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Impact of mordants on fabrics dyed with natural dyes

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Abstract

The art of dyeing fabrics using natural resources has been practiced since ancient times. Textiles have been colored with dyes from plant sources, resulting in a wide range of products. Synthetic dyes, known for being carcinogenic, toxic, and causing pollution, are gradually being replaced by natural dyes. Mordants play a crucial role in both fixing the dye to the fabric and intensifying the color. This study aims to investigate the impact of pre-mordanting with two different mordants, copper sulfate and potassium dichromate, on various naturally dyed fabrics. Natural dyes were extracted from the stem of *Musa paradsiaca*, leaves of *Spinancia oleracea*, leaves of *Brassica oleraceae.var.capitata f, rubra* and rhizome of *Curcuma longa*. Four fabrics were selected cotton, wool, polyester and cotton silk. Absorbance is inversely proportional to the amount of dye ingrained by the fabrics. Results showed that fabrics mordanted with 4% Potassium dichromate had better absorbing capacity than 2% mordanted fabrics and was found as the most influential mordant. From the experiment, it is inferred that effective mordanting can improve the fixation of dyes extracted from natural sources and thus replace the synthetic dyes in the textile industry. This study emphasises the effective use of mordants in natural dyeing process.

Keywords: Natural dyes, Mordants, Absorbance.

Introduction

Textiles are important materials that decorate and protect our bodies and comfort our lives. The textile industry is a constantly growing field, where greater emphasis is placed on development of multifunctional textiles with antifungal, antimicrobial, heat retardant and UV protection. Multiuse textiles must meet increasing demand of consumers such as health, hygiene, comfort while providing protection against chemical, thermal, biological and mechanical effects. A dye is a substance which consist of chemical groups that imparts colour to a material on adhering to it [1]. Natural dyes are eco- friendly, biodegradable and sustainable products without much environment impact [2,3,4]. Nowadays people prefer natural dye over synthetic dye because they are aware of the ecological damage synthetic dye can cause.

The colours produced by the natural dye is because of the pigments present in them. Although natural dye has several disadvantages like non uniform shades, poor colour fastness, lack of standardized protocol for the application of dye etc., all these drawbacks are overlooked as they do not harm the environment [5]. Natural dyes have been used since prehistoric time and are used for colouring leather, textiles etc. Even though people prefer natural dye over synthetic dye, in the 20^{th} century natural dye contribute only 1% in textile industry [6]. This may be due to various reasons like non sustainable, non-availability of various shades that is lack of colours obtained. In order to get natural dyes, natural resources have to be exploited which leads to endangered species.

The large biodiversity can provide all raw materials required for natural dying like bark of tree, seeds, peel of fruits and so on [7,8]. More than 2000 pigments are produced by various plant parts [9]. Various types and forms of pigments are currently used as additives or supplements in the food industry, cosmetics, pharmaceuticals, animal feed, and other applications. Natural dyes extracted from plant sources are also known to show efficient UV and antimicrobial properties [10]. Plant pigments contain a wide variety of components, including anthocyanins, carotenoids, betalains, and chlorophyll. However, these natural dyes have limited colour fastness which can be solved by using a chemical fixative called mordant [11]. Dye and mordant are two essential and dependant aspects responsible for the development of colours applied to textiles [12,13]. Mordants contain metal ions which accepts electrons and forms a co-ordinate bond with the dye molecules thereby making the dye act as a fixative agent and making them insoluble in water [14]. Few mordants are not eco-friendly so care should be taken while selecting the mordants [15] The choice of the fabrics used in the dyeing process is significant in the adherence of the color. The current study highlights the effectiveness of various mordants and their dyeing properties on naturally dyed fabrics.

Materials and Methods

Collection of plant material

The stems of banana (*Musa paradisiaca L.*), leaves of purple cabbage (*Brassica oleraceae.var.capitata f, rubra*), leaves of spinach (*Spinancia oleracea*) and rhizome of turmeric (*Curcuma longa*) were collected from the local market in Bengaluru.

Fabrics and Mordants used

Cotton, wool, polyester and cotton silk were purchased from local shops. It was resized to small pieces with dimension 10 x 10 cm, which was used for dyeing. Copper sulphate ($CuSO_4$) and potassium dichromate ($K_2Cr_2O_7$) were used as mordants.

Scouring of fabrics

The fabrics were scoured by boiling with sodium carbonate (0.5 g/l) and tween 80 (2 g/l) at 50℃ for 25 minutes keeping the material to liquor ratio at 1:40. The scoured fabrics were then washed with cold tap water and allowed to dry at normal room temperature [15].

Mordanting of fabrics

Two different concentrations of the mordants namely copper sulphate and potassium dichromate were prepared at 2% and 4% individually. Pieces of fabrics in triplicates such as cotton, wool, polyester and cotton silk were added into the mordanting solution separately. It was heated upto 85℃ for one hour and then allowed to air dry [16].

Extraction of dye

Different methods were used for extracting dye from various plants:

Musa paradisiaca L: About 2Kg banana pseudo stem was weighed and washed with tap water to remove any debris. Then it was cut into small pieces and crushed with mortar and pestle. The extract was filtered using a muslin cloth to yield natural dye [17].

Brassica oleraceae.var.capitata F. *rubra*: 1Kg of leaves of purple cabbage were weighed and chopped into small pieces. The chopped pieces were placed in a small pot containing 2 litres of water. It was brought to boil at 100℃ with continuous stirring till a dark concentrated solution was obtained. The dark purplish extract was then filtered and used as a natural dye [18].

Spinancia oleracea: 1Kg of fresh and washed spinach leaves were separated and boiled with 2 litres of water. The dye was extracted by heating it to 100℃ with continuous stirring. The extract was filtered using muslin cloth. The green filtrate obtained was used for dying of fabrics [19].

Curcuma longa: 2g of turmeric powder was weighed and boiled with 200 ml of water at 80℃ for 60 minutes. The yellow colour extract was used for dying fabrics [20].

Dye fixation and absorbance studies

Dying of fabrics was done in triplicates. The mordanted fabrics was added separately to the dye bath containing 200 ml of the respective extracted dye and boiled at 90 to 100℃ for 60 minutes with constant stirring. It was then allowed to cool. The fabrics were soaked overnight and then allowed to air dry [18,21]. After the dying process is completed, the absorbance of the remaining solution in the dye bath is recorded [22]. The lowest value of absorbance indicates higher amount of dye absorbed by the fabric. The naturally dyed and dried fabrics were washed with tap water to check the retention of dyes.

Results

Effect of dye on mordanted fabrics

Results [Table 1; Figure 1] show that cotton and wool fabrics when dyed with banana dye produced a coffee brown colour. The colour appeared darker when mordanted with 4% potassium dichromate. Wool absorbed most of the dye, however the colour faded on subsequent washing. 4% potassium dichromate proved to be a better mordant for fixing spinach dyes on polyester fabric. It produced a green colour on the fabric. The dye absorbed by cotton, wool and cotton silk gave a pale colour which faded on repeated washing. The dye extract from purple cabbage produced a prominent bluish-purple colour on cotton and wool, while a blue shade was observed on polyester and cotton silk. Fabrics when dyed with turmeric dye produced shades of yellow that

ranged from dark yellow to orange golden yellow. The turmeric dye was well retained on the fabrics even after several washes.

Effect of absorbance on dying:

Absorbance is inversely proportional to the amount of dye absorbed by the fabrics. Results [Table 2] indicate that 4% $CuSO_4$ and 4% $K_2Cr_2O_7$ mordanted fabrics showed more dye adherence than 2% $CuSO_4$ and 2% $K_2Cr_2O_7$. A darker hue was produced in the fabric which was mordanted with potassium dichromate, while the colour of the fabric mordanted with $CuSO_4$ appeared lighter. Of the two mordants used, 4% potassium dichromate enhanced the fixation of the dyes on all fabrics. Of the fabrics used, wool showed the least absorbance value [Table 2; Figure 2, 3, 4, 5].

Table 1: Effect of natural dye extracts on different fabrics

Plant name	**Fabric**	**2% $CuSO_4$**	**4% $CuSO_4$**	**2% $K_2Cr_2O_7$**	**4% $K_2Cr_2O_7$**
Banana stem	Cotton	Coffee brown	Coffee brown	Coffee brown	Dark brown
	Wool	Dark brown	Dark brown	Dark brown	Dark brown
	polyester	Brown	brown	Dark brown	Dark brown
	Cotton silk	white	white	white	Light brown
Purple cabbage Leaves	Cotton	Purple	purple	Bluish purple	Bluish purple
	Wool	blue	blue	Purplish blue	purplish blue
	polyester	Purple	purple	Blue	Blue
	Cotton silk	white	white	white	Light blue
Spinach Leaves	Cotton	Greenish yellow	Greenish yellow	Greenish yellow	Greenish yellow
	Wool	pale green	pale green	Light green	Light green
	polyester	Greenish yellow	Greenish yellow	Green	Green
	Cotton silk	White	white	white	Pale green
Turmeric Rhizome	Cotton	Dark yellow	Dark yellow	Dark yellow	Dark yellow
	Wool	Dark yellow	Dark yellow	Dark orangish yellow	Dark orangish yellow
	polyester	Yellow	yellow	Dark yellow	Dark yellow
	Cotton silk	Golden yellow	Golden yellow	Orangish Golden yellow	Orangish Golden Yellow

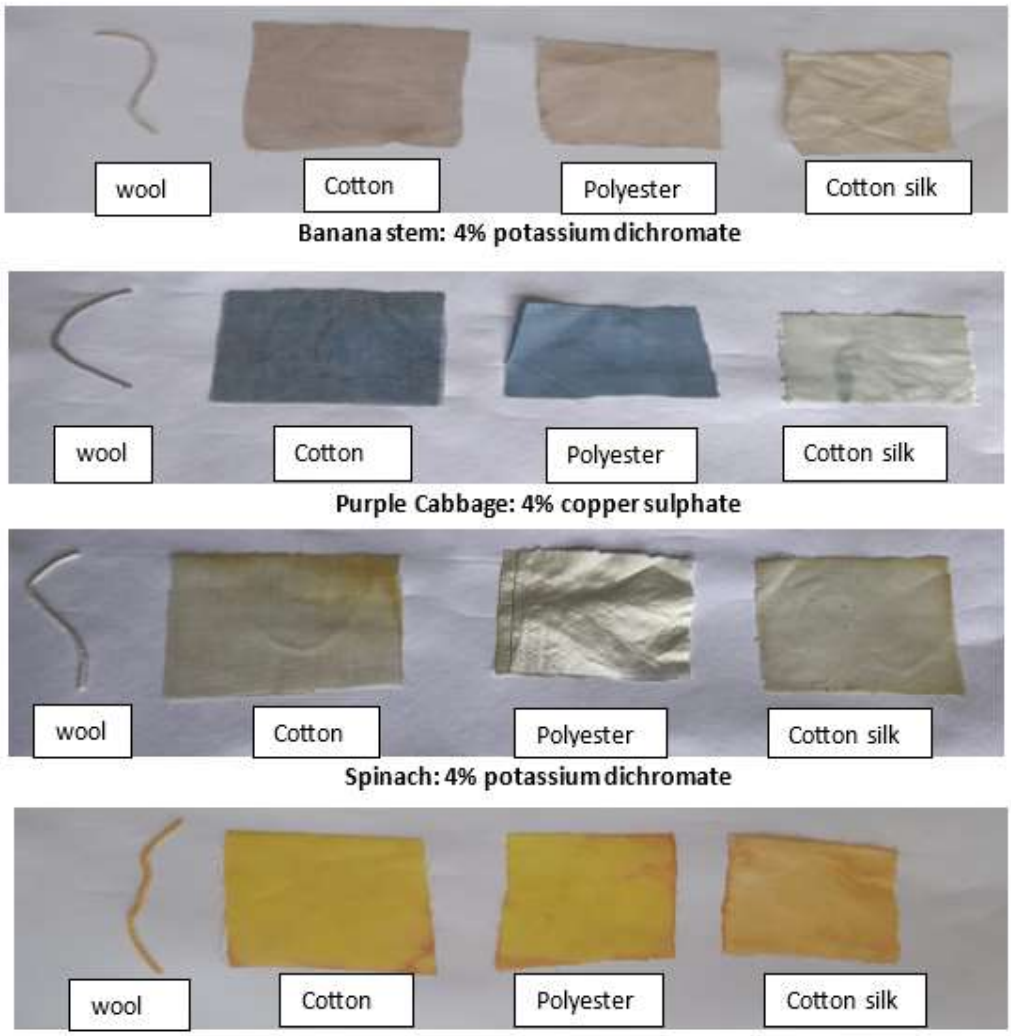

Figure 1: Effect of natural dye extracts on different fabrics

Table 2: Absorbance of Dye

		Absorbance of dye			
Fabric	Mordant	Banana stem at 680nm	Purple cabbage at 490nm	Spinach at 570nm	Turmeric at 620nm
Cotton	2% copper sulphate	1.51	0.82	0.33	0.18
	4% copper sulphate	1.50	0.81	0.33	0.16
	2% potassium dichromate	1.15	0.70	0.30	0.16
	4% potassium dichromate	1.02	0.60	0.30	0.10
Wool	2% copper sulphate	1.06	0.80	0.23	0.16
	4% copper sulphate	1.03	0.61	0.21	0.12
	2% potassium dichromate	0.90	0.48	0.20	0.10
	4% potassium dichromate	0.90	0.41	0.18	0.07
Polyester	2% copper sulphate	1.51	0.86	0.35	0.21
	4% copper sulphate	1.25	0.82	0.35	0.18
	2% potassium dichromate	1.20	0.74	0.34	0.16
	4% potassium dichromate	1.15	0.63	0.33	0.12
Cotton silk	2% copper sulphate	1.77	0.89	0.40	0.44
	4% copper sulphate	1.67	0.87	0.38	0.29
	2% potassium dichromate	1.50	0.76	0.35	0.26
	4% potassium dichromate	1.33	0.69	0.35	0.14

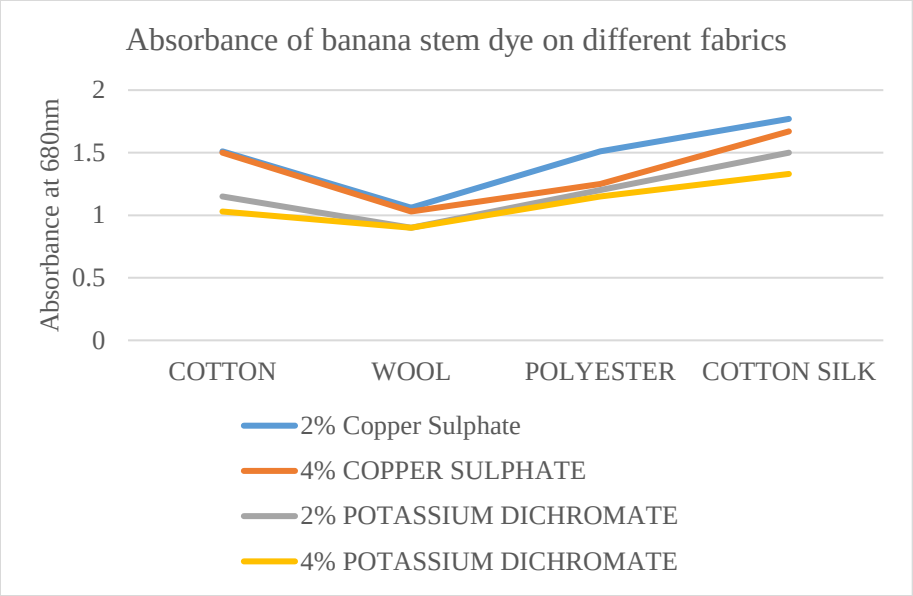

Figure 2: Absorbance of banana stem dye on different fabrics

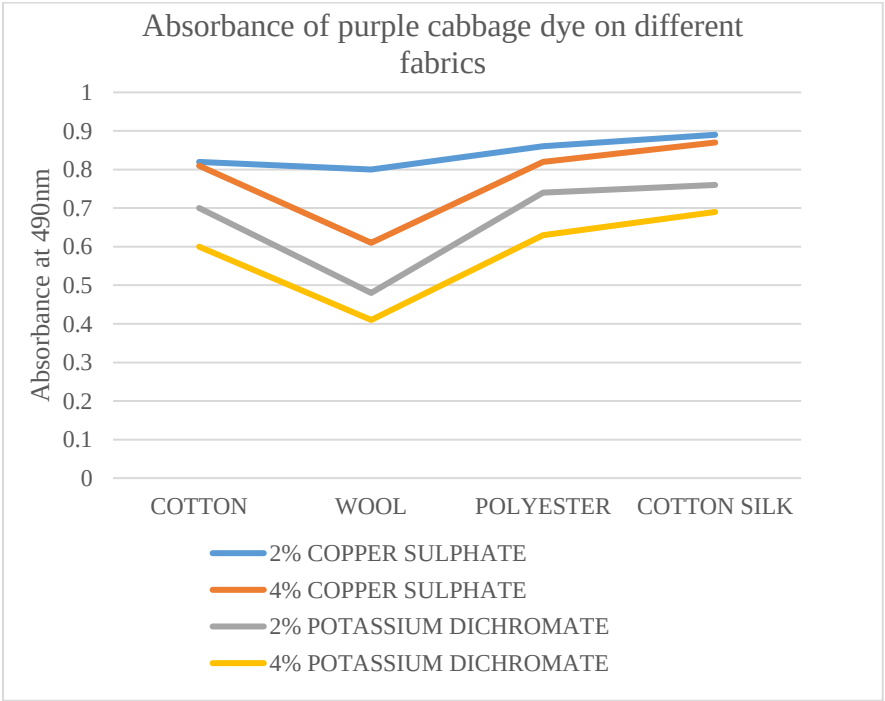

Figure 3: Absorbance of purple cabbage dye on different fabrics

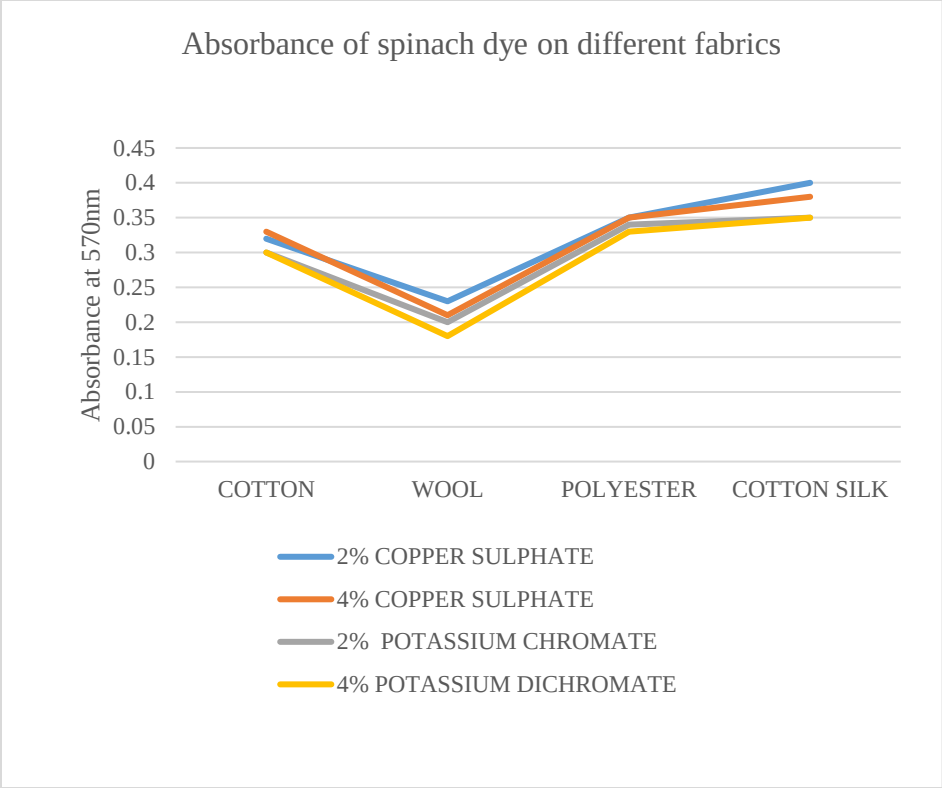

Figure 4: Absorbance of spinach dye on different fabrics

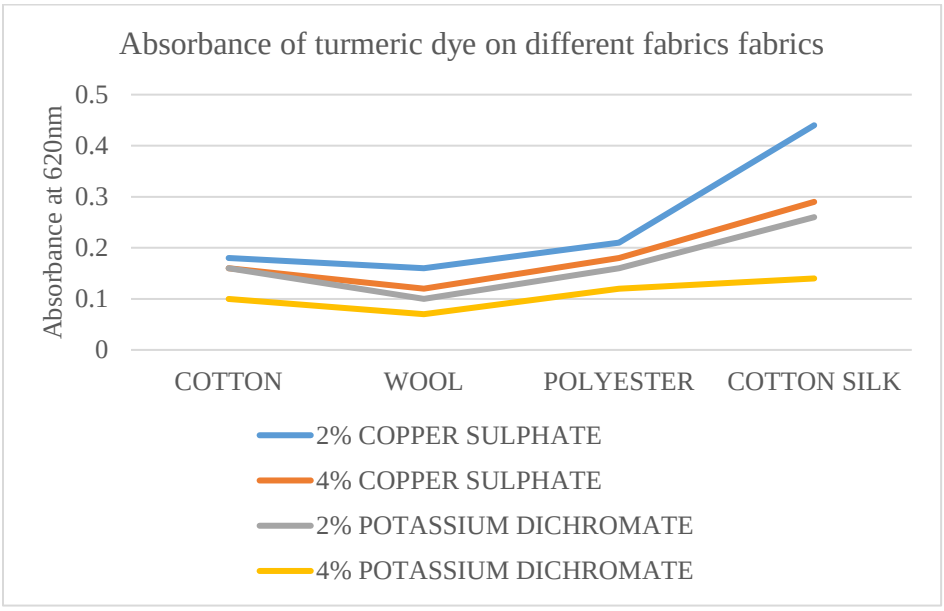

Figure 5: Absorbance of turmeric dye on different fabrics

Discussion

The fabrics mordanted with 4% potassium dichromate gave better results in terms of dye absorption and color retention. The concentration of mordant is directly proportional to the amount of dye absorbed. It is established that high color yield can be obtained by a high mordant concentration [23]. Mordanting methods and mordanting chemicals give rise to various color shades and this is well established by earlier studies [24,25]. Dyeing efficiency also depends upon the extraction method and mordant application. Absorbance value is inversely proportional to the amount of dye absorbed [26]. According to the colorimetric values, the increased concentration of mordant in the fabric increased the dye uptake and potassium dichromate turned out to be the best mordant compared to copper sulphate. Among the four fabrics, mordanted wool is known to absorb more dye. Wool is a natural fibre and is more porous than cotton which allows it to absorb more dye [27,28]. In the current studies, polyester absorbed less dye than cotton fabric while cotton silk absorbed least amount of dye. Although polyester absorbed less dye than cotton, it has greater retention capacity and remained dark even after several washes. Polyester is made from petroleum-based products which makes it more receptive to dyes. Polyester is more resistant to fading and shrinking than cotton [27]. Cotton and wool slightly faded after several washes. Cotton silk is a fabric which consists of both cotton and silk yarn. Silk is hydrophobic they repel water and it is least porous so the dye molecules cannot enter and form bond, hence cotton silk has least absorption capacity. Different mordants produce differences in hue color on various naturally dyed fabrics [16,29]. Conditions may also cause changes on the dyed fabrics [30]. From this study we can conclude that potassium dichromate is a better mordant than copper sulphate as potassium dichromate mordanted fabrics show lesser dye absorbance value compared to copper sulphate. This may be attributed to the fact that potassium dichromate forms a more stable complex with dye molecules resulting in better colour fastness and colour strength. The appearances of the colours, their strength and stability on the fabrics depend to a large extent on the choice of mordant used and the nature of the material [13].

Conclusion

People are more conscious of sustainable and eco-friendly products. Since dyes extracted from natural sources are biodegradable, show non-allergic, nontoxic, effects as well as fewer side effects, it plays a pivotal role in the field of textile dyeing research. This work highlights on the effect of mordants on fabrics dyed with various natural dyes. Dyes extracted from spinach, turmeric, purple cabbage and banana stem yielded various shades of colors with different mordants. The Color characteristic of the dye on different fabrics was enhanced by the increased concentration of mordants. Synthetic mordants are indispensable in dyeing fabrics with natural dyes and impact the hue shades produced depending on the nature of mordant – dye complex formed during the process of dyeing. With the experimental data, it is inferred that effective mordanting can enhance the fixation of naturally extracted dyes and thus replace the synthetic dyes in the textile industry.

Conflict of Interest

All authors declare no conflict of interest.

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