black colour.



Graph 4.12: K/S values of samples bleached with Peracetic acid dyed with Indian Almond Leaves using different mordants

In case of jute dyed with Indian Almond Leaves, the following conclusions were made. Alum was the best mordant which gave the highest K/S value among the three mordants. Also pre-mordanting technique was better than post mordanting technique

in all bleaching agent and for all mordants. Among the three bleaching agents, samples treated with peracetic acid showed the best result in terms of colour strength compared to sodium hypochlorite and hydrogen peroxide. The shades obtained from alum mordanted samples ranged from light brown to dark brown, while the shades for copper sulphate mordanted samples were khaki colour to dark brown and for the samples mordanted with ferrous sulphate the shade ranged burnt seine to blackish brown in colour.

4.2.2 Fastness properties of dyes

For dyed samples it is important to know its fastness or fading behaviour. Wash fastness, rub fastness and light fastness are the three main properties that contribute in assessing the degree of fading of textiles. Hence, these fastness properties of the dyes on jute fabric were assessed according to the standard testing procedure as discussed in the methodology. The results of the tests are discussed below.

Table 4.26 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Madder using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Sodium Hypochlorite						
Standard	3	4	2	2	4	2
Alum Pr	4	4	3	3	3	2
Alum Po	3-4	4	3	2	2-3	3
Cu Pr	4	4	4	4	3	2
Cu Po	3-4	4	3	3	2-3	3
Fe Pr	4	4	4	4	3	2
Fe Po	4	4	4	4	3	2
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	4
Alum Pr	4	4	4	4	4	4
Alum Po	4	4	3	3	3	3

Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3-4	3-4	3	3
Fe Pr	4-5	4	4-5	4	5	5
Fe Po	4-5	4	4-5	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum Pr	4-5	4	4-5	4	5	5
Alum Po	4-5	4	4-5	4	4	4
Cu Pr	4	4	4	4	4	3
Cu Po	4	4	4	4	4	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	4	4	4	3

Note: Std- Standard sample bleached with respected bleaching agent and dyed
Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

It was observed from the table 4.26 that the samples bleached with Sodium Hypochlorite showed average to good fastness properties. As observed from the table, the change in colour ranged between 3-4 to 4 whereas staining on white was rated as 4. This could be due to the superficial dye onto the samples that was removed during the vigorous laundering procedure. The rub fastness ranged between average to good, this could also be due to the superficial dye, which got removed during crocking. Light fastness in this case showed average to poor.

In case of the samples bleached with Hydrogen Peroxide, the fastness properties varied from average to excellent. The light fastness showed better results compared to the samples bleached with Sodium Hypochlorite. Here the light fastness ranged from average to excellent. Staining on white was caused due to the superficial dye on the samples. The ferrous pre-mordanted sample showed the best result in terms of wash, rub and light fastness.

Amongst the three bleaching agents, Peracetic acid treated samples showed the best result in terms of wash, rub and light fastness. As observed from the table 4.26, the values ranged from very good to excellent. The light fastness ratings were in absolute

contrast. The alum mordanted samples showed excellent light fastness ratings for 10 and 20 hours of exposure to light. The copper mordanted samples and ferrous mordanted samples showed good rating for first 10 hours of exposure to light but for the next 10 hours of exposure it showed average rating. The fastness rating of wash and rub ranged from very good to excellent. Amongst the three mordants used, alum mordanted samples showed the best result in terms of wash, rub and light fastness.

Table 4.27 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Turmeric using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Sodium Hypochlorite						
Standard	3	4	2	2	4	4
Alum Pr	3	4	3	3	4	4
Alum Po	3	4	3	2	3	3
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3	3	3	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	4	4	4	4
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	4
Alum Pr	4	4	4	4	4	4
Alum Po	4	4	3	3	3	3
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3-4	3-4	3	3
Fe Pr	4	4	4	4	5	5
Fe Po	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum Pr	4	4	4	4	5	5

Alum Po	4	4	4	4	4	4
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	4	3-4	4	4
Fe Pr	4	4	4-5	4	4-5	4-5
Fe Po	4	4	4-5	4	4-5	4-5

Note: Std- Standard sample bleached with respected bleaching agent and dyed,
Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

It was noted from the table 4.27 that samples bleached with Peracetic acid showed the best result amongst the three bleaching agents. The wash fastness ratings ranged from average to good in terms of colour change and staining on white readings was 4 for all the mordants in case of all the bleaching agents which indicated good fastness to washing. The crock fastness ratings ranged for average to excellent for staining on white (dry). While for staining on white (wet) showed the ratings between poor to excellent in case of overall rub fastness for the samples dyed with turmeric. The light fastness also varied from average to excellent in terms of overall view of the samples dyed with turmeric.

Table 4.28 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Eucalyptus Leaves using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Sodium Hypochlorite						
Standard	3	3	3	3	3	3
Alum Pr	4	4	4	4	4	4
Alum Po	4	4	3-4	3-4	3	3
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3-4	3-4	3	3
Fe Pr	4	4	4	4	4	4

Fe Po	4	4	4	4	4	4
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	4
Alum Pr	3	3	3	3	4	4
Alum Po	3	3	3	3	4	4
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3	3	3	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum Pr	4-5	4	4-5	4	5	5
Alum Po	4-5	4	4-5	4	4	4
Cu Pr	4	4	4	4	4	4
Cu Po	4-5	4	4-5	4	5	5
Fe Pr	4-5	4	4-5	4	4	4
Fe Po	4	4	4	4	4	4

Note: Std- Standard sample bleached with respected bleaching agent and dyed,
Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

Table 4.28 showed the readings of fastness properties of the samples bleached with different bleaching agents and dyed with eucalyptus leaves. Readings from the table 4.28 revealed that the samples bleached with Sodium Hypochlorite showed the overall fastness ratings as average to good. The light fastness of the samples post mordanted with alum and post mordanted with copper showed average readings for 10 hours and more exposure to light while the other samples gave the readings as good with the score of 4. Wash fastness ratings was 4 for change in colour and for staining on white which indicated good wash fastness.

The samples bleached with Hydrogen Peroxide showed average to good results. The wash and rub fastness showed average ratings. This could be due to the superficial dye onto the samples and hence while washing or crocking procedure, the dyes must

have been removed. The light fastness in comparatively good only the post mordanted copper sulphate treated samples showed average readings.

In case of the samples bleached with Peracetic acid, all the samples had good to excellent performance to fastness to laundering, fastness to crocking and fastness to exposure to light.

Table 4.29 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Indian Almond Leaves using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Sodium Hypochlorite						
Standard	3	4	2	2	4	4
Alum Pr	3	4	3	3	4	4
Alum Po	3	4	3	2	3	3
Cu Pr	4	4	4	3	4	4
Cu Po	4	4	3	3	3	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	4	3	4	4
Samples bleached with Hydrogen Peroxide						
Standard	3	3	3	3	3	3
Alum Pr	4	4	4	4	4	4
Alum Po	4	4	3-4	3-4	4	3
Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3-4	3-4	4	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum Pr	4-5	4	4-5	4	5	5
Alum Po	4-5	4	4-5	4	4	4

Cu Pr	4	4	4	4	4	4
Cu Po	4	4	3-4	3-4	3	3
Fe Pr	4	4	4	4	4	4
Fe Po	4	4	3-4	3-4	3	3

Note: Std- Standard sample bleached with respected bleaching agent and dyed,
Al Pr- Samples pre-mordanted with alum,
Al Po- Samples post mordanted with alum,
Cu Pr- Samples pre-mordanted with copper sulphate,
Cu Po- Samples post mordanted with copper sulphate,
Fe Pr- Samples pre-mordanted with ferrous sulphate and
Fe Po- Samples post mordanted with ferrous sulphate

It was observed from the table 4.29, that the samples bleached with sodium hypochlorite dyed with Indian almond leaves showed averaged to good wash fastness in terms of change in colour. In terms of staining on white the readings were 4 for all the samples which indicated good wash fastness. For rub fastness, the staining on white both dry and wet showed average to good readings. Hence, it can be concluded that the samples when bleached with sodium hypochlorite and dyed with Indian almond leaves gave average rub fastness. The light fastness as observed from the table, showed good results except for samples which were post mordanted by alum and copper sulphate.

The overall readings for the samples bleached with hydrogen peroxide dyed with Indian almond leaves showed good rating in terms of wash fastness and light fastness. The rub fastness of these samples showed average to good except for samples which were post mordanted by alum and copper sulphate.

In case of samples bleached with peracetic acid dyed with Indian almond leaves, the wash and crock fastness ratings showed good to excellent readings except for samples post mordanted by copper sulphate and ferrous sulphate in terms of rub fastness. The sample pre mordanted by alum showed excellent ratings while the samples post mordanted with copper sulphate and ferrous sulphate gave average readings in terms of light fastness.

From the pilot work we can draw the following results. The samples pre-bleached with Sodium Hypochlorite, Hydrogen Peroxide and Peracetic acid and subsequently dyed with the natural dyes used in this study produced shades of different hues depending upon the types and methods of mordanting. Alum was found to produce brightest shade amongst the three mordants used. Copper sulphate and ferrous

sulphate has its inherent colours which played a role in the final shade of the sample. Pre- mordanting technique gave better results compared to the post mordanting one. All the pre-bleached and dyed samples showed satisfactory rating when evaluated for washing and rubbing fastness properties. The dyed samples pre-bleached with Peracetic acid showed the best result for K/S values and fastness properties compared to the other two bleaching agents.

The K/S value for madder ranged from 5.8 to 13.8, turmeric ranged from 3.5 to 27.5, Eucalyptus leaves ranged from 5.3 to 18.9 and Indian Almond leaves ranged from 16.4 to 28.3. After visual inspection of the shades obtained from the pilot work; alum and pre mordanting were selected as mordant and mordanting technique respectively for further study.

4.3 Phase- II: Experimentation

4.3.1 Pretreatments of the fabric

From the pilot work, following were taken further for experimentation. Among the three bleaching agents - sodium hypochlorite caused maximum loss of strength. Hence, for rest of the study it was not carried further. Hydrogen Peroxide and Peracetic acid were taken further based on the tensile strength test and SEM images.

The sequence to be followed for the pre-treatments was decided on the basis of the results obtained for whiteness, yellowness and brightness.

4.3.2 Testing of parameters

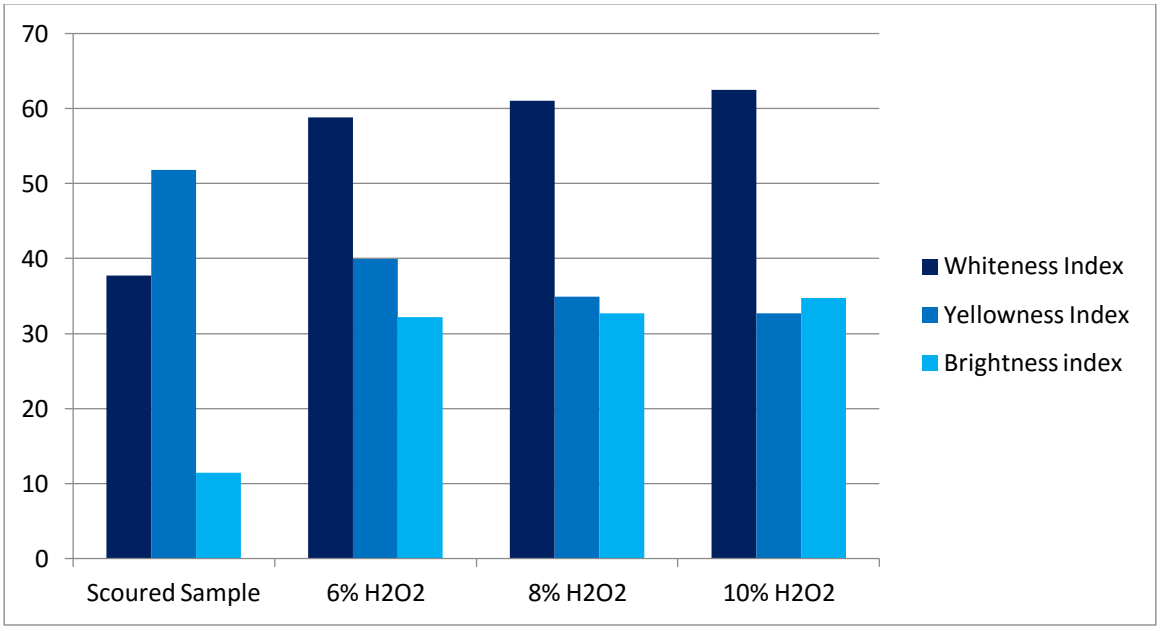
(A) Bleaching Agents

The selected bleaching agents were studied by varying conditions for different parameters. Parameters like optical indices which include whiteness, yellowness, brightness indices, weight loss and tensile strength were studied for both the bleaching agents Hydrogen peroxide and Peracetic acid at different concentration. The concentrations for Hydrogen peroxide studied were 6, 8 and 10%. The results are shown in the following tables and graphs.

Table 4.30: Results of optical indices of the samples bleached with Hydrogen Peroxide

Sr No	Samples Bleached with H_2O_2	Optical Indices		
		Whiteness index	Yellowness Index	Brightness Index
1.	Scoured sample	37.700	51.848	11.458
2.	6% H_2O_2	58.826	39.632	29.558
3.	8% H_2O_2	61.095	34.934	32.700
4.	10% H_2O_2	62.505	32.161	34.716

From the Table 4.30, it was observed that the whiteness increased with the increase in concentration of hydrogen peroxide. 10% concentration of hydrogen peroxide gave the best result. Also the yellowness index readings supported this. With the increase in concentration the yellowness index decreases. With the increase in concentration along with whiteness, brightness also increased. It was observed from the graph 4.13 that there was a major difference between the optical indicies values of scoured sample and the samples treated with hydrogen peroxide at different concentration. Treatment with hydrogen peroxide leads to increase in whiteness and brightness index and decrease in yellowness index indicating reduction in natural colour in the fabric which is a key factor in dyeing. Presence of natural colour restricts the dye to react with the substrate and proper dyeing will not occur.



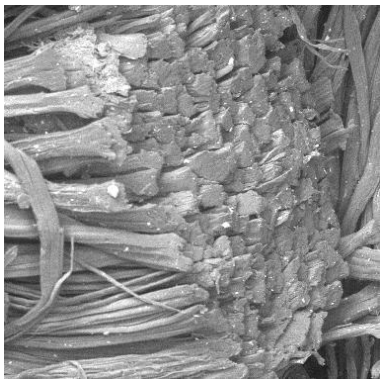
Graph 4.13: Optical indicies of jute fabric bleached with different concentration of Hydrogen Peroxide

Bleaching affects the physical properties of the fabric mainly the strength, so after bleaching the samples were tested for strength and results presented in tables and graphs.

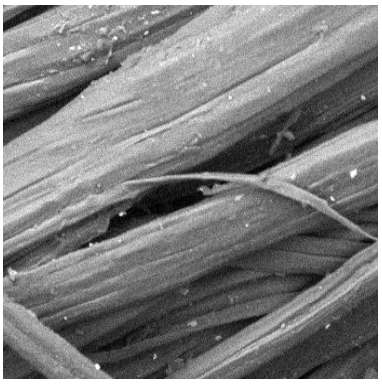
Table 4.31: Breaking Load and Elongation properties of jute fabric bleached with different concentration of Hydrogen Peroxide

Direction of Sample	Scoured Sample		**6% H_2O_2**		**8% H_2O_2**		**10% H_2O_2**	
	Br. Load (kg)	Elongation (mm)	Br. Load (kg)	Elongation (mm)	Br. Load (kg)	Elongation (mm)	Br. Load (kg)	Elongation (mm)
Warpwise	56.14	14.31	54.52	18.95	43.44	20.10	39.82	24.81
Weftwise	54.20	15.32	51.34	20.78	41.65	24.33	36.57	28.79

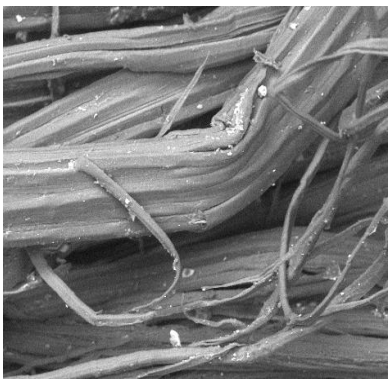
In warp wise direction the highest breaking load amongst the bleached sample ie 54.52kg with minimum elongation value of 18.95mm was seen for the sample which was bleached with 6% hydrogen peroxide. As the warp yarns could be under stress while manufacture of fabric, the samples had decreased load value of 51.34kg in the weft direction for the same sample with increased elongation value of 20.78mm. This was due to the corrugated path that weft yarns followed while weaving. Similar pattern was observed for the samples bleached with 8% and 10% hydrogen peroxide.



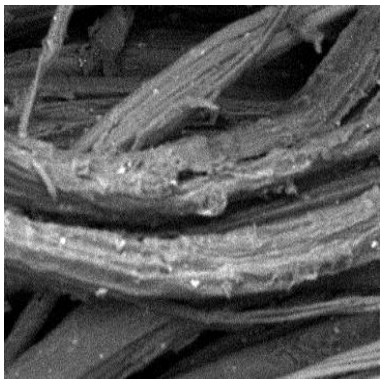
Scoured Sample



6% **H_2O_2**



8% H_2O_2



10% H_2O_2

Plate 4.5 SEM images of scoured jute and bleached with Hydrogen Peroxide at different concentration

SEM microphotographs (Plate 4.5) were taken at × 270 magnification to assess the effect of various concentrations of Hydrogen Peroxide bleach on jute fabric. It shows that in case of scoured sample, the SEM image shows the bundle structure of the jute fabric, with the increase in concentration of Hydrogen Peroxide, the SEM images show increased damage on the fibre structure.

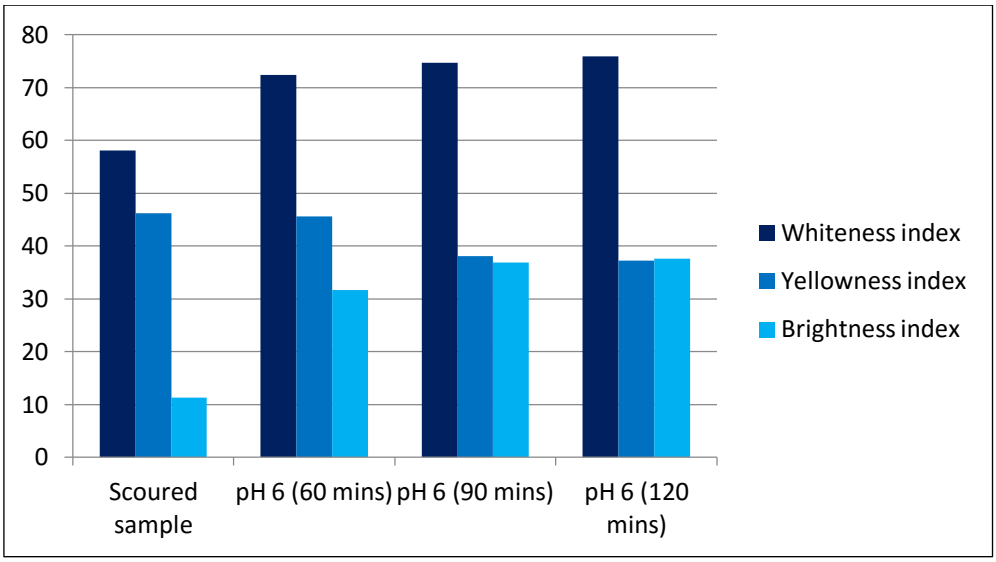
Table 4.32: Results of optical indicies of the samples bleached with Peracetic acid

Sr. No.	Samples bleached with peracetic acid	Parameters		
		Whiteness index	Yellowness index	Brightness index
1.	Scoured sample	58.04	46.20	11.25
2.	pH 6 (60 mins)	72.45	45.64	31.71
3.	pH 6 (90 mins)	74.67	38.10	36.88
4.	pH 6 (120 mins)	75.89	37.24	37.65
5.	pH 7 (60 mins)	77.30	30.84	42.60
6.	pH 7 (90 mins)	79.62	29.34	43.52
7.	pH 7 (120 mins)	79.98	28.88	44.53

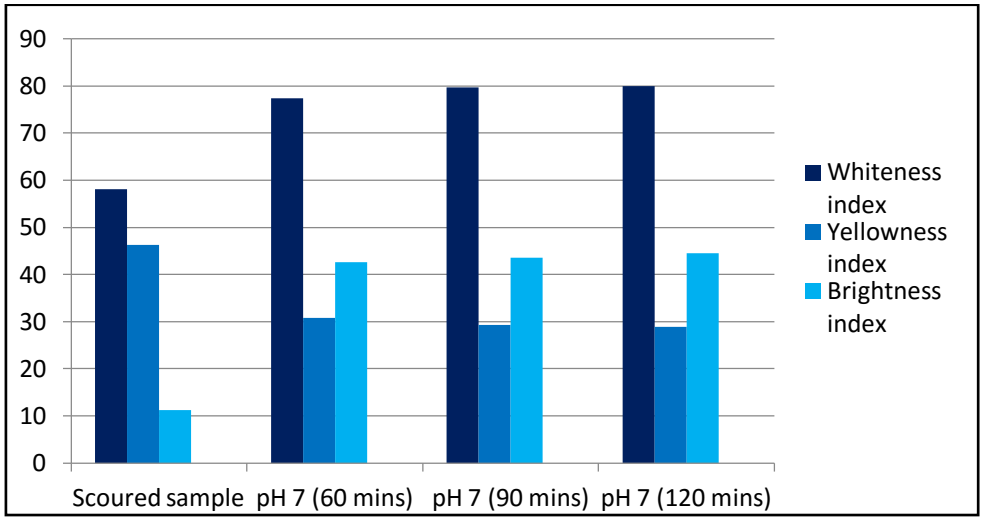
Table 4.32 and the graph 4.14 present the results of the optical indicies of the jute sample bleached with peracetic acid with different concentrations. From the table, it

was observed that for a constant pH, with the increase in period of treatment, the samples became whiter in colour and their yellowness index decreases.

The results for optical indicies of jute fabric bleached with Peracetic acid at different pH is depicted in Graph 4.14.



Graph 4.14: (a): Optical indicies of jute fabric bleached with Peracetic acid at pH 6



Graph 4.14: (b): Optical indicies of jute fabric bleached with Peracetic acid at pH 7

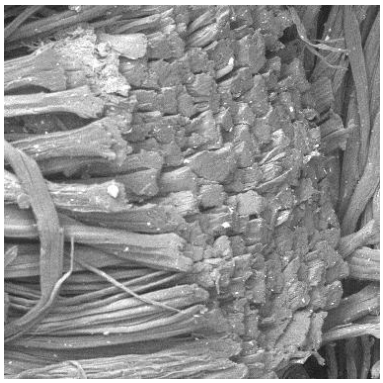
Bleaching affects the physical properties of the fabric mainly the strength, so after bleaching the samples were tested for strength and results presented in tables and graphs.

Table 4.33: Effect of Peracetic acid bleaching on Breaking Load of jute fabric

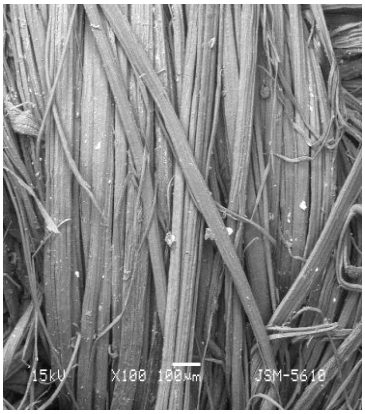
Sr. No.	Samples bleached with peracetic acid	Br. Load (kg)	
		Warpwise	Weftwise
1.	Scoured sample	74.06	73.56
2.	pH 6 (60 mins)	75.7	73.9
3.	pH 6 (90 mins)	75.8	73.7
4.	pH 6 (120 mins)	76.4	74.6
5.	pH 7 (60 mins)	75.0	73.7
6.	pH 7 (90 mins)	75.8	73.5
7.	pH 7 (120 mins)	75.9	73.4

From the table 4.33, it was observed that with the change in time for a constant pH the breaking load in warpwise direction was higher compared to the weftwise direction. Also there was increase in breaking load for a constant pH. This could be because of the shrinkage caused due to the entanglements of fibers which could be seen from SEM images in Plate 4.6. Also when we compare pH 6 and pH 7 ; amongst them pH 7 showed better result.

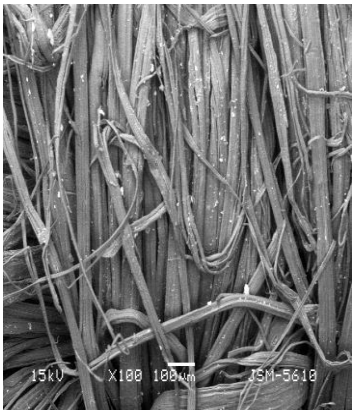
SEM microphotographs (Plate 4.6) were taken at 100 magnifications to assess the effect of various concentrations of Peracetic acid bleach on jute fabric. It shows that in case of scoured sample, the SEM image shows the bundle structure of the jute fabric. After treatment there is change in structure. With the change in pH of Peracetic acid, the SEM images show the entanglement on the fibre structure. Also for a constant pH, there is no significant damage on the fibre structure and only some entanglements can be observed with the increase in time duration.



Scoured Sample

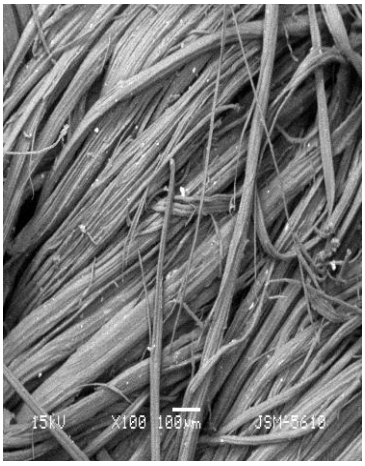


pH 6 (60 minutes)



pH 6 (90 minutes)

pH 6 (120 minutes)



pH 7 (60 minutes)

pH 7 (90 minutes)

pH 7 (120 minutes)

Plate 4.6 SEM images of scoured jute and bleached with Peracetic acid at different pH concentration

From the above results it was observed that bleaching with 10% hydrogen peroxide for 90 minutes produced the best result with some loss in strength whereas for Peracetic acid much higher whiteness was obtained at pH 7 for 90 minutes treatment

with almost no loss in strength. These two conditions for H2O2 and CH3COOOH were therefore selected for further study.

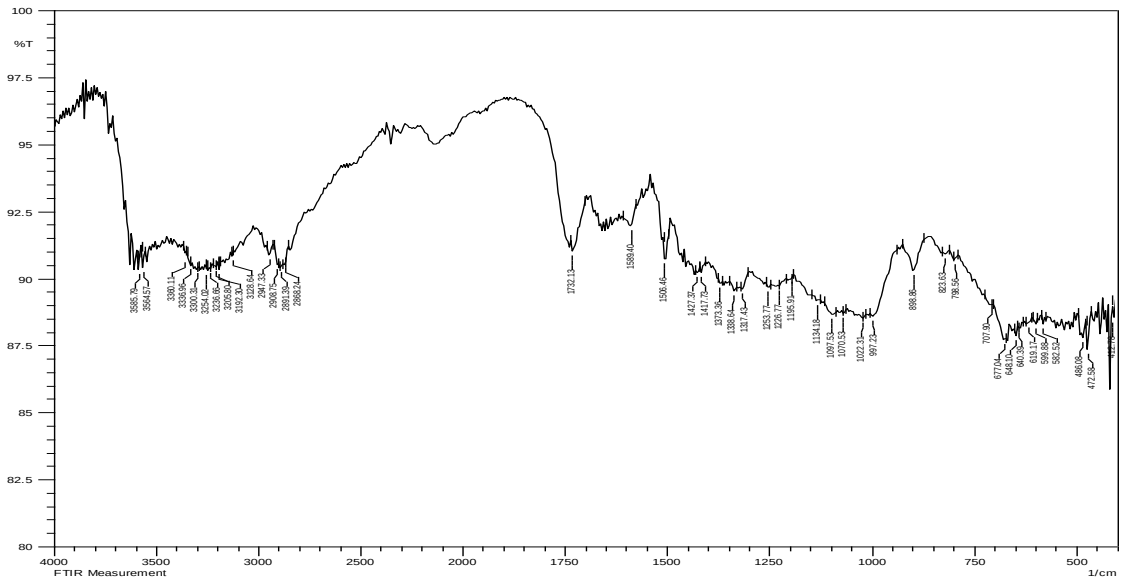
From the theoretical review, it was found that woollenization of jute is also an important pretreatment which affects the physical properties and may be helpful for studying its role in the dyeing ability of jute fabric. Hence, the effect of woollenization ,as a pretreatment for jute fabric , was also investigated.

(B) Woolenization

Woolenization of jute is a process to treat the jute fiber with strong alkali to improve severely the appearance and handle of jute fibers & its blends. According to Mwaikambo (2001) alkalization of plant fibers changes the surface topography of the fibers and their crystallographic structure. The removal of surface impurities is advantageous in fiber matrix adhesion, as it facilitates both mechanical interlocking and bonding reaction due to the exposure of the hydroxyl groups to chemicals such as resin and dyes. Thus, this increases the number of possible reaction sites and allows better fiber absorption. The possible reaction of the NaOH and fiber which is represented as

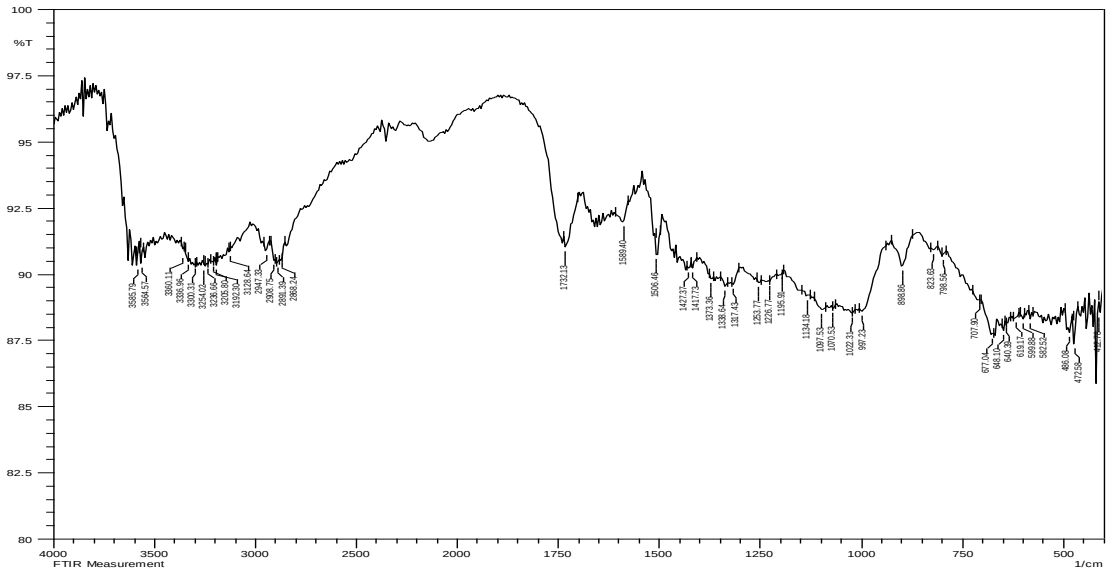
$$NaOH + Fiber\text{-}OH \text{ ---------- } Fiber\text{-}ONa^{+} + H_2O$$

The samples were treated with 15% Sodium hydroxide for 30 minutes at room temperature. The FTIR result for the woollenized sample is shown in Graph 4.15.

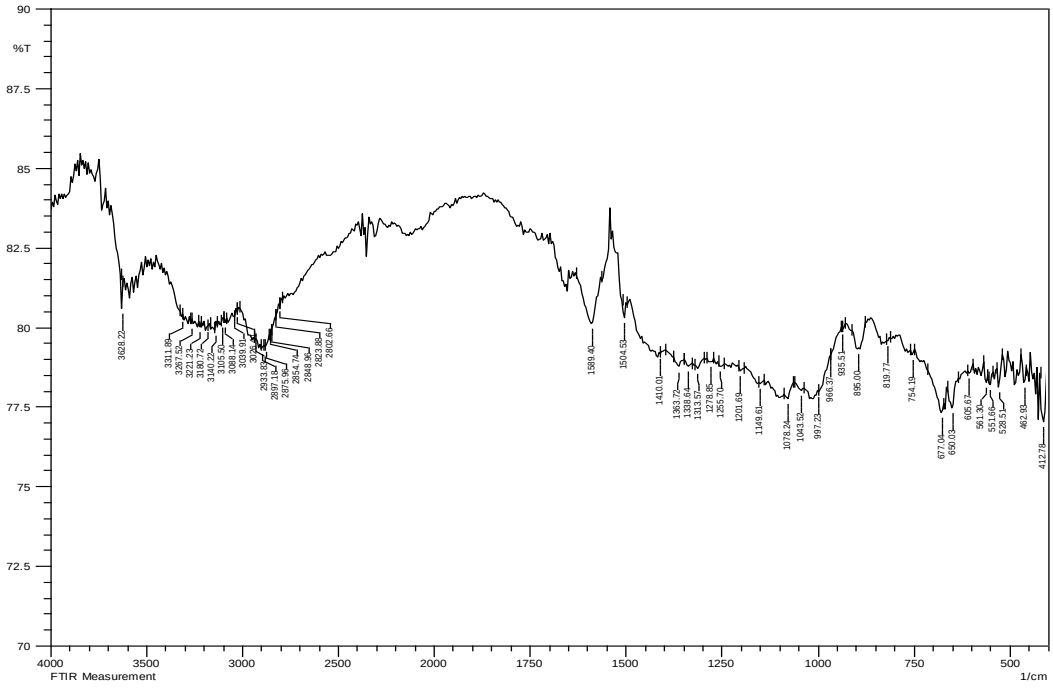


Graph 4.15: FTIR spectra for only woolenized samples

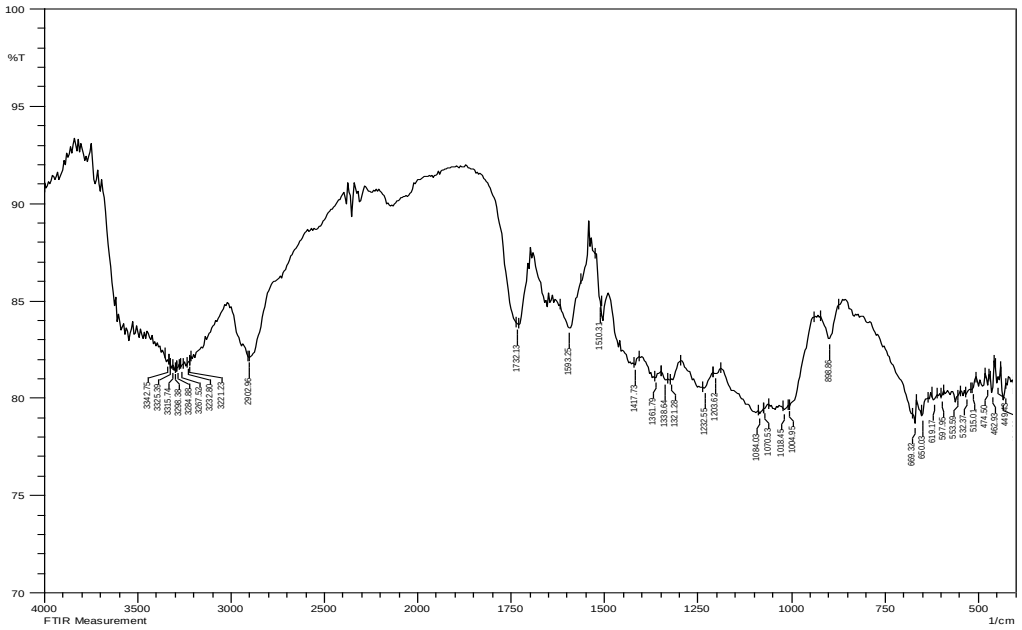
The treatment with alkali gives the jute fabric a yellowish tone whereas the bleaching improves the whiteness index. Hence, it was decided to examine the effect of both woollenization and bleaching for further study. For this three sets of samples were developed one set was only woollenized, the second set was first woollenized and then bleached while the third set was first bleached and then woolenized. The samples were examined visually and analysed scientifically by FTIR analysis.



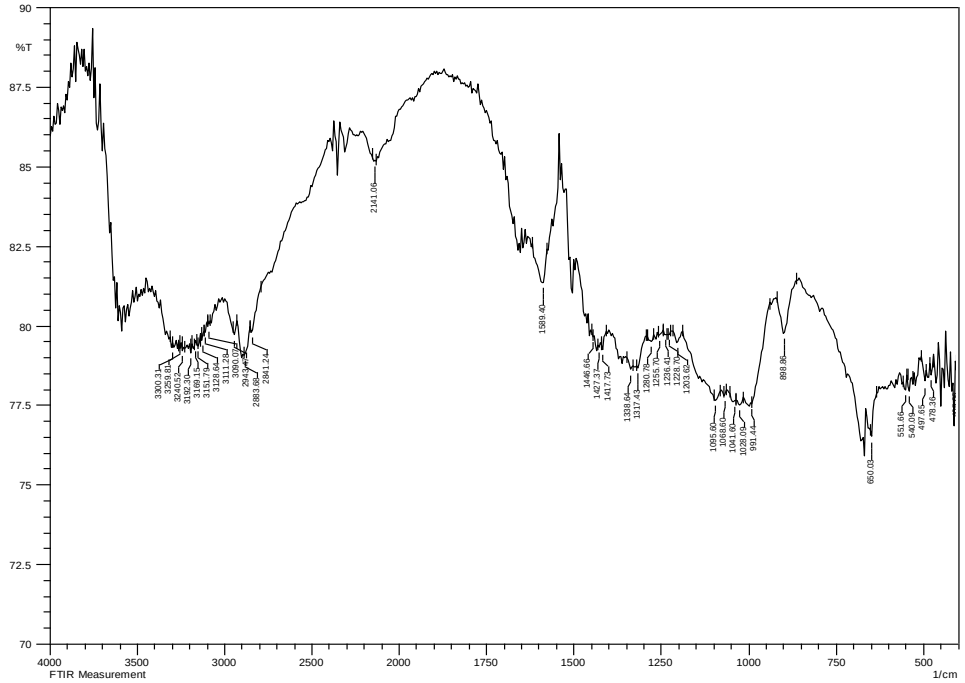
Graph 4.16: FTIR spectra for only woolenized samples



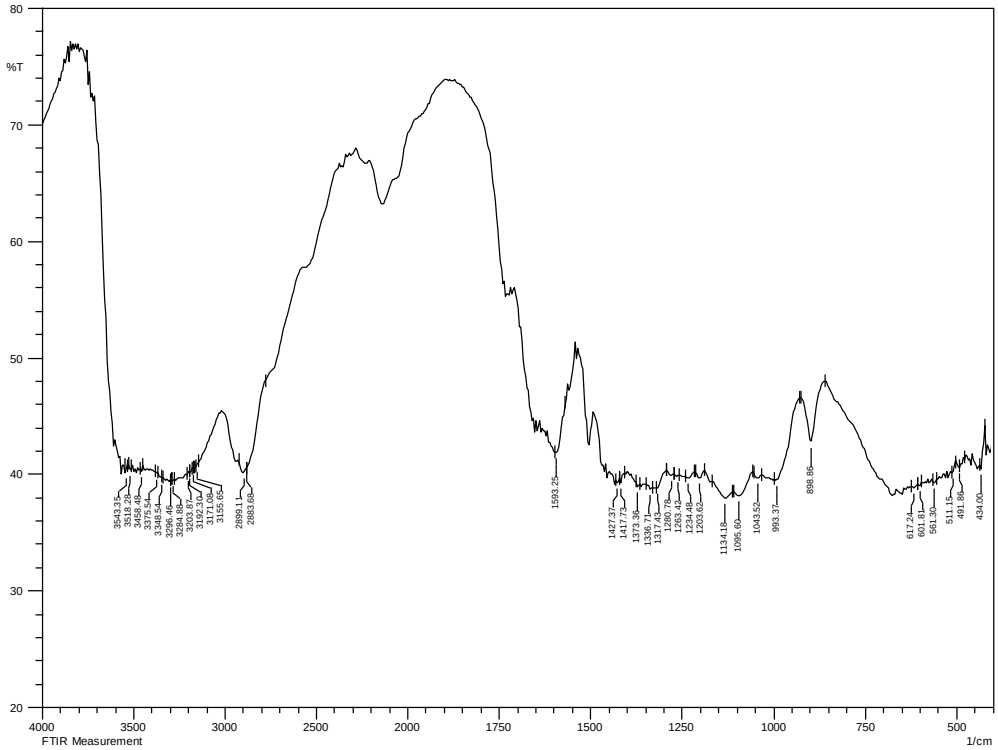
Graph 4.17: FTIR spectra for samples first Woolenized and then bleached with H_2O_2



Graph 4.18 FTIR spectra for samples first Woolenized and then bleached with PAA



Graph 4.19: (a)FTIR spectra for samples bleached with H_2O_2 and then Woolenized



Graph 4.19: (b)FTIR spectra for samples bleached with PAA and then Woolenized

FTIR analysis was conducted to study the characteristics of the jute fibres, before and after bleaching and woollenization treatments. As depicted in Graphs 4.16 to 4.19, the broad peak at 3300 cm−1 which appears in these spectra is attributed to the O–H frequency, whereas the peaks at around 2899 cm−1 predominantly arise from C–H stretching. Another peak at 1732 cm−1 corresponds to ester carbonyl vibrations from the acetyl, feruloyl and p-coumaryl groups in lignin. After bleaching treatment, there was a decrease in the intensity of these peaks, indicating that major part of the lignin has been removed. A stretching peak normally detected at 1635 cm−1 for unbleached fiber is attributed to the carbonyl group of the acetyl ester in hemicellulose and the carbonyl aldehyde in lignin. The absence of this peak after woollenization and bleaching treatment may be due to the removal of lignin and hemicellulose. For bleached jute and woollenized fibres, the disappearance of the vibration peak at round 1,245 cm−1 that corresponds to C–O vibration is also attributed to the removal of lignin.

The sequence to be followed for the pre-treatments was decided on the basis of the results obtained for whiteness, yellowness and brightness. The treatment with alkali

on jute fabrics gave a yellow tint to the fabric. Hence, it was decided to do woolenization followed by bleaching. Standard recipe (given in Chapter III) was followed for woolenization. For bleaching treatments optimised recipe as discussed in Section 4.3.2(A) was followed.

4.3.4 Pre-treatment of the fabric

The scoured samples were woolenized using the standard recipe and then bleached using following three methods:-

Method I: Bleaching with 10% hydrogen peroxide for 90 minutes.

Method II: Bleaching with peracetic acid at pH 7 for 90 minutes.

Method III: The samples were sequentially bleached with Peracetic acid followed by hydrogen peroxide using the conditions used in method I & II.

Optical indices of the bleached samples were measured and sequential bleaching was found to produce the best whiteness. The results are also in accordance with the results reported by Chattopadhyay et.al. (1999). Bleaching with hydrogen peroxide results in strength and weight loss whereas that with peracetic acid gives better feel and high abrasion resistance. Sequential bleaching with peracetic acid and hydrogen peroxide produced higher whiteness, lower loss in strength and abrasion resistance and improved softness. The values of optical indices are presented in table 4.34.

Table 4.34: Results of optical indicies of the samples bleached with three different bleaching agents

Sr. No.	Parameters	Scoured sample	10% H_2O_2	PAA pH 7	Sequential
1.	Whiteness Index	37.7	62.5	79.6	81.7
2.	Yellowness Index	51.8	32.1	29.3	26.5
3.	Brightness index	11.4	34.7	43.5	46.8

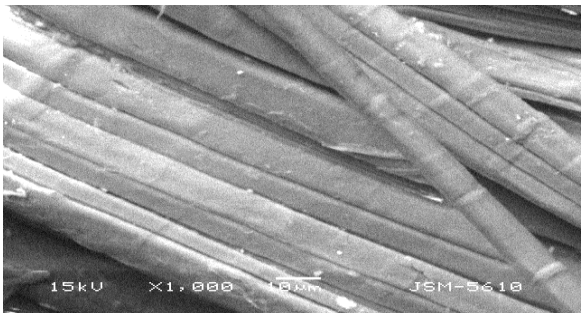
4.3.5 Application of mordants

From the pilot work, it was observed that pre mordanting was found to perform better than post mordanting. Alum was selected as pre-mordanting agents for further work amongst the three mordants viz. alum, copper sulphate and ferrous sulphate used

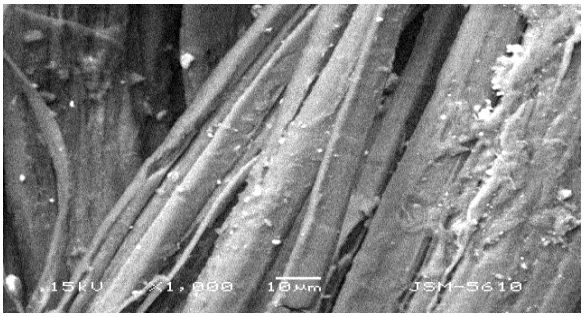
earlier. Beside alum, Harda was used as natural mordant and copper was converted to nano form and used as mordanting agent in this study.

According to Chattopadhyay et. al (2010) copper nano treatment on cotton showed improved tensile strength and was also found to enhance the dyeability of cotton with direct dyes. Both wash and rub fastness were upgraded due to this treatment. It also increased the resistance to microbial attack and thus increasing the effective life span of the treated fabric.

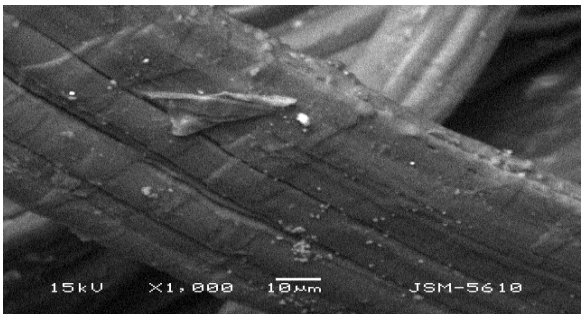
Jute fabric was treated with copper nano following the recipe and methods given in Chapter III. The presence of nano-copper particles on jute can be seen from the scanning electron microphotographs (Plate 4.7).



(A) Woolenized and Bleached Jute Sample



(B) Jute sample pre mordanted with nano-copper

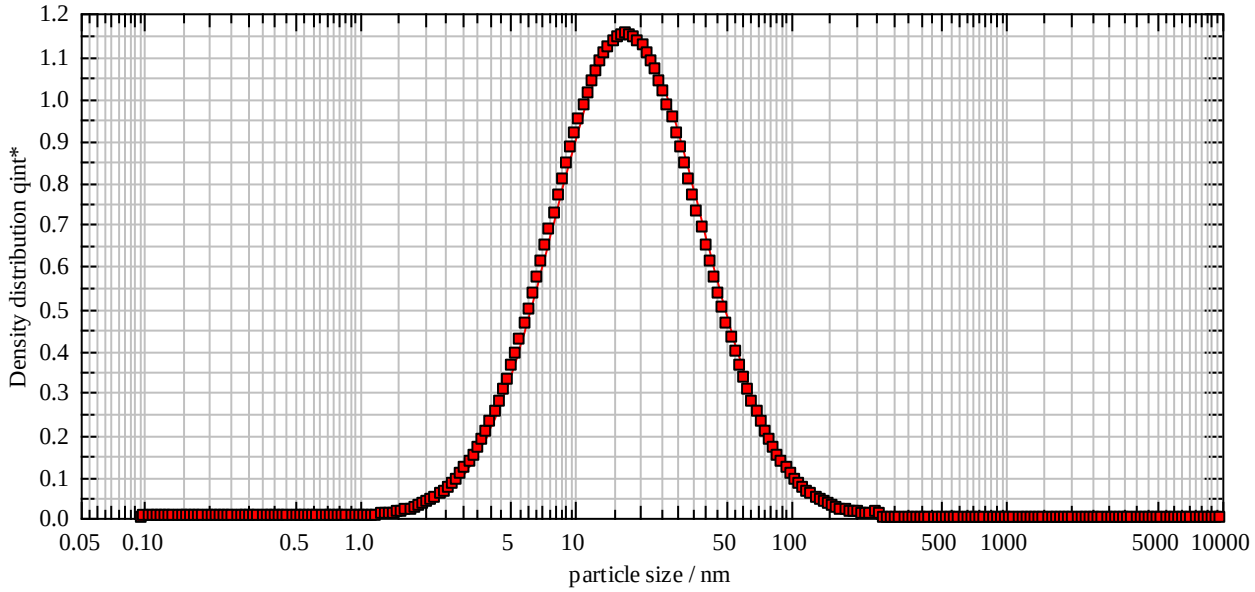


(C) Nano-copper pre mordanted and dyed jute

Plate 4.7 SEM images of woolenized and bleached jute and nano copper treated samples

From the plate 4.7 (B), shows the distribution of nano-copper particles on jute fabric which helped in anchoring dye molecules 4.7(C) and caused improved fastness properties.

Graph 4.20 shows the particle size distribution of synthesized copper nano particles. From the graph 4.20 it is clear that the particle size of the majority of the laboratory synthesized nano copper particles are much lesser than 100nm. The particles therefore easily penetrated inside the fibre structure which could form complex with the natural dyes used resulting improved colour and fastness properties



Graph 4.20 Particle size distribution of synthesized nano Copper

4.3.6 Application of natural dyes

As a natural dye source; madder and turmeric as root source and Eucalyptus leaves and Indian Almond leaves as leaf sources were used. So, a total of four dyes were selected for the study. Mordants selected for the study were alum, harda and nano-copper and their combinations were tried out. Hence, a total of six variations of mordants were tried. Three bleaching agents were selected. Thus, 18 shades per dye were developed using different mordant variations and bleaching agents which resulted a grand total of 72 shades for the four dyes. Plate 4.8 to 4.11 shows the shades produced by these dyes.

Table 4.35 Colour parameters for sample dyed with Madder using different mordants

Samples mordanted with	**Colour Parameters**		
	Da*	Db*	K/S
Samples bleached with H_2O_2			
Alum	27.5	14.6	10.3
Harda	26.7	14.4	9.9
Alum + Harda	26.8	14.9	10.0
Nano Copper	26.9	15.4	8.9
Alum + Nano Copper	27.1	15.5	9.0
Samples bleached with CH_3COOOH			
Alum	27.6	14.8	10.7
Harda	27.2	14.6	10.2
Alum + Harda	26.9	14.2	10.5
Nano Copper	27.2	15.5	9.4
Alum + Nano Copper	27.0	15.8	9.9
Samples bleached with Sequentially			
Alum	27.9	14.9	11.2
Harda	27.3	14.8	10.7
Alum + Harda	26.9	14.4	10.9
Nano Copper	27.6	15.7	9.9
Alum + Nano Copper	27.5	15.9	10.3

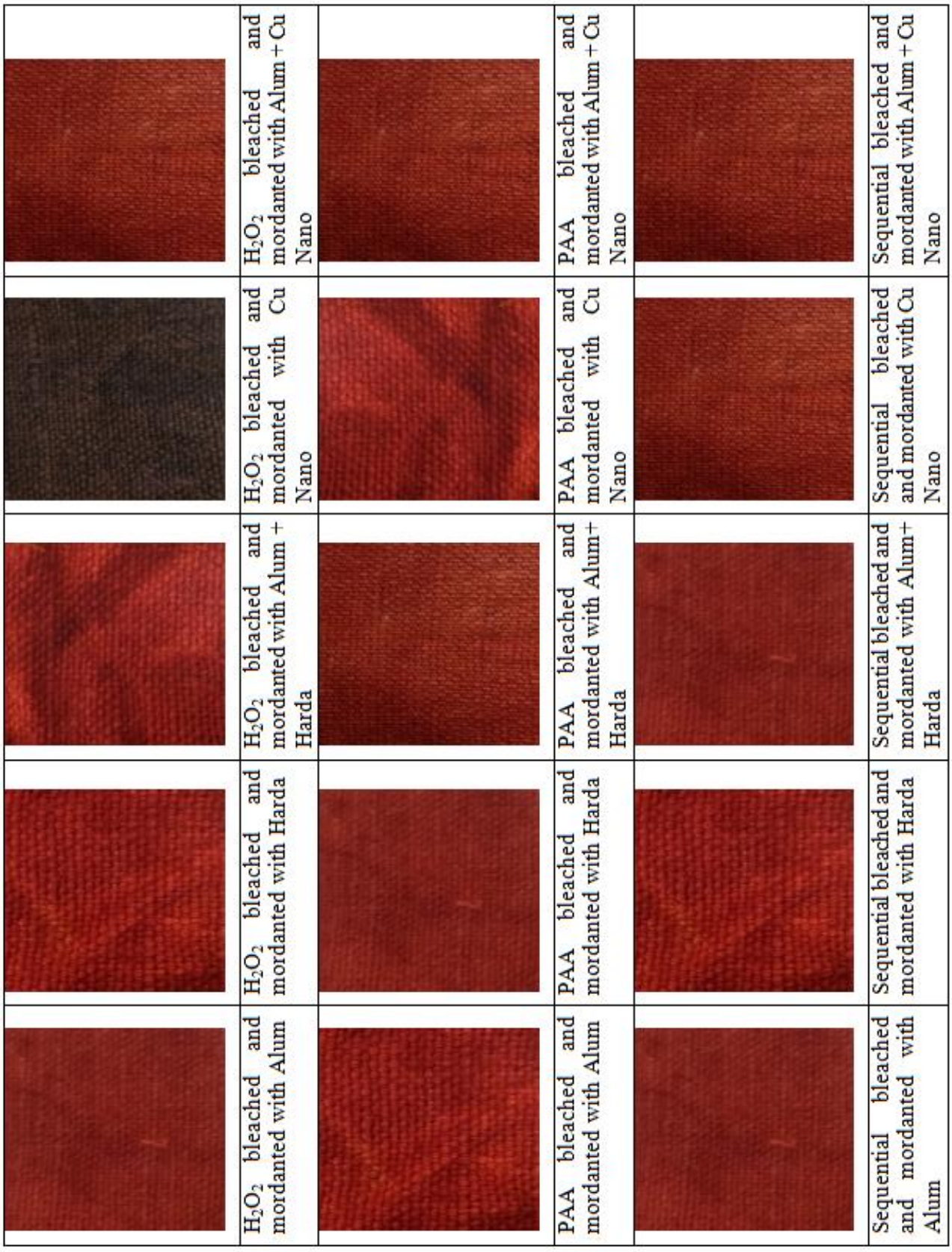


Plate: 4.8 Shades of Madder on pre-bleached samples of jute and dyed

Table 4.35 shows the colour parameters of samples pre bleached with different bleaching agents when pre mordanted with various mordants and dyed with madder dye. From the table, it was observed that the samples pre mordanted with alum in all the bleaching agents show higher K/S values compared to the other mordants. Also, it was observed that the samples pre mordanted with the combinations of alum show good result in terms of K/S compared to the pre mordanted samples with the mordant alone. Among the three bleaching agents viz hydrogen peroxise, peracetic acid and sequential bleaching, the sequential bleaching was observed to give best K/S results. The shades of madder when pre mordanted with alum, harda, nano copper and their combinations varied from maroon to coffee.

Table 4.36 Colour parameters for sample dyed with Turmeric using different mordants

Samples mordanted with	**Colour Parameters**		
	Da*	Db*	K/S
Samples bleached with H_2O_2			
Alum	20.7	58.4	32.3
Harda	19.5	60.1	28.6
Alum + Harda	18.5	59.9	28.7
Nano Copper	21.6	60.9	29.6
Alum + Nano Copper	19.3	63.1	29.7
Samples bleached with CH_3COOOH			
Alum	20.9	58.3	32.8
Harda	19.8	60.6	28.7
Alum + Harda	18.7	59.9	28.9
Nano Copper	21.5	60.5	29.9
Alum + Nano Copper	19.6	62.9	29.8
Samples bleached with Sequentially			
Alum	21.3	57.9	33.1
Harda	19.9	60.5	29.0
Alum + Harda	19.0	59.9	28.9
Nano Copper	21.9	60.7	30.0
Alum + Nano Copper	20.1	63.0	30.1

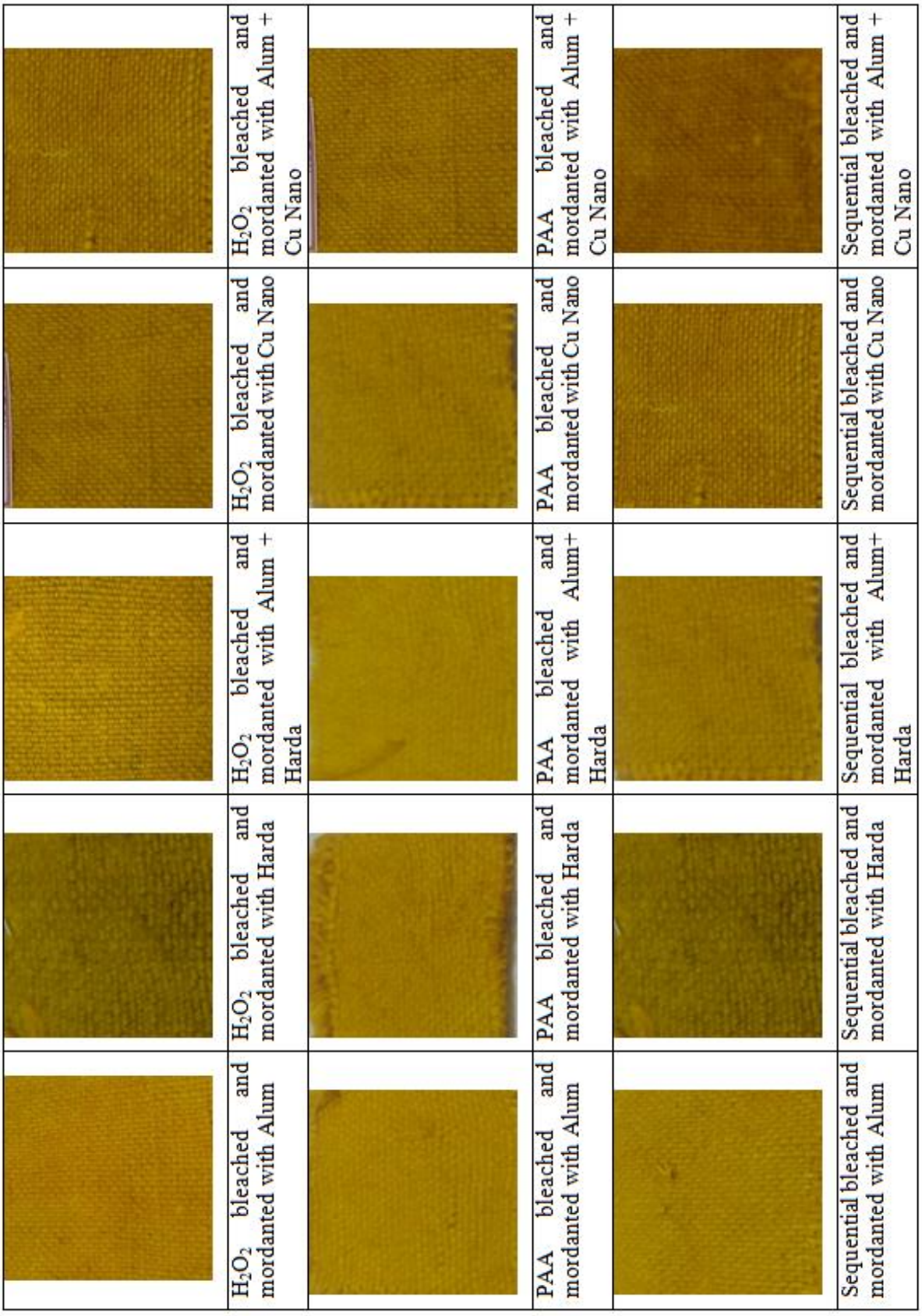


Plate : 4.9 Shades of Turmeric on pre-bleached samples of jute and dyed

From the table 4.36, it was observed that for the samples pre bleached with different bleaching agents and pre- mordanted with various mordants and dyed with turmeric showed the K/S values which ranged from 33.1 to 28.6. The visual inspection of the samples dyed with turmeric dye indicated that the samples obtained yellow ochre to mustard to brown shades. The values of Da^* and Db^* readings indicate that all the samples fall in yellow-green quadrant more towards the yellow axis. The samples pre bleached with sequential bleaching gave the highest K/S values compared to the other bleaching agents.

Table 4.37 Colour parameters for sample dyed with Eucalyptus leaves using different mordants

Samples mordanted with	**Colour Parameters**		
	Da^*	Db^*	K/S
Samples bleached with H_2O_2			
Alum	-3.2	5.6	7.7
Harda	-2.8	3.5	7.5
Alum + Harda	-3.0	3.9	6.7
Nano Copper	-2.2	2.9	6.6
Alum + Nano Copper	-2.6	3.1	7.7
Samples bleached with CH_3COOOH			
Alum	-3.4	5.7	7.9
Harda	-2.9	3.7	7.7
Alum + Harda	-3.1	4.2	6.9
Nano Copper	-2.4	3.1	6.7
Alum + Nano Copper	-2.9	3.4	8.0
Samples bleached with Sequentially			
Alum	-3.6	5.9	8.2
Harda	-3.3	3.8	8.0
Alum + Harda	-3.7	4.6	7.3
Nano Copper	-2.7	3.5	7.0
Alum + Nano Copper	-3.4	3.9	8.5

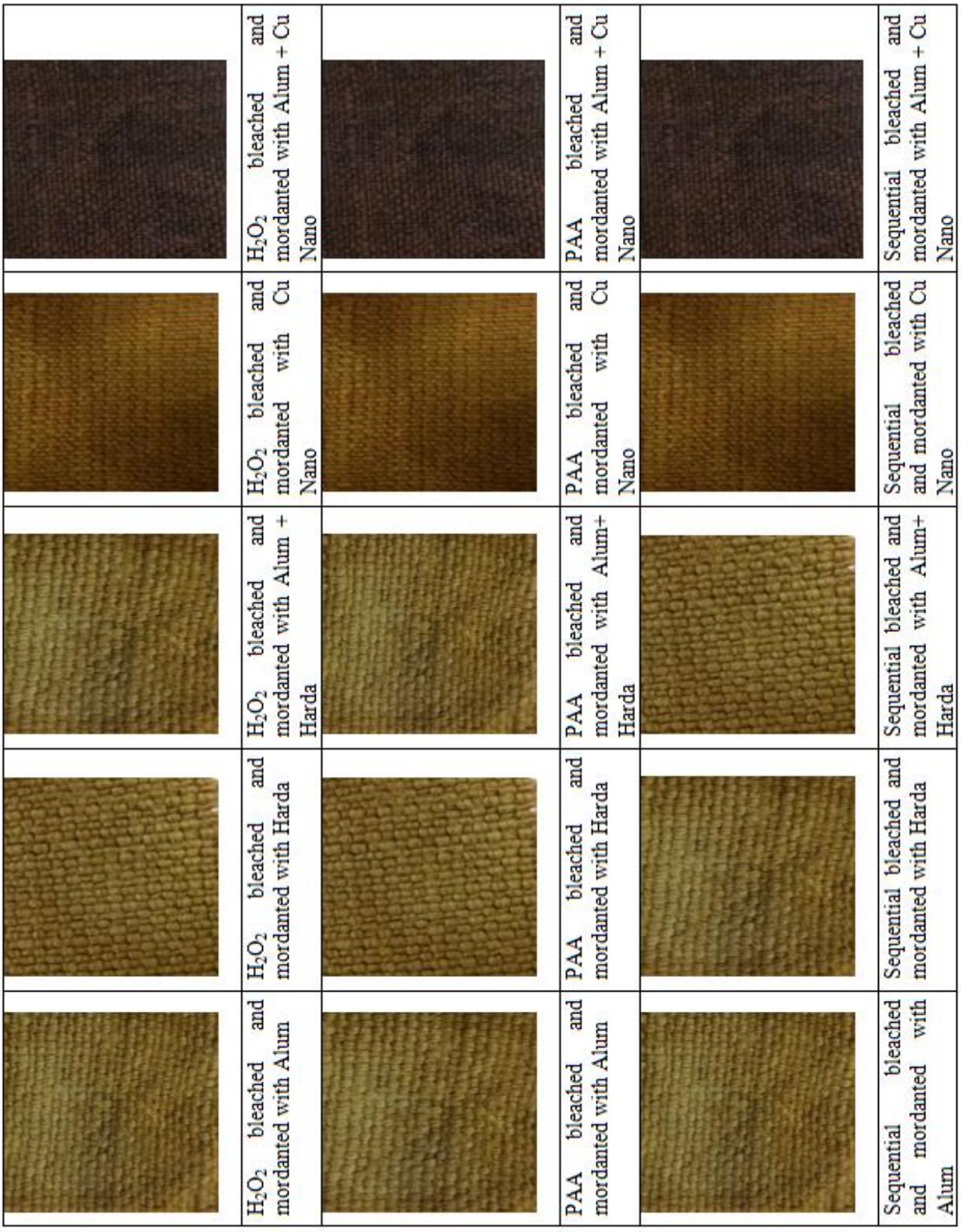


Plate : 4.10 Shades of Eucalyptus leaves on pre-bleached samples of jute and dyed

From the above table 4.37, it was observed that the Da^* values were negative indicating that the samples pre bleached with different bleaching agent and pre-mordanted with various mordants and dyed with eucalyptus leaves indicates the presence of green colour. The visual inspection also supports the fact, where the shades obtained ranged from light fawn to dark brown. The combination of alum and nano copper show the highest K/S values in case of any bleaching agents. The maximum K/S value (8.5) was observed in terms of the sample pre- bleached with sequential bleaching agent and pre mordanted with the combination of alum and nano copper. In was also observed that with the introduction of nano copper the colour strength of the particular sample increased.

Table 4.38 Colour parameters for sample dyed with Indian Almond leaves using different mordants

Samples mordanted with	**Colour Parameters**		
	Da^*	Db^*	K/S
Samples bleached with H_2O_2			
Alum	-2.4	5.6	23.4
Harda	-1.8	3.6	22.9
Alum + Harda	-2.2	4.9	23.0
Nano Copper	-2.8	1.3	21.7
Alum + Nano Copper	-1.9	1.6	22.5
Samples bleached with CH_3COOOH			
Alum	-2.7	5.9	23.8
Harda	-1.9	3.7	23.0
Alum + Harda	-2.6	5.3	23.6
Nano Copper	-2.9	1.7	21.9
Alum + Nano Copper	-2.0	1.9	22.9
Samples bleached with Sequentially			
Alum	-2.9	5.8	24.0
Harda	-2.0	3.9	23.4
Alum + Harda	-2.8	5.4	23.7
Nano Copper	-2.6	1.9	22.0
Alum + Nano Copper	-2.2	2.1	22.9

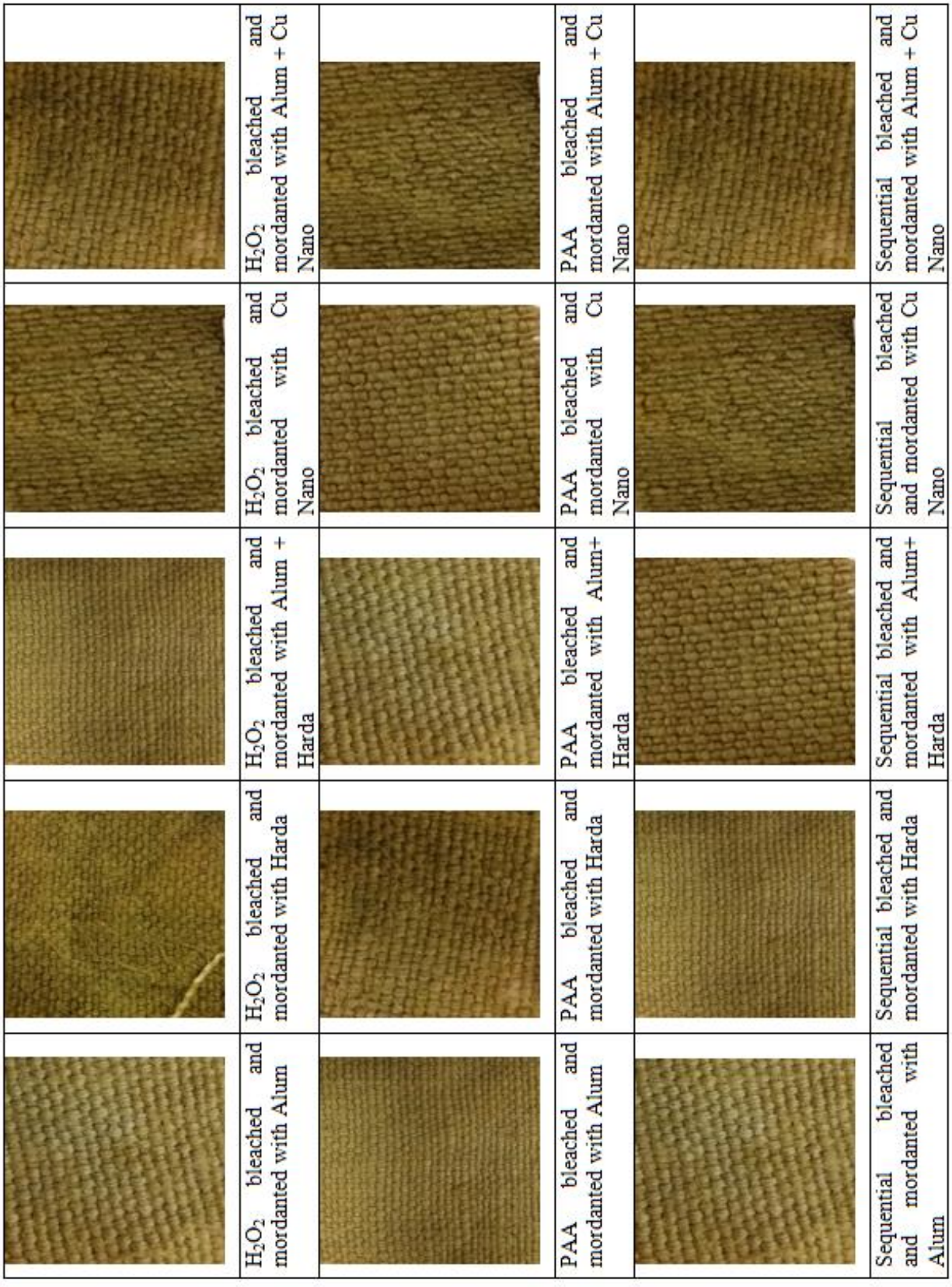


Plate : 4. 11 Shades of Indian Almond leaves on pre-bleached samples of jute and dyed

The shades obtained from the samples dyed with Indian almond leaves showed a beautiful olive green ranging from dark to light depending on the interference from the mordants they were pretreated with. This was supported by the negative Da^* values indicated the presence of green colour. The K/S values for the samples dyed with Indian almond leaves ranged between 22.0 to 24.0. The highest K/S value was observed for the samples pre bleached with sequential bleaching amongst the other bleaching agents. In case of all the bleaching agents, the samples pre-mordanted with alum showed the highest K/S value, which was followed by the samples pre-mordanted with the combination of alum and nano copper.

4.3.7 Fastness Properties of the selected natural dyes

Table 4.39 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Madder using different mordant

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	2
Alum	4	4	3	3	3	2
Harda	3-4	4	3	2	2-3	3
Alum + Harda	4	4	4	4	3	2
Nano Cu	3-4	4	3	4	2-3	3
Alum + Nano Cu	4	4	4	4	3	2
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum	4	4	4	4	4	4
Harda	4	4	3	3	3	3
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	3-4	3-4	3	3
Alum + Nano Cu	4-5	4	4-5	4	5	5
Samples bleached with Sequential						

Standard	3	4	2	2	4	4
Alum	4-5	4	4-5	4	5	5
Harda	4-5	4	4-5	4	4	4
Alum + Harda	4	4	4	4	4	3
Nano Cu	4	4	4	4	4	4
Alum + Nano Cu	4	4	4	4	5	5

It was observed from the table 4.39 that the samples pre bleached with Hydrogen Peroxide and dyed with madder showed average to good fastness properties. As observed from the table, the change in colour ranged between 3-4 to 4 whereas staining on white was rated as 4. This could be due to the superficial dye onto the samples that was removed during the vigorous laundering procedure. The rub fastness ranged between average to good, this could also be due to the superficial dye, which got removed during crocking. Light fastness in this case showed average to poor.

In case of the samples bleached with Peracetic acid, the fastness properties varied from average to excellent. The light fastness showed better results compared to the samples bleached with Hydrogen Peroxide. Here the light fastness ranged from average to excellent. Staining on white was caused due to the superficial dye on the samples. The sample pre-mordanted with the combination of alum and nano copper showed the best result in terms of wash, rub and light fastness.

Amongst the three bleaching agents, the samples pre bleached with sequential bleaching showed the best result in terms of wash, rub and light fastness. As observed from the table, the values ranged from very good to excellent. The light fastness ratings were in absolute contrast. The sample pre-mordanted with the combination of alum and nano copper showed excellent light fastness ratings for 10 and 20 hours of exposure to light. The fastness rating of wash and rub ranged from very good to excellent. Amongst the mordants used, samples pre-mordanted with combination of alum and nano copper showed the best result in terms of wash, rub and light fastness.

Table 4.40 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Turmeric using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	4
Alum	3	4	3	3	4	4
Harda	3	4	3	2	3	3
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	3	3	3	3
Alum + Nano Cu	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum	4	4	4	4	4	4
Harda	4	4	3	3	3	3
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	3-4	3-4	3	3
Alum + Nano Cu	4	4	4	4	5	5
Samples bleached with Sequential						
Standard	3	4	2	2	4	4
Alum	4	4	4	4	5	5
Harda	4	4	4	4	4	4
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	4	3-4	4	4
Alum + Nano Cu	4	4	4-5	4	4-5	4-5

It was noted from the table 4.40 that samples pre bleached with sequential bleaching showed the best result amongst the three bleaching agents. The wash fastness ratings ranged from average to good in terms of colour change and staining on white readings was 4 for all the mordants in case of all the bleaching agents which indicated good fastness to washing. The crock fastness ratings ranged for average to excellent for staining on white (dry). While for staining on white (wet) showed the ratings between poor to excellent in case of overall rub fastness for the samples dyed with turmeric. The light fastness also varied from average to excellent in terms of overall view of the samples dyed with turmeric.

Table 4.41 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Eucalyptus Leaves using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Hydrogen Peroxide						
Standard	3	3	3	3	3	3
Alum	4	4	4	4	4	4
Harda	4	4	3-4	3-4	3	3
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	3-4	3-4	4	4
Alum + Nano Cu	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	4	2	2	4	4
Alum	3	3	3	3	4	4
Harda	3	3	3	3	4	4
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	3	3	3	3
Alum + Nano Cu	4	4	4	4	4	4
Samples bleached with Sequential						
Standard	3	4	2	2	4	4
Alum	4-5	4	4-5	4	5	5

Harda	4-5	4	4-5	4	4	4
Alum + Harda	4	4	4	4	4	4
Nano Cu	4-5	4	4-5	4	5	5
Alum + Nano Cu	4-5	4	4-5	4	4	4

Table 4.41 showed the readings of fastness properties of the samples bleached with different bleaching agents and dyed with eucalyptus leaves. Readings from the table revealed that the samples bleached with Hydrogen Peroxide showed the overall fastness ratings as average to good. The light fastness of the sample pre mordanted with harda showed average readings for 10 hours and more exposure to light while the other samples gave the readings as good with the score of 4. Wash fastness ratings was 4 for change in colour and for staining on white which indicated good wash fastness.

The samples bleached with Peracetic acid showed average to good results. The wash and rub fastness showed average ratings. This could be due to the superficial dye onto the samples and hence while washing or crocking procedure; the dyes must have been removed. The light fastness in comparatively good only the post mordanted copper sulphate treated samples showed average readings.

In case of the samples bleached with sequential bleaching, all the samples had good to excellent performance to fastness to laundering, fastness to crocking and fastness to exposure to light.

Table 4.42 Fastness rating of Jute samples bleached with the three bleaching agents dyed with Indian Almond Leaves using different mordants

Sample	Wash Fastness		Rub Fastness		Light Fastness	
	Change in colour	Staining on white	Staining on white Dry	Staining on white Wet	Rating at 10 hrs	Rating at 20 hrs
Samples bleached with Hydrogen Peroxide						
Standard	3	4	2	2	4	4
Alum	3	4	3	3	4	4

Harda	3	4	3	2	3	3
Alum + Harda	4	4	4	3	4	4
Nano Cu	4	4	4	4	4	4
Alum + Nano Cu	4	4	4	4	4	4
Samples bleached with Peracetic Acid						
Standard	3	3	3	3	3	3
Alum	4	4	4	4	4	4
Harda	4	4	3-4	3-4	4	3
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	4	4	4	4
Alum + Nano Cu	4	4	4	4	4	4
Samples bleached with Sequential						
Standard	3	4	2	2	4	4
Alum	4-5	4	4-5	4	5	5
Harda	4-5	4	4-5	4	4	4
Alum + Harda	4	4	4	4	4	4
Nano Cu	4	4	4	4	4	4
Alum + Nano Cu	4	4	4	4	5	5

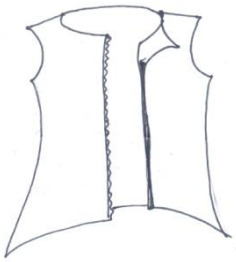
It was observed from the table 4.42, that the samples bleached with hydrogen peroxide dyed with Indian almond leaves showed averaged to good wash fastness in terms of change in colour. In terms of staining on white the readings were 4 for all the samples which indicated good wash fastness. For rub fastness, the staining on white both dry and wet showed average to good readings. Hence, it can be concluded that the samples when bleached with hydrogen peroxide and dyed with Indian almond leaves gave average rub fastness. The light fastness as observed from the table, showed good results except for sample pre mordanted with harda.

The overall readings for the samples bleached with peracetic acid dyed with Indian almond leaves showed good rating in terms of wash fastness and light fastness. The rub fastness of these samples showed average to good except for sample pre mordanted with harda.

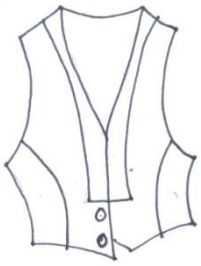
In case of samples bleached with sequential bleaching dyed with Indian almond leaves, the wash and crock fastness ratings showed good to excellent readings. The sample pre mordanted by alum and the samples pre mordanted with the combination of alum and nano copper showed excellent ratings while the other samples gave good readings in terms of light fastness.

4.4 Phase- III: Development of product

To test the applicability of jute fabric other than sacks and packing material, the treated fabric was explored for its use in apparels. For that ten jackets were designed and best four jackets were purposely selected. Two natural dyes namely Turmeric (root source) and Indian almond leaves (leaf source) were selected for dyeing these finalized jackets. Two jackets in each dye were pre mordanted and dyed with turmeric and Indian almond leaves. Plate 4.12 shows the sketches of final four selected jackets which were constructed.



Design 4



Design 6

Design 7

Design 10

Plate 4.12 Sketches of final four selected jackets

Front	Profile	Back
Design 4		

Front	Profile	Back
Design 6		

Front	Profile	Back
Design 7		

Front	Profile	Back
Design 10		

Plate 4.13 Photographs of the constructed jackets

Costing Analysis

		
Front	Profile	Back
Design A		
Cost: 1700/-		
		
Front	Profile	Back
Design B		
Cost: 2000/-		

Design A	
Material Cost for 2mts. of fabric	300/-
Dyeing Charges	200/-
Stitching Charges	1200/-
Total cost of jacket A	1700/-

Design B	
Material Cost for 2mts. of fabric	300/-
Dyeing Charges	200/-
Stitching Charges	1500/-
Total cost of jacket A	2000/-

Costing Analysis

		
Front	Profile	Back
Design C		
Cost: 2000/-		
		
Front	Profile	Back
Design D		
Cost: 1700/-		

Design C

Material Cost for 2mts. of fabric	300/-
Dyeing Charges	200/-
Stitching Charges	1200/-
Total cost of jacket A	1700/-

Design D

Material Cost for 2mts. of fabric	300/-
Dyeing Charges	200/-
Stitching Charges	1500/-
Total cost of jacket A	2000/-