Int.J.Curr.Microbiol.App.Sci (2020) *9*(12): 1421-1434

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 12 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.912.171

Development of Eco-friendly Prints on Cotton Khadi Fabric with Selected Natural Dyes and Natural Mordants

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Keywords

Standardization, Khadi, Prints, Development, Natural, Dyes, Mordants

Article Info

Accepted:
12 November 2020
Available Online:
10 December 2020

A B S T R A C T

Khadi fabric is handspun and hand-woven cloth primarily made out of cotton, but now khadi wool and khadi silk is also available. Khadi fabric has become fashion statement on account of its popularity among youth, adults and designers as well. The use of non-toxic and eco-friendly natural dyes on textiles has become a matter of significant importance because of the increased awareness about environmental pollution and harmful effect of hazardous synthetic dyes. The present paper discusses the standardization process of dyeing and printing with selected three natural dyes and five natural mordants for developing eco-friendly prints on cotton khadi fabric. Effect of dyes and mordants on preliminary properties of khadi fabric and also the varied shades obtained on printed fabric has been analyzed by subjective evaluation.

Introduction

Khadi today is dyed in a variety of colors and decorated by block prints. It is tied and dyed; block printed to give it beautiful surface. In Gujarat Khadi is embellished with embroidery and mirror-work.[1]Nature has given us a number of plants to use them in dyeing processes for safe life. These eco-friendly dyes are non-toxic, non-allergic and non-carcinogenic soothing harmless effects, found very encouraging and cost-effective. Natural dyes/colorants derived from flora and fauna are believed to be safe because of its non-toxic, non-carcinogenic and biodegradable in nature.[2]The use of natural dyes in textile application is growing in popularity because of the natural colour obtained as well as environmental commutability of the dyes[3] but they have limited coloring capacity by themselves; require the aid of mordants to penetrate because most of the dyes are less substantive.[4]The use of natural dyes for textile colouration has been confined to craftsman, small-scale dyers, and printers as well as small exporters and producers dealing with high-value eco-friendly textile production and sales.[5] India is still the largest producer of

natural dyed Textiles.[6] There is need to reinvestigate and re-build the traditional process of natural dyeing to control each treatment and pre-dyeing process (preparation mordanting) and dyeing process variables for producing uncommon shades with balanced colour fastness and eco-performing textiles.[7] In view of the above, present study focusses on *standardization of natural dyeing process on cotton Khadi fabric with selected natural dyes for developing ecofriendly prints.*

Experimental

The study includes experimental research design to develop ecofriendly prints on cotton Khadi fabric using selected natural dyes and mordants. Printed samples have been assessed for shades and colour strength by subjective evaluation method. Pure cotton khadi fabric was procured from Khadi Gram Udyog, Udaipur.

Determination of preliminary data of the selected cotton Khadi fabric

Preliminary properties played a very important role in the selection of fabric. Before and after scouring the preliminary properties were assessed i.e. fabric count, fabric thickness, and fabric weight. The data presented in Table 1, clearly shows that the fabric count of selected cotton khadi fabric was 65 × 43 ends & picks per inch square, weighing. 347 g/m^2 with thickness 1.43 mm.

After scouring the changes were observed in all preliminary properties of selected Khadi fabric. The fabric count of scoured Khadi fabric showed of 67 × 45 ends & picks per inch square, weighing. 224 (g/m^2) with 1.35 mm thickness. After scouring, *Terminalia chebula* was used for pre- mordanting on scoured cotton Khadi fabric with 2% concentration at room temperature.

Selection of dyes and mordants

Three natural dyes i.e. *Butea monosperma Eucalyptus globulus* and *Rubia cordifolia*, and five mordants *Punica granatum, Phyllanthus emblica, Terminalia bellirica, Acacia catechu* and Ferrous sulfate were selected to conduct the experiment using the pre-mordanting method to develop the prints on cotton khadi fabric samples.

Results and Discussion

Standardization of natural dyeing process on cotton Khadi fabric

For standardization of the dyeing process, different dyeing parameters were optimized i.e. dye extraction time, dyeing concentrations and dyeing time based on percent dye absorption and visual evaluation.

Optimization of dye extraction time of selected natural dyes

The dye extraction time was optimized from five-time durations i.e. 1 hours, 6 hours, 12 hours, 24 hours and 48 hours at room temperature. Table 2 exhibits the data regarding the selection of dye extraction time of different natural dye sources for the treatment of cotton Khadi fabric.

It was found that as the extraction time of the dye increased, the percent dye absorption also increased. It is clear from the Table that the time duration of 48 hours obtained percent dye absorption of 50.53, 50.93 and 49.39 with *Butea monosperma, Eucalyptus globulus* and *Rubia cordifolia,* dyes respectively. On the other hand, the maximum percent dye absorption was absorbed with *Eucalyptus globulus* and *Butea monosperma*dye sequentially on the basis of the present results the optimum extraction time duration of 48 hours was selected.

Selection of three dyeing concentrations of selected natural dyes

The data regarding the concentrations of different dye solutions is presented in Table 3 which was carried out at five different dye concentrations i.e. 10% 20%, 30%, 40% and 50%. It is apparent from the Table that when the dye concentration was increased, the percent dye absorption also increased. *Rubia cordifolia* dye observed 55.31 to 60.19 percent dye absorption with all dye concentrations. *Eucalyptus globulus* showed 52.39, to 59.02 percent dye absorption and *butea monosperma* dye observed 53.00 to 58.97 percent dye absorption at selected dye concentrations. Three dye concentrations of selected natural dyes selected were 10, 20 and 30 percent concentration for the fixation of the colour to the cotton Khadi fabric.

Optimization of dyeing time of selected natural dyes

It is apparent from the Table 4 that the dyeing treatment was given for different time duration i.e. 30, 45, 60, 75 and 90 minutes. When the dyeing treatment was carried out for 30 minutes the percent dye absorption was 30.92, 24.34, 31.34, 35.84, 33.45 and 31.39 with different dyes i.e. *Butea monosperma, Eucalyptus globulus, Rubia cordifolia, Quercus infectoria, Alkanna tinctoria* and *Thuja orientalis* respectively.

As the time duration of the dyeing treatment was increased from 30 minutes - 90 minutes, increase in the percent dye absorption was noticed from 30.92- 58.89, 24.34 - 59.39 and 31.34 - 61.37 with selected dyes i.e. *Butea monosperma, Eucalyptus globulus* and *Rubia cordifolia* sequentially. It is clear from the Table that 90 minutes of dyeing treatment obtained highest percent dye absorption. Hence 90 minutes time duration was selected for the further treatment of cotton Khadi fabric with natural dyes. The data in Table 5 presented the optimized dyeing parameters. The findings are supported by Raj *et al.,* (2016) emphasized on the standardization of the shades of natural dyes, improving the colour fastness and following modern trends of fashion. The researcher has used organic mineral salts those, which are eco-friendly and less harmful for the nature thus producing vibrant shades.

The fabric samples were printed with 3 selected concentrations (i.e. 5%, 10% and 15%) of each of the 5 selected mordants using the pre-mordanting method. These printed samples were dyed with 3 optimized dyeing concentrations of each of the 6 selected natural dyes. In all,45 dyed and printed Khadi samples were developed with each dye source, thus totaling of 135 (45 samples of each dye multiplied by 3 dye sources=135) dyed and printed samples.

Effect of dyes and mordants on preliminary properties of khadi fabric

Determination of fabric count of printed cotton Khadi fabric

Fabric count, (number of ends and picks per unit area), is affected by the compactness of the weave and determined as per ISI 1963 – 1981 test method.

Table 6 describes the mean value of fabric count of control (scoured) fabric sample and dyed & printed fabric samples with different mordants at different mordanting concentrations i.e. 5%, 10% and 15% using petals of *B.monosperma* dye, with different dyeing concentrations i.e. 10%, 20% and 30%. Table reveals the mean value of fabric count of the control sample is 67 × 45 ends & picks per inch square. The mean value of *B. monosperma* dyed samples, printed with *P. granatum* mordant has good fabric count

i.e.67×46 ends & picks per inch square at 30% dye and 15% mordant concentration whereas the mean value of *T. bellirica* mordant printed samples rang exhibited between 69×49 to 67×47 ends & picks per inch square.

Table.1 Preliminary data of the undyed cotton Khadi fabric

Cotton Khadi Fabric	Fabric count (threads/inch)		Fabric weight (g/m^2)	Fabric thickness (mm)
	Warp/ends	Weft/picks		
Before scouring	65	43	0.347	1.43
After scouring (Control)	67	45	0.224	1.35

Table.2 Optimization of dye extraction time of selected natural dyes

Dye extraction time (hours)	*Percent dye absorption of selected natural dyes*		
	Butea monosperma	***Eucalyptus globulus***	***Rubia cordifolia***
1	34.41	34.71	31.43
6	40.20	40.39	35.45
12	45.57	45.24	38.53
24	50.19	50.05	49.07
48	50.53	50.93	49.39

Table.3 Selection of three dyeing concentrations of selected natural dyes

Dye concentrations	*Percent dye absorption of selected natural dyes*		
	Butea monosperma	***Eucalyptus globulus***	***Rubia cordifolia***
10%	53.00	52.39	55.31
20%	55.04	54.78	56.45
30%	58.97	59.73	60.93
40%	58.78	59.64	60.32
50%	58.43	59.02	60.19

Table.4 Optimization of dyeing time of selected natural dyes

Dyeing time (minutes)	*Percent dye absorption of selected natural dyes*		
	Butea monosperma	***Eucalyptus globulus***	***Rubia cordifolia***
30	30.92	24.34	31.34
45	35.34	38.42	35.56
60	41.56	44.45	43.25
75	49.67	53.54	52.65
90	58.89	59.39	61.37

Table.5 Optimized dyeing parameters selected for the study

Dyeing parameters	Selected Variables
Dye extraction time	24 hours
Dye Concentration	10%, 20% & 30%
Dyeing time	90 minutes

Table.6 Effect of *Butea monosperma* dye on the fabric count of dyed and printed cotton Khadi fabric

Dye (%)	Mordants Mordant concentration	Fabric count (ends & picks/ inch^2)									
		T. bellirica		*P. granatum*		*A. catechu*		*Ph. emblica*		*F. sulfate*	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
	Control	67	45	67	45	67	45	67	45	67	45
10%	5%	69	49	69	48	69	48	70	49	67	46
	10%	67	47	67	46	68	48	69	49	67	46
	15%	67	47	68	46	68	47	67	47	67	46
20%	5%	67	47	67	47	67	47	67	47	67	46
	10%	67	47	67	45	66	47	67	47	67	47
	15%	67	46	68	45	68	47	67	47	67	47
30%	5%	68	46	68	46	68	46	67	46	67	47
	10%	68	46	68	47	68	46	68	46	68	47
	15%	67	47	67	46	68	46	68	46	68	47

Table.7 CRD ANOVA for fabric count in warp direction with *Butea monosperma* dye

SN SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	221.21481	5.0276094	18.854**	0.298	0.838	1.110
2. M	4	6.4	1.6	6.000**	0.099	0.279	0.370
3. D	2	168.548	84.2741	316.028**	0.077	0.216	0.287
4. C	2	29.3481	14.6741	55.028**	0.077	0.216	0.287
5. MxD	8	11.8222	1.47778	5.542**	0.172	0.484	0.641
6. MxC	8	2.13333	0.266667	1.000	0.172	0.484	0.641
7. DxC	4	0.518519	0.12963	0.486	0.133	0.375	0.496
8. MxDxC	16	2.44444	0.152778	0.573	0.298	0.838	1.110
9. Error	90	24	0.266667				

*,** Significant at 5% and 1% respectively
GM = 67.363 CV = 0.77
M= Mordants, D= Dye, C= Concentration

Table.8 CRD ANOVA for fabric count in weft direction with *Butea monosperma* dye

SN. SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	393.43704	8.9417508	25.149**	0.344	0.967	1.281
2. M	4	21.6593	5.41481	15.229**	0.115	0.322	0.427
3. D	2	317.437	158.719	446.396**	0.089	0.250	0.331
4. C	2	30.2815	15.1407	42.583**	0.089	0.250	0.331
5. MxD	8	11.0074	1.37593	3.870**	0.199	0.558	0.740
6. MxC	8	5.4963	0.687037	1.932	0.199	0.558	0.740
7. DxC	4	0.518519	0.12963	0.365	0.154	0.433	0.573
8. MxDxC	16	7.03704	0.439815	1.237	0.344	0.967	1.281
9. Error	90	32	0.355556				

*,** Significant at 5% and 1% respectively
GM = 46.548 CV = 1.28
M= Mordants, D= Dye, C= Concentration

Table.9 Effect of *Eucalyptus globulous* dye on fabric count of dyed and printed cotton Khadi fabric

Dye (%)	Mordants / Mordant concentration	Fabric count (ends & picks/ inch^2)									
		T. bellirica		*P. granatum*		*A. catechu*		*Ph. emblica*		F. sulfate	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
	Control	67	45	67	45	67	45	67	45	67	45
10%	5%	67	46	67	45	68	45	66	46	67	45
	10%	67	46	67	45	68	45	66	45	67	45
	15%	67	47	67	46	68	46	67	45	67	46
20%	5%	67	47	68	46	68	46	67	46	67	46
	10%	67	47	67	47	67	47	67	46	68	47
	15%	67	47	67	45	66	45	68	47	67	47
30%	5%	67	46	68	45	68	45	68	45	67	47
	10%	68	46	68	46	68	46	68	45	66	46
	15%	68	46	68	47	68	46	69	45	69	47

Table.10 CRD ANOVA for fabric count in warp direction with *Eucalyptus globulous* Dye

SN SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	324.41481	7.373064	30.163**	0.285	0.802	1.063
2. M	4	33.0074	8.25185	33.758**	0.095	0.267	0.354
3. D	2	230.77	115.385	472.030**	0.074	0.207	0.274
4. C	2	40.9481	20.4741	83.758**	0.074	0.207	0.274
5. MxD	8	12.1926	1.52407	6.235**	0.165	0.463	0.613
6. MxC	8	2.23704	0.27963	1.144	0.165	0.463	0.613
7. DxC	4	1.36296	0.340741	1.394	0.128	0.359	0.475
8. MxDxC	16	3.8963	0.243519	0.996	0.285	0.802	1.063
9. Error	90	22	0.244444				

*, ** Significant at 5% and 1% respectively
GM = 67.237 CV = 0.74
M= Mordants, D= Dye, C= Concentration

Table.11 CRD ANOVA for fabric count in weft direction with *Eucalyptus globulous* Dye

SN SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	449.74815	10.221549	43.122**	0.281	0.790	1.046
2. M	4	3.15556	0.788889	3.328*	0.094	0.263	0.349
3. D	2	349.437	174.719	737.094**	0.073	0.204	0.270
4. C	2	56.4593	28.2296	119.094**	0.073	0.204	0.270
5. MxD	8	16.4889	2.06111	8.695**	0.162	0.456	0.604
6. MxC	8	4.8	0.6	2.531*	0.162	0.456	0.604
7. DxC	4	0.785185	0.196296	0.828	0.126	0.353	0.468
8. MxDxC	16	18.6222	1.16389	4.910**	0.281	0.790	1.046
9. Error	90	21.3333	0.237037				

*,** Significant at 5% and 1% respectively
GM = 46.430 CV = 1.05
M= Mordants, D= Dye, C= Concentration

Table.12 Effect of *Rubia cordifolia* dye on fabric count of dyed and printed cotton Khadi fabric

Dye (%)	Mordants / Mordant Concentration	Fabric count (ends & picks/ inch^2)									
		T. bellirica		*P. granatum*		*A. catechu*		*Ph. emblica*		F. sulfate	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
	Control	67	45	67	45	67	45	67	45	67	45
10%	5%	68	45	67	45	65	45	68	45	65	46
	10%	66	45	67	45	65	45	68	45	65	46
	15%	65	46	67	46	65	46	68	46	65	46
20%	5%	65	46	67	46	67	46	68	46	67	46
	10%	67	46	67	47	67	46	67	47	65	46
	15%	67	46	67	47	67	46	67	47	65	46
30%	5%	68	46	67	47	67	46	66	46	65	47
	10%	68	46	67	46	67	46	66	46	68	46
	15%	68	47	67	46	68	46	67	46	68	47

Table.13 CRD ANOVA for fabric count in warp direction with *Rubia cordifolia* dye

SN SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	386.77037	8.7902357	33.905**	0.294	0.826	1.094
2. M	4	68.6222	17.1556	66.171**	0.098	0.275	0.365
3. D	2	243.437	121.719	469.486**	0.076	0.213	0.283
4. C	2	51.2148	25.6074	98.771**	0.076	0.213	0.283
5. MxD	8	12.7111	1.58889	6.129**	0.170	0.477	0.632
6. MxC	8	1.37778	0.172222	0.664	0.170	0.477	0.632
7. DxC	4	1.18519	0.296296	1.143	0.131	0.369	0.489
8. MxDxC	16	8.22222	0.513889	1.982*	0.294	0.826	1.094
9. Error	90	23.3333	0.259259				

*,** Significant at 5% and 1% respectively
GM = 67.081 CV = 0.76
M= Mordants, D= Dye, C= Concentration

Table.14 CRD ANOVA for fabric count in weft direction with *Rubia cordifolia* dye

SN SOURCE	DF	SS	MS	F	SE(m)	CD5%	CD1%
1. Treat.	44	539.97037	12.272054	17.625**	0.482	1.354	1.793
2. M	4	121.23	30.3074	43.527**	0.161	0.451	0.598
3. D	2	307.037	153.519	220.479**	0.124	0.349	0.463
4. C	2	72.4593	36.2296	52.032**	0.124	0.349	0.463
5. MxD	8	4.14815	0.518519	0.745	0.278	0.781	1.035
6. MxC	8	3.83704	0.47963	0.689	0.278	0.781	1.035
7. DxC	4	1.27407	0.318519	0.457	0.215	0.605	0.802
8. MxDxC	16	29.9852	1.87407	2.691**	0.482	1.354	1.793
9. Error	90	62.6667	0.696296				

*,** Significant at 5% and 1% respectively
GM = 46.652 CV = 1.79
M= Mordants, D= Dye, C= Concentration

Table.15 Mean score and SD of the samples dyed with different concentrations of *Butea monosperma* dye at different mordant concentrations

Mordants & its concentrations	Dye (10%)					Dye (20%)					Dye (30%)				
	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD
T. bellirica															
5%	2.6	2.6	2.4	2.533	0.115	2.8	2.9	2.7	2.8	0.1	3.1	3.3	3.2	3.2	0.1
10%	3.0	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	3.5	3.8	3.8	3.7	0.173
15%	3.3	3.6	3.5	3.4666	0.152	3.5	4.6	4.5	4.2	0.608	4.6	4.6	4.7	4.633	0.057
P. granatum															
5%	2.6	2.6	2.4	2.533	0.115	2.8	2.9	2.7	2.8	0.1	3.7	3.6	3.7	3.666	0.057
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.6	4.4	4.7	4.566	0.152
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.6	4.8	4.9	4.766	0.152
A. catechu															
5%	2.6	2.4	2.6	2.533	0.115	2.8	2.9	2.7	2.8	0.1	3.7	3.6	3.7	3.666	0.057
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.8	4.7	4.6	4.7	0.1
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.7	4.6	4.8	4.7	0.1
P. emblica															
5%	2.6	2.6	2.4	2.533	0.115	2.8	2.9	2.7	2.8	0.1	3.7	3.6	3.8	3.7	0.1
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.7	4.5	4.4	4.533	0.152
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.6	4.6	4.8	4.666	0.115
F. sulfate															
5%	4.7	4.6	4.7	4.666	0.057	4.2	4.5	4.3	4.333	0.152	4.8	4.9	4.9	4.866	0.057
10%	4.5	4.6	4.9	4.666	0.208	3	4.1	4.5	3.866	0.776	4.5	4.5	4.5	4.5	0
15%	4.6	4.5	4	4.366	0.321	3.5	4.4	4.4	4.1	0.519	4.2	4.5	4.3	4.333	0.152

Table.16 Mean score and SD of the samples dyed with different concentrations of *Eucalyptus globulous* dye at different mordant concentrations

Mordants & its concentrations	Dye (10%)					Dye (20%)					Dye (30%)				
	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD
T. bellirica															
5%	2.6	2.6	2.4	2.533	0.115	2.8	2.9	2.7	2.8	0.1	4.3	4.5	4.3	4.366	0.115
10%	3.0	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.8	4.6	4.9	4.766	0.1527
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	3.9	4.5	4.5	4.3	0.346
P. granatum															
5%	2.5	3.1	3.4	3	0.458	2.7	2.3	2.8	2.6	0.264	3.7	3.6	3.7	3.666	0.0577
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.6	4.4	4.7	4.566	0.152
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.6	4.8	4.9	4.766	0.152
A. catechu															
5%	2.6	2.4	2.6	2.533	0.115	3.1	3.3	2.5	2.966	0.416	3.7	3.6	3.9	3.733	0.152
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.5	4.6	4.6	4.566	0.057
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.7	4.6	4.7	4.666	0.057
P. emblica															
5%	2.3	2.6	3.4	2.766	0.568	2.8	2.7	2.7	2.733	0.057	4.6	4.6	4.3	4.5	0.173
10%	3	3.3	2.9	3.066	0.208	3	4.1	4.5	3.866	0.776	4.7	4.6	4.8	4.7	0.1
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.6	4.233	0.635	4.5	4.4	4.5	4.466	0.057
F. sulfate															
5%	4.7	4.6	4.7	4.666	0.057	4.7	4.6	4.6	4.633	0.057	4.9	4.8	4.9	4.866	0.057
10%	4.5	4.6	4.9	4.666	0.208	3.8	4.1	4.5	4.133	0.351	4.3	4.5	4.3	4.366	0.115
15%	4.6	4.5	4	4.366	0.321	3.5	4.4	4.4	4.1	0.519	3.6	3.4	4	3.666	0.305

Table.17 Mean score and SD of the samples dyed with different concentrations *Rubia cordifolia* dye at different mordant concentrations

Mordants & its concentrations	Dye (10%)					Dye (20%)					Dye (30%)				
	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD	Clarity of design	Sharpness of design	Level of shades	Mean	SD
T. bellirica															
5%	2.6	2.6	2.4	2.533	0.115	3	3.1	3	3.033	0.057	4.4	4.3	4.2	4.3	0.1
10%	3.0	3.3	2.9	3.066	0.208	3.6	4.5	4.7	4.266	0.585	4.6	4.7	4.7	4.666	0.057
15%	3.3	3.6	3.5	3.466	0.152	3.5	4.6	4.5	4.2	0.608	4.3	4.4	4.4	4.366	0.057
P. granatum															
5%	3.6	3.6	3.6	3.6	0	2.8	2.9	2.7	2.8	0.1	3.9	3.8	3.9	3.866	0.057
10%	3.2	3.7	3.1	3.333	0.321	3	4.1	4.5	3.867	0.776	4.4	4.7	4.2	4.433	0.251
15%	3.5	4	3.7	3.733	0.251	3.5	4.6	4.5	4.2	0.608	4.6	4.8	4.9	4.766	0.152
A. catechu															
5%	3.4	3.4	3.1	3.3	0.173	3.4	3.3	2.9	3.2	0.264	3.7	3.6	2.9	3.4	0.435
10%	3.2	3.7	2.9	3.266	0.404	3.6	4.4	4.4	4.133	0.461	4.8	4.6	4.5	4.633	0.152
15%	3.3	3.6	3.5	3.466	0.152	4.1	4.5	4.5	4.366	0.230	4.8	4.7	4.8	4.766	0.057
P. emblica															
5%	3.6	3.6	3.6	3.6	0	3.4	3.3	3.3	3.333	0.057	4.7	4.4	4.4	4.5	0.173
10%	3.2	3.9	3.3	3.466	0.378	4.4	4.5	4.5	4.466	0.057	4.8	4.8	4.9	4.833	0.057
15%	3.4	4	3.7	3.7	0.3	3.6	4.5	4.7	4.266	0.585	4.4	4.5	4.6	4.5	0.1
F. sulfate															
5%	4.8	4.6	4.8	4.733	0.11	4.5	4.5	4.8	4.6	0.173	4.4	4.5	4.3	4.4	0.1
10%	4.5	4.6	4.9	4.666	0.208	3	4.1	4.5	3.866	0.776	4.8	4.9	4.9	4.866	0.057
15%	4.6	4.5	4	4.366	0.321	3.5	4.4	4.4	4.1	0.519	4.5	4.4	4.7	4.533	0.152

The fabric count of *Ph. emblica* and *A. catechu* mordant printed samples obtained 70×49 to 68×46 and 69×46 to 68×44 ends & picks per inch square mean value with all dye and mordant concentrations respectively. Ferrous sulfate showed a range of 67×46 to 68×47 ends & picks per inch square at 10-30% dyeing and 5-15% mordant concentration sequentially. Initially higher the mean value was found in printed samples with *A. catechu* and *P. granatum* in the weft direction and *P. granatum* showed in the warp direction. Hence, as the concentrations of dye and mordants were increased the mean value of printed cotton Khadi samples with different mordants using *B. monosperma* dye, showing lower the fabric count in warp and weft direction.

Table – 7 explicit the fabric count in warp direction of printed Khadi fabric with different mordants using *Butea monosperma* dye and observed the three-factorial interaction among Mordants (M), dye (D) and concentrations (C). In other way, it showed the significant difference between dye and mordants (MxD) at 1% level of significance while there is no significant difference was observed between MxC, DxC and MxDxC factors.

Table 8 shows the significant difference between the calculated F values of the different Mordants (M), dye (D), different concentrations (C) and dye and mordants (MxD). The significant difference is showing at 1% level of significance with fabric count in weft direction using *Butea monosperma* dye. There is no significant difference was observed between MxC, DxC and MxDxC factors of weft fabric count.

Table 9 depicts, the mean value of fabric count of control (scoured) fabric samples and dyed & printed cotton Khadi fabric samples with different mordants at different mordant concentrations i.e. 5%, 10% and 15% using *E. globulous* dye, with different dyeing concentrations i.e. 10%, 20% and 30%. The fabric count of the control sample is 67 × 45 ends & picks per inch square. The mean value of dyed samples with *E. globulous* and printed with F. sulfate, *Ph. Emblica* and *A. catechu* mordants obtained 67s-69s, 67s-69s & 67s-68s ends/inch^2 in warp direction at lower to higher concentrations with both dye and mordants respectively while printed with *T. bellirica* and *P. Granatum* exhibited 67s-68s & 67s-68s ends/inch^2 in warp direction at lower to higher concentrations with both dye and mordants respectively.

In terms of weft fabric count of dyed and printed cotton Khadi fabric with ferrous sulfate mordant ranged between 45s- 47s picks/inch^2 at 10%-30% dyeing and 5%-15% mordanting concentrations respectively. *T. bellirica*, and *Ph. Emblica* mordants obtained 46s picks/inch^2 at 5% mordant and 10% dyeing concentration whereas *P. granatum* and *A. catechu* obtained 45s picks/inch^2 at the same concentrations. On the other hand, *T. bellirica*, and *P. granatum* showed 46s & 47s picks/inch^2 at 15% mordants and 30% dyeing concentrations while *A. catechu* and *Ph. emblica* mordants exhibited 46s & 45s picks/inch^2 at the same concentrations of both respectively.

Table 10 presents the significant difference between the calculated F values of different Mordants (M) with *Eucalyptus globulous* Dye (D) using different concentrations (C), mordants and dye (MxD) with the tabulated values. The significant difference was found between the calculated F values at 1% level of significance in warp direction with the tabulated values. It was interpreted that some mordants and their concentration are not significant for this dye and also some dye concentrations are not significant.

Table 11 reveals the three-factorial interaction among different factors of the weft fabric

count with *Eucalyptus globulous* Dyed fabric samples using different mordants and their concentrations. The significant difference between the calculated F values of M (Mordants) and MxC (mordants and their concentrations) obtained with the tabulated values at 5% level of significance whereas the significant difference between the calculated F values of treatment 1, D (Dye) and C (Concentrations), MxD (mordants and dye), MxDxC (Mordants, Dye and its Concentrations) obtained at 1% level of significance and no significant difference was observed between DxC factors.

Table 12 explicit the mean values of fabric count of untreated cotton Khadi fabric and treated cotton Khadi fabric with different mordants using *R. cordifolia* dye with three different dye and mordant concentrations. The fabric count obtained by control sample is 67 × 45 ends & picks/ inch^2. In the Table, the fabric count of Ferrous sulfate exhibited 65 × 46 ends & picks/inch^2 at 5% mordant and 10% dye concentration which was increased with the increasing in the concentration of dye and mordant i.e. 68 × 47 ends & picks per inch square at 15% mordant and 30% dye concentration. In the same way, the fabric count was increased with all the mordant printed samples dyed with *R. cordifolia* dye that is, the initial mean value of *T. bellirica*, *Ph. emblica, A. catechu* and *P. granatum* mordants showed 68 × 45, 67× 45, 67 × 45 and 67 × 45 ends & picks/ inch^2 at 5% mordant and 10% dye concentrations, on the other hand, the same mordants showed 68 × 47, 67 × 46, 68 × 46 and 67 × 46 ends & picks/ inch^2 the mean values of fabric count with 30% dye and 15% mordant concentrations respectively.

Table 13 showed the three factorial ANOVA between the warp fabric count of cotton Khadi printed fabric with different mordants and dyeing with *Rubia cordifolia* dye. It exhibited that the significant difference between calculated F value of different Mordants (M), dye (D) and concentrations (C) and Mordants and its concentrations (MxC) at 1% level of significance with tabulated values of the same where as MxDxC showing the significant results at 5% level of significance. Rest factors were not showing the significant difference.

Table 14 depicts the significant difference between the calculated F values with tabulated values of weft fabric count with *Rubia cordifolia* dyed fabric samples. The significant difference obtained between the calculated F values of Treatment 1, Mordants (M), dye (D), concentrations (C) and interaction among all three factors (MxDxC) with tabulated values of the same.

Evaluation of developed prints

Developed printed samples were visually examined by 10 subject matter experts on five-pointlikert scale in terms of different parameters i.e. clarity of designs, the sharpness of design and level of shades.

Evaluation of developed prints on cotton khadi fabric with *Butea monosperma*dye

Mean and SD of cotton Khadi fabric dyed with *B. monosperma*dye and printed with different mordants at different concentrations of dye and mordants using the pre-mordanting method has been depicted in Table 15. On the parameter of design, the dyed samples printed with *P. granatum, A. catechu, Ph. Emblica* and *T. bellirica* showed 4.76, 4.7, 4.66 and 4.33 mean score respectively with 30% dye and 15% mordant concentrations whereas printed samples with ferrous sulfate exhibited 4.66, 4.66 and 4.33 mean with 5%, 10% and 15% mordant concentration respectively at 10% dye concentration. It was found that the same mordant obtained mean of 4.86, 4.5 & 4.33 at 30% dyeing and 5%, 10%, and 15% mordant concentration sequentially. The results showed that Ferrous sulfate mordant

printed samples got excellent ratings on all parameters i.e. clarity of design, sharpness of design and level of shades at low mordant concentration. Further, all the mordants gave best results with 30% dye concentrations.

Evaluation of developed prints on cotton khadi fabric with*Eucalyptus globulous* dye

Table 16 shows the mean and SD of printed samples with different mordants using *Eucalyptus globulous* dye. In terms of clarity of design, most of the mordants showed a very good rating of clarity with 10% mordants and 30% dye concentrations whereas ferrous sulfate mordanted samples showed best results at 5% & 10% mordant concentrations with all the three selected dye concentrations. In terms of sharpness of design, *T. bellirica* treated samples obtained 4.6 mean score with 10% mordant and 30% dye concentration.

The printed samples of *p. granatum* mordant observed mean score of 4.8 with 30% dye and 15% mordant concentration. The results of A. catechu mordanted sample obtained 4.6 at 10% & 15% mordant and 30% dye concentrations. Another mordant *P. emblica* obtained again 4.6 mean score with 30% dye and 10 & 15% mordant concentrations. Whereas Ferrous sulfate mordant observed 4.8 mean scores at 5% mordant and 30% dye concentration.

In terms of the level of shades, *T. bellirica* treated samples showed 4.9 mean scores at 10% mordant and 30% dye concentration. The mordant *p. granatum* obtained 4.7 & 4.9 mean scores with 30% dye and 10% & 15% mordant concentration. A. catechu mordant obtained 4.6 at 10% & 15% mordant and 30% dye concentrations. The results of *P. emblica* mordant obtained again 4.7 mean scores with 30% dye and 15% mordant concentrations. Ferrous sulfate mordanted samples observed 4.9 mean scores at 5% mordant and 30% dye concentration.

Based on the parameters of printed samples, very good to excellent ratings were observer with 30% concentration of *E. globulous* dye and 15% *Ph. Emblica and A. catechu* mordant concentration. On the other hand, samples printed with *P. granatum* and *T. bellerica* showed good results good results at 30% dye and 10% mordant concentration while Ferrous sulfate gave the same value of 30% dye and 5% mordant concentrations.

Evaluation of developed prints on cotton khadi fabric with *Rubia cordifolia* dye

The data in Table 17 depicts the mean of samples dyed with *Rubia cordifolia* dye and printed with *P. granatum, Ph. emblica, A. catechu, T. bellerica* and Ferrous sulfate using different dyeing and mordanting concentrations. Printing with *T. bellerica* mordant obtained 4.66 ± 0.057 Mean score and SD at 10% mordant and 30% dyeing concentration. With 15% mordant and 30% dye concentration, *A. catechu* mordanted samples were observed 4.76 ± 0.152 Mean score and SD. Printed samples with *P. granatum* mordant obtained the same mean score as *A. catechu* at 15% mordant and 30% dye concentration. Another mordant printed sample with *Ph. emblica* observed 4.83 ± 0.057 Mean score and SD at 10 % mordant and 30% dyeing concentration.

The mordant Ferrous sulfate used at a different concentration with different concentration of dyeing on cotton Khadi fabric samples found the highest mean score i.e. 4.866 with 5% mordant and 30% dyeing concentration. Printing with *Ph. Emblica* and Ferrous sulfate exhibited 4.8 - 4.9 mean score with 5% mordant and 30% dyeing concentrations. On the basis of parameters of designs, *P. granatum, A. catechu,* and *T. bellerica* gave best results with 15% mordant and 30% dyeing concentrations.

Hence it can be concluded that the use of different mordant concentrations showed different colour effect on Khadi fabric with various concentration of selected natural dyes. It is interesting to note that ferrous sulfate is the only mordant that gave the best results at 5% & 10% concentration with most of the dyes used by the researcher.

With the increase in the concentration of dyes and mordants, ferrous sulfate mordant gave very good shades of prints on khadi samples. Based on the parameters of design, (i.e. clarity, sharpness and level of shades), different dye and mordant concentrations gave different colour shades of developed prints varying from orangish yellow, pale, beige, and light brown to dull brown with *Butea monosperma* dyed samples using different mordants. *Rubia cordifolia* dyed samples showed pink maroon, reddish yellow, pinkish brown, magenta and reddish violet using different mordants at different concentrations. *Eucalyptus globulus* dyed samples obtained pale, creamish, yellow, beige and light brown colour. Therefore, Khadi fabric can be printed with natural dyes to obtain pleasing shades in wide range.

Results are supported by Srivastava *et al.*, (2008) in which pretreated cotton fabric with 20% myrobalan concentration showed better dye uptake. The color obtained with petals of Kesula flower ranged from cream to gold with alum, lemon to honey with copper sulfate, slate to burgundy with ferrous sulfate and ochre to chrome with stannous chloride.

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How to cite this article:

Adya Tiwari and Meenu Srivastava. 2020. Development of Eco-friendly Prints on Cotton Khadi Fabric with Selected Natural Dyes and Natural Mordants. *Int.J.Curr.Microbiol.App.Sci.* 9(12): 1421-1434. doi: https://doi.org/10.20546/ijcmas.2020.912.171