



Natural Dye from *Torenia* SP Flower for Colouring Silk Yarn using Biomordants- An Ecofriendly Approach

R Manimozhi* and Shyamala Kanakarajan

Department of Plant Biology and Plant Biotechnology, Ethiraj College for Women, Chennai, Tamil Nadu, India

ABSTRACT

Natural dyes have been a part of human life since time immemorial due to their non-toxic and biodegradability. Environmental and health hazards created by synthetic dyes once again proved the importance of natural dyes. In the present study, dye from *Torenia* sp was extracted by crushing the flowers with water and extraction was optimized with different temperature, pH and time. Silk yarn has been pretreated to remove dirt and improve texture. Biomordant (Tannin) from *Peltophorum pterocarpum* bark and *Tamarindus indica* seed coat were used to improve binding of dye to the silk yarn. Extraction of biomordant and mordanting process were standardized to study their effect on colour and fastness properties. The conditions optimal for dyeing such as pH, temperature, time and dye concentration were also standardized. Dyed yarn has been evaluated for its fastness properties such as light, wash and perspiration using standard ISO methods. The results showed good fastness properties with the application of biomordant. Phytochemical, TLC, UV-Visible, and FTIR analysis were done to investigate the pigment present in the dye. Results showed the presence of Anthocyanin group of compounds that are responsible for the blue colour of the flower and gives green colour to the dye upon change in pH. Since green coloured dye is not commonly available from natural source, *Torenia* sp flowers can be effectively used in textile industries as an alternative for synthetic green dye.

Keywords: Natural dye; *Torenia* sp; Biomordant; Colour fastness; Anthocyanin

INTRODUCTION

The art of dyeing dates back since Bronze Age in Europe. In 1856, William Henry Perkins accidentally discovered synthetic dye which declined the use of natural dyes because the synthetic dye was able to fulfil the demand of the market [1]. Most of the synthetic colours are manufactured from petrochemical sources with hazardous chemicals which pollutes the environment adversely through their wastes [2]. In German and European countries there is a ban implemented for the use of benzidine dyes in textile industries [1].

Natural dyes are nontoxic and eco-friendly due to their easy biodegradability. The dyes obtained from plants are pigmentary molecules which gives colour to the textile materials. These molecules have an aromatic ring structure with a side chain which is needed for resonance and imparting colour. The chemical structure is correlated with the colour and the chromophore with the auxochrome [1]. India had a virtual monopoly in the production of textile materials which is painted, dyed and printed with natural dyes during 7th century [3]. The most famous and costly dye was train purple which was obtained from spiny dye- murex shellfish, noted in Bible [4]. Aqueous extraction of natural dyes was most preferred method by textile dyers [5]. The standardized dyeing techniques are needed for the better commercialization of natural dyes [6]. Natural dyes has less substantivity to the fibre and have poor fastness properties, hence requires a mordant to improve their fixation in the fibre by forming a mordant - dye complex through chemical bonds [7]. Mordants are metal salts which produce affinity between dye and the fibre [6]. Mordants not only help in dye uptake and colour fastness, it also helps in achieving different colour shades in the

textiles [8]. The use of harmful chemical mordants such as Copper sulphate, Stannous chloride, Stannic chloride, Zinc sulphate and Potassium dichromate also contributes to the toxicity of the effluent released from textile industries. So to avoid such toxicity caused by metal mordants, natural mordants (biomordants) started gaining interest. Tannin is a widely used biomordant. Tannin has been used as mordant since the textile colouration started. Tannin was used for dyeing and printing by people from Tamilnadu, Maharashtra, Andrapradesh (Masulipatnam) and Rajasthan which has been exhibited in museums. Printing of multani saris and the famous kalamkari works of earlier days was done mostly with tannins [9]. Tannin is a naturally occurring water soluble polyphenolic compounds which contains phenolic hydroxyl groups that can crosslink with proteins [7].

Silk has been known as "queen of fibres" due to their luster, fine and smooth texture and superior mechanical performance [10]. Silk is one of the important natural protein fibres that has highly oriented molecular structure which is used in textile industry since many centuries [11]. *Torenia sp* is an ornamental plant belongs to the class Magnoliopsida and family Scrophulariaceae, which is commonly known as the 'figwort family'. The common name for *Torenia sp* is wishbone derived from the chicken wishbone-shaped stamens [12]. The origin of *Torenia sp.* is not known [13], though they are reportedly native to South East Asia, Africa and Madagascar [14].

Anthocyanins are flavonoids with largest group of water-soluble natural pigments responsible for red, pink, scarlet, mauve, violet and blue colours in the petals, leaves and fruits of higher plants [15]. In the present study, natural dye was extracted from flowers of *Torenia sp* by optimizing the extraction process. Dyeing of silk yarn with the dye extract was optimized with biomordant from *Tamarindus indica* seed coat and *Peltophorum pterocarpum* bark. Colour fastness of the yarn was evaluated. The dye pigment was identified through various analyses.

MATERIALS AND METHODS

Collection of Plant Material

Torenia sp is the plant used in this study for extraction of dye, which was collected from Society of Horticulture and maintained. The part used for the dye extraction was only flowers.

Optimization of Dye Extraction

Fresh flowers of *Torenia sp* were collected and weighed 10 gm. Different temperature (30°C, 40°C, 50°C, 60°C), pH (5, 7, 9) and time (15, 30, 45 and 60 min) were optimized to study the efficient extraction of dye. The flowers were crushed in mortar and pestle and soaked with 100 ml of distilled water in room temperature for 30 min and then extracted. The sample to liquor ratio was maintained as 1:20. The extracted dye was filtered and used for dyeing.

Collection of Silk Yarn

Silk yarn was purchased from TANSILK, Salem, Tamil Nadu, India.

Pretreatment of Silk Yarn

The degummed silk yarn was soaked in mild detergent at room temperature for 1 hour and then washed with running tap water to remove the natural impurities and improve the texture of silk yarn for dyeing.

Mordanting

Tannin extracted from *Peltophorum pterocarpum* bark (P.PT-B) and *Tamarindus indica* seed coat (T.I-S.C) has been used as mordant to avoid toxicity caused by harmful chemical mordants. Extraction method has been standardized for maximum yield of tannin.

Extraction of Tannin

Plant sample (T.I-S.C and P.PT-B) to liquor ratio was maintained as 1:15. Extraction was carried out with only distilled water, distilled water with 1% and 5% sodium carbonate solution. Distilled water to sodium carbonate solution was maintained at 2:1 ratio. The setup was kept for boiling for 60 min. The extracted tannin was filtered and was used for mordanting.

Standardization of Biomordant

Different concentration (30% - 100%), time (30 min – 60 min) and temperature (40°C - 100°C) were standardized for mordanting of silk yarn. Pre mordanting of silk yarn was done before dyeing. Meta mordanting was done by adding mordant to the dye bath containing silk yarn. Dyeing and mordanting were carried out simultaneously. Post mordanting was done after dyeing of silk yarn.

Dyeing

The pretreated silk yarn was dyed using dye extracted from *Torenia sp* flowers. Optimization of dyeing of silk yarn were studied at different pH (5, 6, 7, 8, 9), temperature (30°C, 40°C, 50°C, 60°C), time (15, 30, 45 and 60 min) and material to liquor ratio (ML) (1:20, 1:40, 1:60). After dyeing the dye bath exhaustion was calculated and based on the percentage of dye exhaustion, the optimum pH, temperature, time, and material to liquor ratio were selected. The dyed yarns were air dried and checked for colour fastness.

Dye Exhaustion

The percentage of dye bath exhaustion was calculated using an equation on the basis of absorbance values recorded before and after dyeing with UV-Visible spectrophotometer [16].

$$\%E = \frac{A_0 - A_1}{A_0} \times 100$$

Where, %E is dye exhaustion, A_0 and A_1 are the absorbance of the dye bath before and after dyeing, respectively.

Colour Fastness

The dyed silk yarn was evaluated to colour fastness to light (ISO 105 B02-2013), washing (ISO: 105C-06:2010) and perspiration (ISO 105 E04-2013) using standard ISO methods.

Identification and Characterization of Dye

Phytochemical analysis:

The aqueous dye extract was checked for the presence of secondary metabolites such as carbohydrates, tannins, phenols, alkaloids, flavanoids, terpenoids, proteins and amino acids, gum/mucilage using standard procedure [17].

Thin layer chromatography:

Silica gel coated plates were used for the separation of pigments of the dye extract. The solvent system used were 1% aqueous HCl, n-Butanol : HCl (18:2), Isopropanol : Ethanol: Water : Acetic acid (11:4:4:1) and Methanol: HCl (0.99:0.1) and n-Butanol: Acetic acid: Water (4:1:5). After separation the R_f values were calculated.

UV-visible spectroscopy:

The dye extract was analyzed in UV-Visible spectrophotometer (Shimadzu-1650 PC) at the range of 400-800 nm with a resolution of 1 nm, to study the maximum absorption spectrum (λ_{max}) of the dye pigment.

FT-IR spectroscopy:

The dye extract was mixed with Potassium bromide (KBr) salt and compressed into a thin pellet and the spectrum of sample was recorded on FT-IR instrument (Shimadzu, IR Affinity 1, Japan), equipped with a DLATGS detector with a mirror speed of 2.8 mm/sec. All measurements were carried out in the range of 500-4000 cm^{-1} at a resolution of 4 cm^{-1} .

RESULTS AND DISCUSSION

Optimization of Dye Extraction

Optimization of aqueous extraction of dye was studied at different pH, temperature and time. On comparing the absorbance of the sample with the calibration curve, the best parameters were selected. The dye was extracted best by crushing the flowers of *Torenia sp* in room temperature (30°C) at neutral pH in less time (Figure 1). The colour of the dye extract thus obtained appeared violet (Figure 2). pH 5 and 9 was not having much effect on the extraction but the temperature had the drastic effect on the extract colour. At 40°C and 50°C the pigment was stable but when the temperature was increased to 60°C the pigment was found to be disintegrating, turning the violet colour extract to pale brown colour. Prolonged time also had an effect on the pigment stability. Only less time and temperature was sufficient for the dye extraction. It has been reported that *Torenia sp* flowers contains the major pigment as anthocyanin [18,19] stated that higher temperature led to anthocyanin degradation. The crude dye obtained may contain mixture of water soluble compounds, some of them will contribute to the colour and some do not. The nature of the chromophore and the auxochrome of dye molecule are responsible for the intensity of the colour [20].



Figure 1: *Torenia sp*- flower



Figure 2: Dye extract from *Torenia sp*

Pretreatment of Silk Yarn

The silk yarn pretreated with mild detergent has removed the impurities and improved the texture of the silk fibre for dyeing.

Mordanting

Extraction of tannin with distilled water, distilled water with 1% and 5% sodium carbonate solution from T.I-S.C and P.PT-B were studied. Only water extraction for P.PT-B and water with 1% sodium carbonate solution for T.I-S.C yielded the best extraction of tannin. In case of tamarind seed coat, the solubilization of condensed tannins were increased to a higher quantities by adding sodium carbonate (Na_2CO_3) to the extraction process and also increased the pH of the tannin extract to alkaline condition [21]. Similar observation was seen in the present study. The phenols are acidic enough to be converted to their salts (deprotonation of the -OH group) by reaction with sodium carbonate. Hydrogen bonds can be formed between the phenolic compounds of tannin and the carboxyl group of protein fibres. Further two more possible bonding can be involved, i) an ionic bond is formed between the anion charge of the phenolic groups and cationics (amino groups) of the protein fibre; ii) a covalent bond can also form between quinone or semiquinone groups which is present in tannin with suitable reactive groups of silk fibre [22]. Different temperature, time and concentration of biomordant have been standardized for mordanting process. Silk yarn meta mordanted with T.I-S.C and P.PT-B has shown positive results but T.I-S.C comparatively gave best results than P.PT-B. Pre mordanting and post mordanting was not giving promising results with both the biomordants. In pre mordanting and meta mordanting the mordant interacts with the silk fibre and produces more active sites for natural dyes to easily get absorbed by forming a silk-mordant dye complex. So natural dyes were easily fixed to the silk fibre through the complex formed. But in post mordanting the amount of natural dyes adsorbed to the silk fibre was less, due to the lack of the mordant in the dye bath [23,24] confirmed that tamarind seed coat extract contains condensed tannins which has phenolic (-OH) groups and can be used as mordant for

natural dyes with silk fibre. The depth of dyeing was also improved by the tamarind seed coat tannin which contains phenolic hydroxyl group forming a complex with dye molecules leading to better dye fixation on the fabric.

Dyeing

Optimization of dyeing of silk yarn was studied at different pH, temperature, time and material to liquor ratio or yarn to dye ratio. After dyeing the percentage of dye bath exhaustion was calculated.

Effect of pH on dyeing:

The effect of pH on dyeing of silk yarn was studied at different pH such as 5, 6, 7, 8 and 9 for silk yarn meta mordanted with T.I-S.C and meta mordanted of P.PT-B. As shown in Figure 3 the maximum dye exhaustion was obtained at pH 9 for the silk yarn mordanted with both biomordants. According to [25] the dye bath pH has an effect on the colour strength due to the interaction between dye and silk fibre. As the pH of dye bath increases the colour strength also increases. The dye uptake at pH 9 was higher compared to other pH, but beyond pH 9 the dye uptake decreased due to the electrostatic repulsion between dye and the fibre. VA Shennai [26] stated that the reaction speed of dye and fibre was high at alkaline pH. According to [27] stability of some anthocyanins was increased in alkaline pH around 8-9. Anthocyanin properties become more distinguishable in the alkaline pH. In aqueous solution anthocyanin structure exist in five forms depending on the pH, such as red flavylium cation, colourless carbinol pseudobase, purple quinoidal base, blue quinoidal base anion and yellow chalcone [28,29]. In the present study, the anthocyanin pigment of *Torenia sp* flower was found to be stable at pH 9 and gave green colour to the dye extract. The acidic and neutral pH did not favour the dyeing effectively. S Bondre et al. [30] reported anthocyanin giving green colour at alkaline pH 9 to 10.

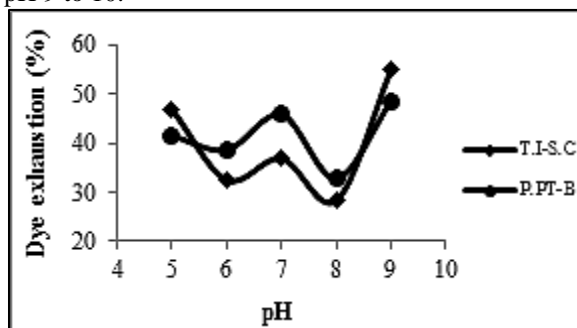


Figure 3: Effect of pH on dyeing of silk yarn with biomordants T.I-S.C and P.PT-B

Effect of temperature on dyeing:

Temperature plays an important role in dyeing since it is one of the factors that helps in maximum sorption of the dye at optimal condition [31]. The effect of temperature on dyeing of silk yarn was studied at different temperature such as 30°C, 40°C, 50°C and 60°C. As shown in Figure 4, the maximum dye exhaustion was achieved at 60°C for silk yarn pre mordanted with the biomordant T.I-S.C and meta mordanted with the biomordant P.PT-B because the speed of diffusion was high at higher temperature, but the pigment was found unstable at higher temperature changing the green colour extract to pale greenish brown colour or into colourless. The hydrolytic degradation of dye might occur due to the stripping of dye in the higher temperature [32].

Hence, 50°C was selected as best temperature since the dye exhaustion was also good compared to other lesser temperatures and the pigment was also found stable. The colour of tannin interference was seen in the dyeing, thereby developing a new shade of greenish brown colour to the dyed yarns. When temperature increased the silk fibre swells and the aggregated dye molecules in the dye bath breaks down and diffuses easily to the fiber thus increasing the dye exhaustion [33]. Similarly when the temperature is increased from 30°C to 50°C, the dye uptake was found better.

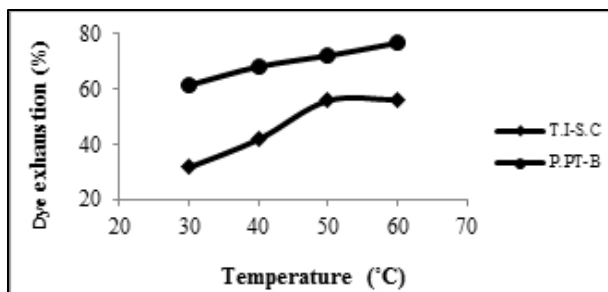


Figure 4: Effect of temperature on dyeing of silk yarn with biomordants T.I-S.C and P.PT-B

Effect of time on dyeing:

The effect of time on dyeing of silk yarn was studied with different time such as 15, 30, 45 and 60 min. As shown in Figure 5, the maximum dye exhaustion was obtained with increase in time. But in prolonged dyeing time equilibrium was attained at 45 and 60 min and also the colour started degrading. Hence, the best dyeing time has been selected as 30 minutes, since the dye uptake was better and stability of the dye was maintained. According to MM Hasan et al. [34] the colour strength was decreased when the fabrics were dyed for long time. This is due to the fact that desorption of the dye molecules might happen because of over dyeing. So, the time for maximum exhaustion of dye may depend on few factors like percentage of shade and other dyeing conditions.

The colour strength value increases when the dyeing time is increased till the dye exhaustion achieves equilibrium, but the colour strength is decreased when increased further. This happens due to the shift in the equilibrium of the dye molecule from the dyeing material into the dye bath [26]. This indicates that the silk fiber each saturation and does not absorb more dye [35].

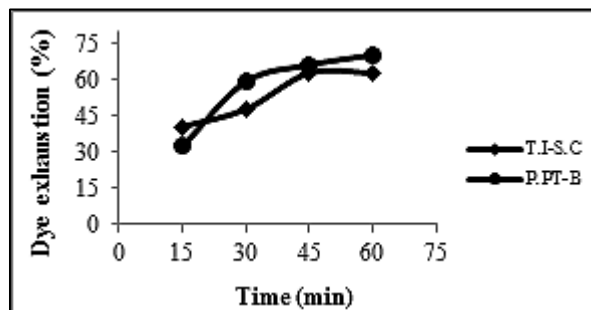


Figure 5: Effect of time on dyeing of silk yarn with biomordants T.I-S.C and P.PT-B

Effect of dye concentration:

The effect of dye concentration on dyeing of silk yarn was studied with different dye concentration such as 1:20, 1:40 and 1:60. As the concentration of the dye increases the concentration gradient increases, thereby increasing the rate of diffusion of dye to the dyeing material [36]. Similarly in the present study when the concentration increased from 1:20 to 1:40 and 1:60 (Figure 6), the colour strength increased. But the maximum dye exhaustion was obtained at 1:20 and was found sufficient for an even dyeing of silk yarn. When the concentration further increased to 1:60, the dye uptake showed similar results with that of 1:40 because of the equilibrium attained between the dye in the dye bath and the dye in the yarn. Since the adsorption capacity of surface of the fibre is limited for the dye molecules, when the concentration of dye was further increased, the surface of the fibre gets saturated gradually [25].

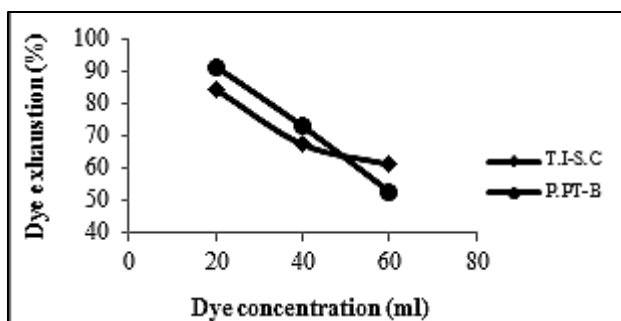


Figure 6: Effect of dye concentration on silk yarn with biomordants T.I-S.C and P.PT-B



Figure 7: Dyeing of T.I-S.C meta mordanted silk yarn with *Torenia sp* flowers (50°C, pH 9, 30 min, ML-1:20)



Figure 8: Dyeing of P.PT-B meta mordanted silk yarn with *Torenia sp* flowers (50°C, pH 9, 30 min, ML-1:20)

Colour Fastness

The dyed silk yarn was evaluated for colour fastness to light, washing and perspiration on a grey scale using standard ISO methods. Silk yarn meta mordanted with T.I-S.C (Figure 7) showed fair to good fastness to light, washing and perspiration than meta mordanted with P.PT-B (Figure 8). Silk yarn meta mordanted with tannin from tamarind seed coat had the effect of insolubilizing the dye and giving good colour fastness. The rate of diffusion of dye molecules and the nature of dye molecules inside the fibre influences the wash fastness. The molecular size of dye molecules has been increased because the dyes tend to aggregate inside the fibre resulting in good wash fastness [37]. The colour change in the wash fastness may be due to two reasons when a standard alkaline detergent solution was used, i) there is an ionization of hydroxyl groups of dye molecules, or ii) dye itself may be decomposed which

results in colourless compound or appears as different colour [38,39]. When the fibre mordanted with tannin is used for dyeing, the size of the dye molecules increases resulting in good fastness properties [33].

The dye chromophore has an inherent resistant property for a chemical or photochemical attack, but the auxochrome might also have an effect on fastness [40]. The degradation of dye colour occurs when the light breaks the chemical bonds present in it. The shorter wavelength of UV causes physical damage to the fibre but the longer wavelength UV and the visible light often causes the fading of textile materials. This results in photochemical oxidation of the dye chromophore which can be reduced by using mordants that will form a complex with dye and helps in protection [7].

Identification and Characterization of Dye

Phytochemical analysis:

Phytochemical analysis of aqueous dye extract of *Torenia sp* showed the presence of Alkaloids, Glycosides, Carbohydrates, Proteins and Aminoacids, Phenols, Flavonoids, Tannins and Terpenoids.

Thin layer chromatography (TLC):

The chromatogram was developed with mobile phase as 1% aqueous HCl showed the presence of Anthocyanin with reference to the Rf value calculated. One of the main factors that determine the Rf value is the number of sugars attached to the anthocyanin. Figure 9 shows the separation of violet coloured anthocyanin pigment with the Rf value of 0.88. Similar results were supported by [41,42]. According to R Curtright et al. [43], the Rf value above 0.62 refers to the anthocyanin without hydrolysis.

UV-visible spectroscopy:

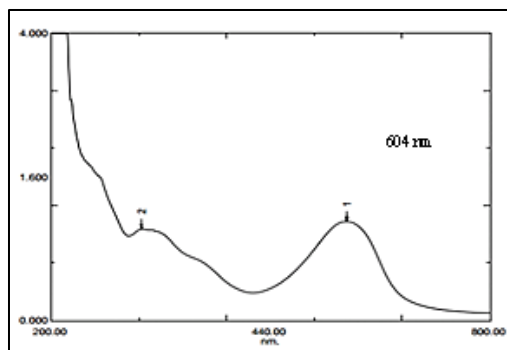
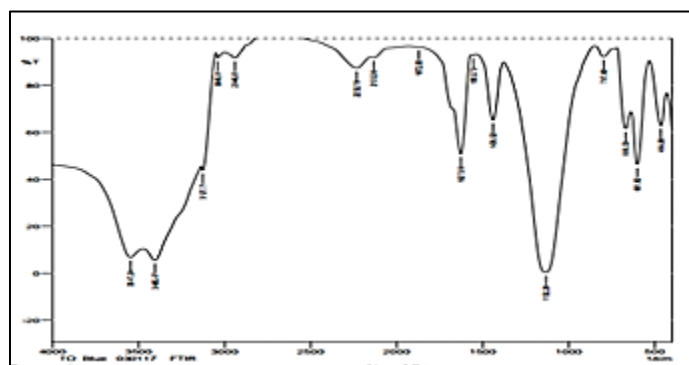
Any colourant show its maximum peak in UV-Visible spectra at a particular wavelength representing the main hue [6]. Chromophore is a part of the molecule that is responsible for the colour and auxochrome is a functional group attached to chromophore which changes the ability of chromophore to absorb light. The dye extract analyzed in the range of 400-800 nm showed the maximum absorption (λ max) at 604 nm (Figure 10) which is a characteristic absorption of violet and blue coloured pigments. Similar results were reported confirming the dye pigment as anthocyanin [27,44].

FT-IR spectroscopy:

FT-IR analysis has been done to identify the auxochromes which are responsible for the persistence of dye [36] and to study the functional groups present in it. The FT-IR analysis (Figure 11) of the dye extract showed a broad peak at $3400-3600\text{ cm}^{-1}$ assigned to basic stretching vibration of O-H hydroxyl groups which confirm the presence of auxochrome. The C=C present at 1553 cm^{-1} and 1439 cm^{-1} represents the aromatic bands. The peak at 2930 cm^{-1} corresponds to the aliphatic CH vibrations and 1627 cm^{-1} to the C=O conjugated with aromatic ring. Similar results have been reported by [44,45]. These peaks are the characteristic feature of anthocyanin. The peaks showing below 1200 cm^{-1} regions are due to the vibrations of the whole molecule and are called as 'fingerprint region'.



Figure 9: TLC of dye extract

Figure 10: UV-visible spectrum of *Torenia sp*Figure 11: FT-IR spectrum of *Torenia sp*

CONCLUSION

An attempt has been made to produce an eco-friendly dye from natural source with biomordants. From the present study, *Torenia sp* flowers were found to have good dye ability. Best extraction of dye can be obtained at pH 7, 30°C with less time. Silk yarn meta mordanted with biomordant tannin from *Tamarindus indica* seed coat (T.I.-S.C) showed good to very good fastness to light, wash and perspiration than meta mordanted with *Peltophorum pterocarpum* bark (P.PT-B). Best dyeing was achieved at pH 9, 50°C, for 30 min with 1:20 dye concentration, in which the dye colour obtained was green due to alkaline pH. The violet coloured pigment responsible for the dye extract was identified as Anthocyanin. Since green colour textile dye is very rare from natural sources, *Torenia sp* flowers can be highly recommended for textile industries as an alternative for harmful synthetic green dyes.

ACKNOWLEDGEMENT

The authors thank Mrs. Prema Sampathkumar, Associate professor and Head, the Faculty members and non-teaching staff of the Department of Plant Biology and Plant Biotechnology, Dr. A Nirmala, Principal, Ethiraj College for Women (autonomous), Chennai- 600008, for their valuable support and encouragement. We would also like to thank Central Instrumentation Centre of Ethiraj College for Women for extending the facilities. Sincere thanks to TANSILK (Salem) and Textile Committee, Ministry of Textiles, Mylapore, Chennai, Tamilnadu. We would also like to thank Adidraavidar and Tribal Welfare Department, Government of Tamilnadu for their financial support.

REFERENCES

- [1] SV Singh; MC Purohit. *Universal J Environ Res Technol.* **2012**, 2(2), 48-55.
- [2] KS Ashis; K Adwaita. *Intech Open Sci Europe.* **2011**, 29-56.
- [3] CH Parkes. *Knitter's Review.* **2002**.
- [4] R Siva. *Curr Sci.* **2007**, 92(7), 916-925.
- [5] K Sinha; PD Saha; S Datta. *Industrial Crops Products.* **2012**, 37, 408-414.

- [6] AK Samanta; IP Agarwa. *Indian J Fibre Textile Res.* **2009**, 34, 384-399.
- [7] KH Prabhu; AS Bhute. *J Nat Prod Plant Res.* **2012**, 2(6), 649-664.
- [8] Abdu Zubairu; YMM Shelia. *Sci Technol.* **2015**, 5(2), 26-32.
- [9] L Ammayappan; JJ Moses. *Man Made Textiles India.* **2007**.
- [10] Z Cai; G Jiang; S Yang. *Colouration Technol.* **2001**, 17,161.
- [11] KP Chellamani; D Veerasubramanian; RS Vignesh Balaji. *J Academia Industrial Res.* **2014**, 3(3), 127-131.
- [12] Biology of *Torenia sp.* (torenia), **2008**, Australian Government, Version 2.
- [13] E Fisher. JW Kaderiet. *Springer- Verlag.* NewYork, **2008**, 333-391.
- [14] T Yamazaki. *J Faculty Sci.* **1985**, 13, 575-624.
- [15] JB Harborne. Phytochemical methods-a guide to modern techniques of plant analysis, published by Chapman & Hall, an imprint of Thomson Science, **1998**, 66.
- [16] P Velmurugan; A TamilSelvi; P Lakshmanaperumalsamy; J Parke; BT Oha. *Coloration Technol.* **2013**, 129, 246-251.
- [17] N Raaman. Phytochemical techniques, New India Publishing agency, **2006**, 5, 19-25.
- [18] T Endo. *Japanese J Genetics.* **1962**, 37(4), 284-290.
- [19] S Oancea; O Draghici. *Czech J Food Sci.* **2013**, 31(3), 283-291.
- [20] RBA Kechi Chavan; R Moeckel. *Textiles Light Industrial Sci Technol.* **2013**, 2(3), 137-145.
- [21] MC Vieira; RC Costa Lelis; BC da Silva; GL Oliveira. *Florestae Ambiente.* **2011**, 18(1), 1-8.
- [22] BJ Agarwal; BH Patel. *Man-Made Textiles India.* **2002**, 45, 237-241.
- [23] C Wang; C Xu; A Tian; S Fu; C Wang. *Society Dyers Colourists Coloration Technol.* **2012**, 129, 32-38.
- [24] KH Prabhu; MD Teli. *J Saudi Chem Society.* **2011**, 1-9.
- [25] PB T; RV Adivarekar. *J Textile Institute.* **2013**, 104 (10), 1080-1088.
- [26] VA Shennai. Technology of textile processing, 2nd edition, Mumbai:Sevak, **1997**.
- [27] L Cabrita; T Fossen; OM Andersen. *Food Chem.* **2000**, 68,101-107.
- [28] P Keusch. Demonstration Experiments and labs, Chemistry visualized, Institute of organic chemistry, University of Regensburg. **2003**.
- [29] CE Lewis; JRL Walker; JE Lancaster. *Food Chem.* **1995**, 54, 315.
- [30] S Bondre; P Patil; A Kulkarni; MM Pillai. *Int J Adv Biotechnol Res.* **2012**, 3(3), 698-702.
- [31] S Adeel; IA Bhatti; A Kausar; E Osman. *Indian J Fibre Textile Res.* **2012**, 37, 87-90.
- [32] IA Bhatti; S Adeel; R Nadeem; T Asghar. *Radiation Physics Chem.* **2012**, 81, 264-266.
- [33] Haji; Aminoddin. *Iranian J Chem Chem Eng.* **2010**, 29(3), 55-60.
- [34] MM Hasan; KA Nayem; AY Mohammad; NC Ghosh. *J Textiles.* **2015**.
- [35] VNarayana; KN Gowda; R Sudhakar. *J Institution Eng (India): Series E.* **2016**, 97 (1), 31-38.
- [36] M Shabbir; SUI Islam; MN Bukhari; LJ Rather, M Ali. *Textiles Clothing Sustainability.* **2016**, 2, 1.
- [37] MG Uddin. *Textiles Clothing Sustainability.* **2015**, 1, 7.
- [38] R Raisanen; P Nousiainen; PH Hynninen. *Textile Res J.* **2002**, 72, 973-976.
- [39] D Jothi. *AUTEX Res J.* **2008**, 8, 49-53.
- [40] MU Ghurde; MM Padwad; VR Deshmukh; SN Malode. *Int J Sci Res.* **2014**, 5(1), 1272-1276.
- [41] F Tatsuzawa; M Hosokawa. *Horticulture J Preview.* **2002**.
- [42] MS Sheeja; AK Bopaiah. *Int J Pharm Biological Archives.* **2014**, 5(5), 158-162.
- [43] R Curtright; JA Rynearson; J Markwell. *J Chem Edu.* **1996**, 73(4), 306-309.
- [44] Z Chikwambi; M Muchuweti. *American J Food Technol.* **2008**, 3(1), 1-12.
- [45] PK Mishra; P Singh; KK Gupta; H Tiwari; P Srivastava. *Indian J Fibre Textile Res.* **2012**, 37, 83-86.