Colorimetric and spectrophotometric analyses for an ecoinnovative application of natural dyeing in textile conservation

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ABSTRACT

An eco-innovative application of natural dyes and nontoxic mordants was recently experimented at Centro Conservazione e Restauro "La Venaria Reale" (CCR, Italy) in the conservation of some historical tapestries, in collaboration with Coulers de Plantes (CdP, France).

Until now, textile conservation makes use of synthetic pre-metallized dyes that contain heavy metals such as chrome and cobalt: the synthetic dyes allow to obtain different hues and saturation levels of the textile fibres simply varying ratio and concentration of three primary dye. This project aimed at finding eco-friendly materials for substituting the synthetic ones. All dyes and mordants used in this application were produced by CdP inside the INNOCOLORS project, carried out by CCR and ARRDHOR CRITT Horticole. A palette of textile fibres was made with 7 natural dyes and 4 nontoxic mordants with more than 300 different recipes. Spectrophotometric and colorimetric analyses were used to evaluate and compare the natural palette with the synthetic one. As expected, the colours of the synthetic palette show to vary linearly changing the ratios of the three pre-metallized dyes, whereas, in the natural palette, each ingredient plays an important, not predictable rule on the final colour. The analyses so carried out allowed to better understand in particular the influence of mordant on the final colour of the textile fibres. The study allowed to modulate the recipes in order to obtain precise colours. The samples' lightfastness was monitored and studied.

At the end, some lacunae on historical tapestries were integrated in this innovative way.

KEYWORDS

Natural dyes, Nontoxic mordants, Eco-innovative dyeing, Textile conservation, Historical tapestry, Fiber Optics Reflectance Spectroscopy (FORS), Colorimetry

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1. INTRODUCTION

Within a European project[a], Centro Conservazione e Restauro *"La Venaria Reale"* (CCR, Italy) in collaboration with Couleurs de Plantes (CdP, Rochefort, France) and ARRDHOR CRITT Horticole (CRITT, Rochefort, France) recently experienced an eco-innovative application of natural dyeing in the conservation of an ancient tapestry.

For integrating *lacunae* on historical tapestries, it is necessary to use textile fibres - suitable for conservation - dyed *ad hoc* in the requested colour. Nowadays most of conservators use synthetic pre-metallized dyes, which contain heavy metals such as chrome and cobalt. The idea of testing eco-friendly products for dyeing arose from the necessity of protecting operator health and reducing environmental impact.

On the other hand, synthetic dyes are very easy-to-use, as you can get requested colour in a one-step process, varying relative ratios of three *primary* dyes and their concentration in the dyeing bath. Once fibres dried, they are ready-to-use.

Since project started, we guessed that natural dyes, coming from different flowers and plants, would not behave at the same manner of synthetics and that colour reproduction would be more difficult. Moreover, the use of natural dyes requires to treating the textile fibres preliminarily with a mordant, implying a two-step dyeing process [1]. The challenge was to offer to the conservators a complete palette of colours and recipes with natural products and with streamlined dyeing processes.

Colorimetric and spectrophotometric analyses provided useful data for studying behaviour and interaction of those products and for getting some colours – as a yellow, a green and a brown - specifically requested in the conservation of a 17th century tapestry.

2. EXPERIMENTAL AND METHOD

Among the *colour triangles* currently used by conservators as reference for dyeing, we considered the yellow, magenta and grey (YMG) triangle (figure 1). In this triangle, pre-metallized primary colours at the maximum saturation value lie at vertex and two-dye mixtures lie on the triangle sides. All the others are three-dye mixtures. Inside the triangle, relative ratios among dyes change with a 10% step from 0% to 100%, forming in total 66 colours (i.e. Y:20%, G:50%, M:30%). As mentioned, operator can obtain simply further colours, since it is possible to change hue modifying dyes' ratio and to change saturation varying dyes' concentration in the dyeing bath.

In the preliminary, practice part of the project, CRITT tried to reproduce the YMG triangle using natural dyes and non-toxic mordants produced by CdP and testing more than three hundred recipes. The set of recipes, simulating the 66 synthetic colours, contains old fustic, weld, madder, dyer's broom, myrobalan, logwood, cochineal and alder buckthorn as dyes, and aluminium lactate, titanium oxalate, copper acetate, iron lactate, woad and gallnuts as mordants. As textile support, CRITT used commercial wool yards that are compact and elastic likewise the wool but more easily available.

Firstly, by means of colorimetric analyses we compared the colours of the original synthetic triangle to the natural ones made by CRITT and we recognized a *critical* area inside both the two triangles that means an area where colour deeply changes moving from one sample to the other. So, for completing the palette, it would be necessary to obtain in that area other *intermediate* colours. While the use and the matching of synthetic dyes give predictable colours, we supposed it would be difficult to obtain intermediate colours by using natural dyes, in that area above all.

Therefore, in the second phase of the research, we deepened the study about dyes and mordants' behaviour by spectrophotometric and colorimetric analyses, aiming at individuating recipes that could integrate the set of references providing to the conservator a more complete palette.

At the end, thanks to a general comprehension about mordants' contribution to the textile fibres' final colours, we could modify some CRITT recipes in order to reproduce on wool[b] samples precise colours, requested by the conservators for the tapestry's integration. On these samples, we could evaluate by colorimetric analyses three important aspects: the influence of the different textile support on the final colour; the possibility of preparing fibres before (treating them with mordants in a previous separate moment), in order to offer to the conservators a faster and streamlined dyeing process; the colour fading and light stability of dyeing.

Colorimetric analyses were carried out by means of a spectrophotometer Konica Minolta CM700d that works in a d/8° optical geometry along a 400 nm to 700 nm wavelength range, with a 10 nm step resolution. The instrument was set to provide CIELAB 1976 (L^*, a^*, b^*, C_{ab}^*) chromatic coordinates, where L* corresponds to lightness, a* from negative to positive corresponds respectively to the green or red component and b* from negative to positive corresponds respectively to the blue or yellow component, for standard illuminant D_{65}.

Colour differences (ΔE_{00}) were calculated from those coordinates using the CIEDE2000 formula [2, 3].

Figure 1 - One of the colour triangle of pre-metallized dyes based on yellow, magenta and grey (YMG) primary colours

Spectrophotometric analyses were performed in Fibre Optics Reflectance Spectroscopy (FORS), using an Ocean Optics HR2000+ES spectrophotometer and an Ocean Optics HL2000 halogen lamp, bounded by optical fibres of 400 µm in diameter, working in a 2x45°/0° geometry and collecting spectra along a 350 nm to 1000 nm wavelength range with a 0.5 step resolution.

3. RESEARCH

3.1. SYNTHETIC AND NATURAL COLOUR TRIANGLES

Comparing synthetic colour triangle to the one reproduced by CRITT with natural dyes, we did not find in general a perfect correspondence. In fact, the average ΔE_{00} calculated between any sample and its reproduction with natural dyeing is around 19.7 and this is principally due to the different level of saturation. Colours obtained from natural dyeing appear, in fact, more saturated, showing averagely lower L* values (average $\Delta L^*_{CRITT-YMG}$: -17.8). Anyway, this alone should not be a problem, since in general it is possible to weak the colour simply diluting the dyeing bath.

For comprehending behaviours of synthetic dyes, we firstly focused on the three sides of the YMG triangle, where there are binary mixtures (YM, YG and GM), so working with two only variables.

The first result was that the sides of the triangle behave as a sort of chromatic scale of equidistant colours, so representing a satisfying palette for the conservators, excluding the area near to the yellow vertex. In fact, ΔE_{00} calculated between synthetic close samples show always low and homogenous values of around 3 units, but in that *critical* area: as shown in table 1, adding 10% of magenta or grey into pure yellow, ΔE_{00} respect to yellow can rise up to 26 units. This means that operator can obtain almost all possible colours exploiting that palette, but he could probably obtain many other intermediate colours starting from pure yellow.

Considering CRITT samples simulating the triangle's sides, one problem about the use of natural dyes emerges soon: ΔE_{00} calculated between close natural samples (table 1) are high and non-homogenous, suggesting that operator

SAMPLES OF COLOURS ALONG THE YMG TRIANGLE'S SIDES								
Pre-metallized YM mixtures		CRITT natural dyeing	Pre-metallized YG mixtures		CRITT natural dyeing	Pre-metallized MG mixtures		CRITT natural dyeing
Magenta %	ΔE_{00} between close samples	ΔE_{00} between close samples	Grey %	ΔE_{00} between close samples	ΔE_{00} between close samples	Grey %	ΔE_{00} between close samples	ΔE_{00} between close samples
0			0			0		
10	19.2	19.1	10	26.3	12.4	10	5.2	6.2
20	11.3	12.2	20	9.2	21.3	20	4.1	11.3
30	5.1	11.4	30	6.4	14.5	30	2.2	7.4
40	4.3	6.3	40	4.1	5.1	40	2.1	3.3
50	1.2	7.2	50	3.2		50	2.3	4.1
60	3.4	7.3	60	3.1	18.2	60	2.3	5.2
70	2.1	15.3	70	3.1	5.4	70	2.1	4.2
80	2.2	7.2	80	2.4	6.1	80	2.4	5.3
90	2.4	2.2	90	2.2	4.1	90	1.2	4.1
100	3.3	3.4	100	2.1	3.2	100	1.3	3.2

Table 1 - Trends of the ΔE_{00} calculated between couples of close samples along the YMG triangle' sides and between their respective couples of samples reproduced by CRITT with natural ingredients

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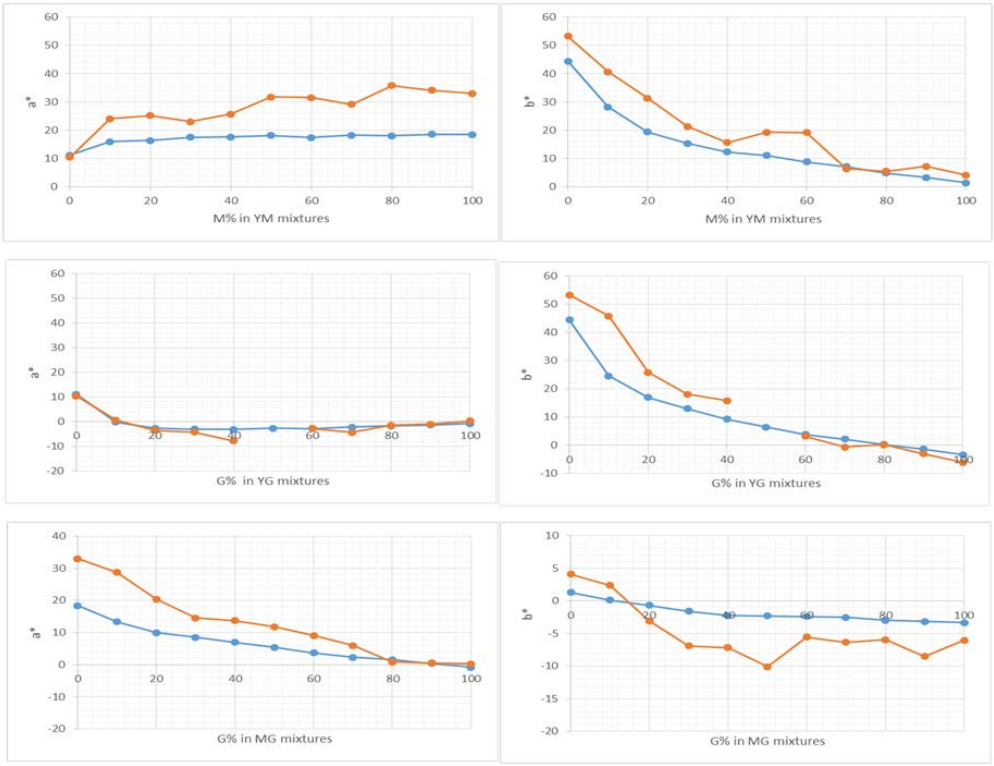

Figure 2 - Trends of a* and b* values in pre-metallized dyeing along the triangle sides (blue curves) and respective reproductions made by CRITT with natural dyes (orange curves).

Table 2 - CIELAB1976 coordinates of samples dyed with chlorophyll, previously treated with four different mordants

CRITT sample name	CRITT recipe		CIELAB 1976 chromatic coordinates		
	Mordant	Dyes	L*	a*	b*
284	2% aluminium lactate	Chloropyll 1%	56.1	-9.5	16.0
285	2% iron lactate	Chloropyll 1%	52.9	-7.0	20.1
286	2% copper acetate	Chloropyll 1%	58.2	-9.3	17.8
287	2% titanium oxalate	Chloropyll 1%	58.2	-9.4	17.8

should not use them as a palette of equidistant colours. Analysing a* and b* values, in fact, we noticed they have discontinuous trends all along the triangle's sides (orange curves, figure 2). Moreover, the problem of a critical area near yellow vertex exists also in the natural palette, as confirmed again by ΔE_{00} values (table 1).
Those outcomes addressed us to deepen the research on natural yellow and green yellowish dyes and their behaviours.

3.2. NATURAL DYES AND NON-TOXIC MORDANTS BEHAVIOR

Inside the collection of natural samples made by CRITT, many recipes contain more than one dye and/or more than one mordant.
As mentioned, mordants used in the 66 colours that simulate the synthetic triangle are aluminium lactate, iron lactate, copper acetate and titanium oxalate.
Trying to understand their effect on the textile fibres' final colour, we chose groups of samples dyed with one only dye, and treated with anyone of those mordant, with fixed values of concentrations.
Studying and comparing samples by means of colorimetric and spectrophotometric analyses, we could appreciate how mordants have some distinct effects on the fibres' final colour.
In particular:

- the the use of iron lactate as mordant makes the colour browner;
- the use of aluminium lactate makes the colour lighter;
- the use of titanium lactate or of copper acetate have a similar effect and colour is more or less intermediate in relation to the previous two cases;
- copper acetate makes the colour a little bit greener, even if the greening effect is obviously less visible in green samples.

For instance, inside the group of *green* samples, we did not individuate relevant colour differences that could be clearly ascribable to the different mordant. Nevertheless, we could verify that iron lactate, in general, makes colour a little bit browner. Table 2 and figure 3 relate to green samples dyed with chlorophyll: here, the use of aluminium lactate, copper acetate and titanium oxalate yield to the fibres the same colour - as shown by chromatic coordinates -, while the textile fibres treated with iron lactate are browner, showing lower L* and a* values

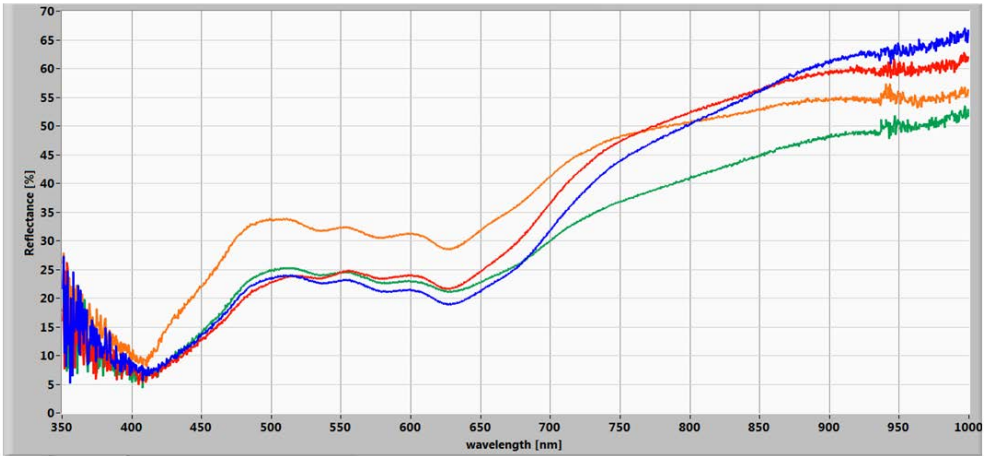

Figure 3 - Reflectance spectra of samples dyed with 1% chlorophyll, previously treated with four different mordants (blue curve: 2% alum lactate; red curve: 2% iron lactate; green curve: 2% copper acetate; orange curve: 2% titanium oxalate)

CRITT sample name	CRITT recipe		CIELAB 1976 chromatic coordinates		
	Mordant	Dyes	L*	a*	b*
345	2% aluminium lactate	Old fustic 2%	55.5	4.1	37.7
346	2% iron lactate	Old fustic 2%	35.8	3.6	19.0
347	2% copper acetate	Old fustic 2%	46.9	6.4	38.4
348	2% titanium oxalate	Old fustic 2%	50.7	9.7	40.9

Table 3 - CIELAB1976 coordinates of samples dyed with old fustic, previously treated with four different mordants

CRITT sample name	CRITT recipe		CIELAB 1976 chromatic coordinates		
	Mordant	Dyes	L*	a*	b*
156	2% aluminium lactate	Madder 2%	45.3	34.8	20.5
45	2% iron lactate	Madder 2%	32.7	10.3	9.3
158	2% copper acetate	Madder 2%	46.8	16.5	9.6
3	2% titanium oxalate	Madder 2%	43.3	25.7	15.6

Table 4 - CIELAB1976 coordinates of samples dyed with madder, previously treated with four different mordants

and a higher b* value. On the other hand, their reflectance spectra are all comparable: in the four spectra, absorption bands are all aligned at the same wavelength suggesting they are due to the dye, while it is not possible to recognize any spectral characteristic directly ascribable to mordants.

Inside the wider group of *yellow and yellowish* samples, it is possible to observe by the naked eye that samples treated with aluminium lactate are the lightest ones while the ones treated with iron lactate are the darkest ones and appear browner. On the contrary, textile fibres treated with copper acetate and titanium oxalate appear quite similar, even if copper yield to a lightly greener colour.

Table 3 and figure 4 relate to yellow samples dyed with old fustic. In this case, colorimetric values give evidence of the browning caused by iron-based mordant, of the lightness caused by aluminium and of the greening (lower a* value) due to the copper, visible by comparing samples 347 and 348. Reflectance spectra have, in fact, different behaviours, showing low reflectance values in the case of iron lactate treatment and higher values in the case of aluminium lactate, where it is also visible a flex at around 490 nm. Differently from the case of chlorophyll, it seems impossible to recognize spectral characteristics clearly ascribable to old fustic inside the considered wavelength range.

Also concerning *pink* samples, the use of aluminium lactate gives the lightest result, while iron lactate makes the final colour browner and darker. As for green and yellow samples, titanium oxalate and copper acetate have similar effects on the final colour, even if you can distinguish lower a* and b* values in the case of copper based treatment.

Table 4 refers to the group of pink samples dyed with madder, reported as example of those chromatic behaviors. In figure 5, FORS spectra of samples treated with aluminium-, copper- and titanium-based mordants show characteristic and recognizable spectral behavior of madder [4, 5]. On the contrary, the use of iron lactate involves a deep flattening of the reflectance curve and a shift of the main flex (600 nm) towards longer wavelengths range, identifiable in the browning effect of the sample.

The knowledge about the influence of different mordants in the final colour helped us in modifying some CRITT recipes, with the final aim of getting precise colors requested for tapestry's conservation.

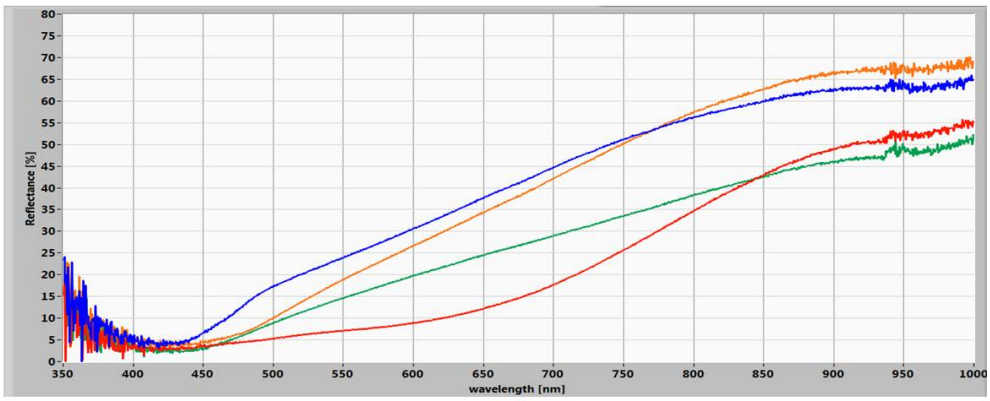

Figure 4 - Reflectance spectra of samples dyed with 2% fustet, previously treated with four different mordants (blue curve: 2% alum lactate; red curve: 2% iron lactate; green curve: 2% copper acetate; orange curve: 2% titanium oxalate)

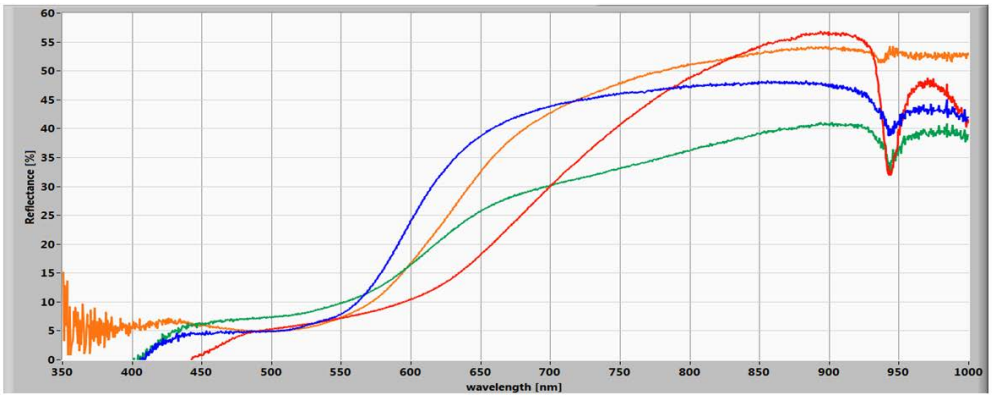

Figure 5 - Reflectance spectra of samples dyed with madder, previously treated with four different mordants (blue curve: 2% alum lactate; red curve: 2% iron lactate; green curve: 2% copper acetate; orange curve: 2% titanium oxalate)

Table 5 - Colour difference between commercial and restoration wool and effects on some dyeing's final colour

Pre-metall. dyes YMG %	Natural dyes Recipe n°	CRITT – Natural dyeing on commercial wool			CCR – Natural dyeing on restoration wool			Colour difference CIEDE2000
		L*	a*	b*	L*	a*	b*	ΔE_{00}
(NOT DYED WOOL)		88.7	-0.4	10.5	83.8	0.62	12.8	19.2
Y:70% M:10% G:20%	46 - CCR 46	38.7	3.9	18.6	39.9	3.2	17.7	1.2
Y: 60% M: 20% G: 20%	50 - CCR 50	36.8	4.0	7.4	36.8	3.6	6.2	1.0

4. APPLICATION

4.1. TEST ON TEXTILE SUPPORT

As mentioned, CRITT had tested recipes on samples of commercial wool. Since wool generally undergoes some chemical treatment - as blanching or softening made with products such as silicon that can inhibit the dyeing – we reproduced some recipes as they are on restoration wool, in order to evaluate the influence of the textile support on the final colour. Comparing colorimetric values of commercial and restoration wool yarns – as they are and when dyed with the same recipe – we could evaluate the colour difference.

As reported in table 5, commercial wool not dyed is of a brighter white, probably because of some blanching treatment received during the production process, while the wool normally used for conservation, before the dyeing, is more yellow and a little bit darker, showing a colour difference (ΔE_{00}) of 19.2 units. Nevertheless, the starting colour of conservation wool seems not to have a relevant influence on the yarns' final colour (ΔE_{00} around 1).

As table 5 shows, the two green samples of two different wools both treated with 2% iron lactate and dyed with 2% old fustic (recipe n° 46) have very similar chromatic coordinates, with a ΔE_{00} of 1.2 units. The other example (recipe n° 50) relates to two grey samples, both treated with 2% iron lactate and dyed with 3% myrobalan, which show a ΔE_{00} of 1 unit.

4.2. TEST ON A STREAMLINED DYEING PROCESS

Since all natural recipes require a two-step dyeing process - the first one involving the treatment with mordants, the second one concerning the dyeing of the textile fibres while they are still wet - we imagined a way for providing to the conservators a streamlined dyeing process, shortening the working time.

The idea was to supply to the conservators textile

"COLOUR FINDING": YELLOW						
CCR sample name	Dyeing recipe		CIELAB 1976			Colour difference CIEDE2000 relative to the original tapestry
	Mordant	Dyes	L*	a*	b*	ΔE_{00}
Original tapestry	-	-	43.7	9.4	32.5	-
CCR 1	10% aluminium lactate	5% old fustic 5% weld	64.5	4.9	54.7	23.8
CCR 1b	10% aluminium lactate	6% fustet 3% weld	66.0	4.8	57.6	25.4
CCR 1d	10% aluminium lactate 0.5% iron lactate	10% Fustet	54.3	3.7	49.0	15.6
CCR 1e	10% aluminium lactate 0,5% iron lactate 1% titanium oxalate	10% Fustet	51.9	15.6	54.7	11.2
CCR 1f	8% aluminium lactate 1% iron lactate	10% Fustet	47.2	3.2	39.9	8.6

Table 6 - Schema of the CIELAB1976 chromatic coordinates measured on a yellow area of the historical tapestry, compared to some samples made by CCR using natural dyes and non-toxic mordants modifying CRITT recipe

"COLOUR FINDING": GRAYISH BROWN						
CCR sample name	Dyeing recipe		CIELAB 1976			Colour difference CIEDE2000 relative to the original tapestry
	Mordant	Dyes	L*	a*	b*	ΔE_{00}
Original tapestry	-	-	26.0	3.6	8.9	-
CCR 49	2% iron lactate	1% old fustic 1% madder	34.2	6.6	11.6	7.2
CCR 49b	5% iron lactate	5% madder 5% fustet	23.3	7.3	8.6	4.7
CCR 49c	5% iron lactate	10% old fustic 1% madder	28.7	5.1	14.5	4.4
CCR 49d	5% iron lactate	8% fustet 2% madder	24.6	6.0	11.6	3.0

Table 7 - Schema of CIELAB1976 chromatic coordinates measured on a grayish brown area of the historical tapestry, compared to some samples made by CCR using natural dyes and non-toxic mordants modifying CRITT recipe.

"COLOUR FINDING": GREEN						
CCR sample name	Dyeing recipe		CIELAB 1976			Colour difference CIEDE2000 relative to the original tapestry
	Mordant	Dyes	L*	a*	b*	ΔE_{00}
Original tapestry	-	-	43.1	4.4	17.9	-
CCR 46	2% iron lactate	2% fustet	39.9	3.2	17.7	3.1
CCR 51	1% iron lactate 1% copper acetate	1% fustet 1% weld	46.79	1.79	30.64	9.7
CCR 51a	2% iron lactate	1% fustet 1% weld	40.9	3.4	18.7	2.4

Table 8 - Schema of the CIELAB1976 chromatic coordinates measured on a green area of the historical tapestry, compared to some samples made by CCR using natural dyes and non-toxic mordant modifying CRITT recipe

fibres already treated with mordants at different levels of mordant concentration. As the mordant effect and its concentration are decisive in the final colour of textile fibres, conservators should use that set of fibres, differently pre-treated, for varying whatever recipe and obtaining different colours. For this reason, we had to verify if an interruption between the first and the second step of the dyeing process could have some effect in the final colour.

Comparing some samples dyed following the normal process to other ones dyed 28 days after the mordant treatment, the ΔE_{00} results averagely of 1.4 units, confirming it is possible to interrupt the dyeing process without causing any relevant variation.

4.3. ACHIEVEMENT OF FITTING COLOURS REQUESTED FOR TEXTILE CONSERVATION

The conservative intervention on the historical tapestry required textile fibres of some fitting colours, for integrating original areas that displayed some lacunae.

As mentioned, most of colours requested were lightly different from the ones obtained by CRITT. The first work of *colour finding* involved a yellow: it was necessary to get a colour similar to the pre-metallized Y 100% sample, but lightly darker and a little bit greenish. The Y 100% sample had been reproduced by CRITT using 10% aluminium lactate as mordant and 5% old fustic with 5% weld as dyes. Starting from that recipe, we modified dyes' concentration

as shown in table 6, adding also iron lactate to get the browning effect: sample CCR 1f fitted well the requested colour and it was used for the textile conservation. After that, we worked on a grayish brown colour: in this case, the most similar synthetic sample was a three-dye mixture made with Y:60%, M:20% and G:20%.
Its reproduction with natural ingredient contained 2% iron lactate as mordant and 1% old fustic and 1% madder as dyes.
Since conservation required a browner colour, we firstly added iron lactate to the mordant, increasing contemporarily dyes quantities (sample 49b, table 7). While iron mordant had given the desired effect to the colour, probably the increasing of madder carried it towards a too red hue. Therefore, we modified again dyes ratios finding at the end a suitable colour for conservation.
Table 8 shows other examples about green colours. The first (CCR 46) is one of the cases in which the recipe gave a good correspondence with the green original tapestry area, so that conservator could exploit the recipe as it is. The second case is about the recipe made with old fustic and weld, and with iron and copper-based mordants (CCR 51), in which we could get the right colour varying mordants (see CCR 51a, table 8).

4.4. LIGHT-STABILITY EVALUATION OF DYED SAMPLES

In order to verify the light-stability of the natural ingredients we used, we submitted all dyed samples to an accelerated ageing by means of a controlled light exposure.
We used a Camera Sun-Test CP equipped with a Xenon lamp (1500 W) that provides an irradiation of about 750 W/m2; a filter cuts the wavelength range under 320 nm, aiming at simulating the solar light indoor exposure of samples through a window.
Table 9 shows some representative dyed samples, reporting their chromatic coordinates and the colour differences calculated before and after the light exposure.
The result was that samples underwent a feeble discoloration after 24 hours exposure, suggesting they can be used for restoration.

5. CONCLUSIONS

In the field of textile conservation, most of conservators now use synthetic pre-metallized dyes, which contain heavy metals such as chrome and cobalt. All tests made within this project on eco-friendly products for dyeing, risen from the necessity of protecting operator health and reducing environmental impact, allowed to provide an efficient alternative for dyeing.
Using natural dyes (old fustic, weld, madder, dyer's broom, myrobalan, logwood, cochineal and alder buckthorn) and non-toxic mordants (aluminium lactate, titanium oxalate, copper acetate, iron lactate, woad and gallnuts) produced by CdP, in fact, CRITT prepared with different recipes a wide set of coloured samples, that can be used as a new reference palette for dyeing.
Moreover, the spectrophotometric and colorimetric study about mordants, carried out at CCR, provided useful indication for comprehending how to modify recipes whenever the conservative intervention requests further colours. For those cases, it should be even possible to equip conservation laboratories with textile fibres pre-treated with mordants at different values of concentration: therefore, the dyeing process at the expense of the conservator would be also extremely streamlined.
Thanks to this project, a yellow, a green and a brown obtained by modifying some CRITT recipes were used by conservators to integrate lacunae of a 17th century tapestry. On the other hand, FORS spectra collected on more than three hundred samples represent now a new database on which to deepen the research, also by means of other spectroscopic techniques, in order to use data as diagnostic tool for future investigation.

Table 9 - Colour differences ΔE_{00} measured on some samples after 24 h of UV exposure

CCR sample name	CIELAB 1976 chromatic coordinates before light exposure			CIELAB 1976 chromatic coordinates after 24 hours of light exposure			Colour difference CIEDE2000 before and after light exposure
	L*	a*	b*	L*	a*	b*	ΔE_{00}
CCR 46	42.6	3.5	18.0	44.7	4.0	18.3	2.0
CCR 51	54.1	1.6	28.7	54.2	3.1	27.5	1.8
CCR 51a	46.3	3.4	17.7	47.8	4.5	18.9	1.7
CCR 1f	54.0	17.2	54.8	51.5	15.2	46.6	3.8
CCR 49	36.2	6.5	10.8	37.7	6.5	12.8	2.1
CCR 49b	25.8	7.2	8.5	27.8	6.5	9.5	1.9
CCR 49c	30.9	6.9	13.4	30.9	6.5	12.8	0.5
CCR 49d	29.4	6.3	12.4	31.3	6.7	13.2	1.6

NOTES

a - INNOCOLORS CROSSTEXNET ERA-PROJECT 2011 "Study of stability of traditional natural dyes and their interaction with textile fibers in comparison with new natural dyes and new dye techniques, applicability to industrial production and restoration of ancient textiles".

b - Wool weave yards BE-MI-VA, title 2/22 nm, colour 27666 15/00351

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CONFLICT OF INTEREST

No financial/personal interest have affected the authors' objectivity. The authors claim that no potential conflicts exist.

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