ISOLATION OF ECO-FRIENDLY LEATHER DYES FROM THE INDIGENOUS PLANTS OF CENTRAL AND NORTHERN PUNJAB FOR GREEN ECONOMY

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By

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DEDICATED

TO

HOLY PROPHET HAZRAT MUHAMMAD (PBUP)

MY BELOVED MOTHER, FATHER

AND

SUPERVISOR

PROF.DR.TAHIRA AZIZ MUGHAL

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LIST OF ABBREVIATIONS

%	Percentage
ºC	Degree Centigrade
BS	British Standards
CDM	Clean Development Mechanism
EU	European Union
g	Gram
GHGs	Greenhouse Gases
hrs	Hours
ISO	International Organization for Standardization
K/S	Kubelka-Munk Equation
min	Minutes
mL	Millilitre
PCSIR	Pakistan Council of Scientific & Industrial Research
pH	Potential of Hydrogen
PTFE	Polytetrafluoroethylene
UV	Ultra Violet Radiation

ABSTRACT

The leather industry is one of the biggest consumers of azo dyes which belong to the chemical class of synthetic dyes. Synthetic dyes are produced from cheap petroleum and coal-tar sources. Synthetic dyes have detrimental effects on humans as well as on the environment and are known to be carcinogenic, toxic and allergic. Stringent environmental legislation and export regulation of the European Union (EU) banned the use of synthetic carcinogenic dyes which increased the scope and demand of natural dyes. So, keeping in view the flourishing leather industry of Punjab and the growing problems of environmental health owing to synthetic dyes, the present study was designed to investigate the diversity of available indigenous plants of the Punjab for dye extraction which considered eco-friendly as compared to synthetic dyes. Research investigations were carried out based on the comprehensive analysis of eight dye yielding flowers which are considered to be an inexpensive source of natural dyes. The eight selected floral dyes were used for the first time for leather dyeing such as *Bellis perennis, Bombax ceiba, Bougainvillea glabra, Celosia cristata, Lantana camara, Papaver rhoeas, Rosa damascena* and *Tagetes erecta*. Moreover, eco-friendly and commercial mordants were used to evaluate the dye potential of leather. One hundred and sixty eight shades on leather were developed through pre-mordanting and post-mordanting methods using ten different mordants whereas eight shades were developed without mordant. Colour fastness to rubbing, mild washing and daylight were determined using ISO and BS standards. Results of the study revealed that developed shades were found good to very good in terms of dye evenness. In colour fastness properties, these dyes showed very good to excellent colour fastness grades. Very good to excellent results with respect to rubbing (dry and wet) were obtained with and without mordant. Colour fastness to mild washing was observed very good to excellent in terms of staining and colour change results except with *P. rhoeas* dye. Colour fastness to daylight was recorded with fair to good results. In addition, good colour fastness properties of rubbing and mild washing were obtained with un-mordanted dyed leather specimens too. Findings of the study demonstrated that floral dyes are effectively and commercially viable for leather industry. Moreover, these shades of dyed leather specimens would serve as a shade catalogue guide and an opportunity to promote leather industry. Present study also revealed that

selected dyes are a good source of natural dye for leather dyeing, which will help local tanning industry to minimize environmental problems, lessen dermal issues by providing eco-friendly, non-carcinogenic and non-allergic dyes at low cost. This study will help to strengthen economy through sustainable yield and export of dye bearing plants and save our environment and precious planet (Earth). Therefore, the role of the government should be to encourage the use of natural dyes by providing credit, financial support, provide assistance in marketing and by rewarding the environment friendly industries to improve the socio-economics condition of Pakistan. Moreover, detailed studies and technical investigations are yet to be made to assess the structure of available indigenous dye-bearing plants.

CHAPTER 1

INTRODUCTION

In the human civilization, biodiversity provides a strong plant-human association for livelihood (Nadeem *et al.*, 2013). Plants are multi-functional and used to fulfill the basic needs of life such as food, fiber, fuel, medicines, clothes, shelter (Shah, 2005; Panhwar and Abro, 2007; Chengaiah *et al*., 2010; Zareen *et al.*, 2013). They also absorb carbon dioxide (McPherson, 1998), contribute to balance ecology and ecosystem, help to increase soil fertility, control erosion and improve stability of watershed. Globally, plants have a significant influence on economic growth. They also provide a wide range of goods and services to boost income through commercialization of plant products (Rao *et al.*, 2014) and natural dye is one of its significant components (Peter, 2008; Chengaiah *et al*., 2010; Das and Mondal, 2012). Natural dye is reported for dyeing different substrates such as textiles (silk, cotton and wool) and leather (Cristea and Vilarem, 2006; Samanta and Agarwal, 2009; Bhatti *et al.*, 2010) since prehistoric times and up to this day.

In classical era the preparation and application of natural dye was one of the favourite human activities (Yusuf *et al.*, 2015). Historically, plant dyes were used to paint caves, decorating shells, coloring feathers, celebrating religious festivals (Siva, 2007; Savvidis *et al.*, 2013) and traded since the prehistoric times (Vankar *et al.*, 2007). The historical evidences of dyeing materials records were found in China 2600 BC (Gokhale *et al*., 2004), Indus Valley Civilization (2500 BC) at Mahenjo-daro and Harappa ruins (3500 BC). Archaeologists also reported that Egyptian mummies were wrapped in dyed clothes using *Carthamus tinctorius* dye (Siva, 2007). Evidences of dyeing materials were also found by excavation at archaeological sites where ancient fabrics were unearthed. The use of natural dye saffron is also mentioned in the Holy Book Bible (Gulrajani, 2001).

Natural dyes are obtained from plants, animals, insects, and mineral resources (Bulda *et al.*, 2008) and source wise almost whole plants parts were used to extract and prepare dyes such as roots, stems, barks, leaves, fruits, seeds and flowers (Kamel *et al.*, 1991; Angelini *et al.*, 2003; Siva, 2007; Adeel *et al.*, 2009; Savvidis *et al.*, 2013) and considered the most important natural dyestuff (Bechtold *et al.*, 2002) and cultivated in southwest Asia since ancient times (Zohary and Hopf, 1993). Most of the known, common families of plants were reported to isolate natural dye such as Rosaceae, Asteraceae, Polygonaceae, Lamiaceae, and Euphorbiaceae for dyeing fabric (Ozturk *et al.*, 2013).

The real breakthroughs in the history of natural dyes came in 1856 when a teenager William Perkins an English chemist accidently discovered a synthetic colouring compound called 'mauveine'. The advent of synthetic dyes reduced the consumption of natural dyes (Kwok *et al.*, 1999; Mahanta and Tiwari, 2005; Holme, 2006; Chengaiah *et al.*, 2010; Shahid and Mohammad, 2013; Srivastava and Gautam, 2014) which were consumed largely in leather and textile industries till the middle of 19th century (Vankar *et al.*, 2007).

Since then, the leather industry is one of the biggest consumers of azo dyes (Sudha *et al.*, 2014; Upadhyay and Mahajan, 2014). Azo dyes belong to the chemical class of synthetic dyes (Saratale *et al.*, 2011) and possess several side effects as they are produced from cheap petroleum and coal-tar sources (Siva, 2007; Devi *et al.*, 2013) which not only destroy the environment (Carneiro *et al.*, 2010; Ferrero and Periolatto, 2012) during their synthesis but also discharge effluents into water bodies after dyeing process (Kumar *et al.*, 2006; Hameed *et al.*, 2008; Zaharia *et al.*, 2012; Gupta *et al.*, 2013). Synthetic dye effluents are difficult to eradicate through conventional waste water treatment process (Nam and Renganathan, 2000; Oliveira *et al.*, 2007) as they are high soluble in water (Suzuki *et al.*, 2001; Ratnapandian *et al.*, 2012). They are hazardous for human health (Sharma and Sobti, 2000; Kadirvelu *et al.*, 2003; Kamel *et al.*, 2005; Ahlstrom *et al.*, 2005; Dincer *et al.*, 2007; Elsalam *et al.*, 2008; Shen *et al.*, 2009; Sinha *et al.*, 2012; Thiyagarajan *et al.*, 2015), destroying eco-system (Kant, 2012; Das and Mondal, 2013), toxic to aquatic biodiversity (Danazumi and Bichi, 2010).

Owing to mutagenic and teratogenic impacts of synthetic dyes (Abramian and El-Rassy, 2009) Germany was the first country which imposed ban on carcinogenic dyes (Sankat and Siddique, 2008). In addition, European and Asian countries, such as Sweden, France, Denmark, Netherland, Turkey and India also prohibited their use (Nadigera, 2001; Kadolph, 2008; Sankat and Siddique, 2008; Patel, 2011; Kanchana *et al.*, 2013) to control environmental pollution (Meksi *et al.*, 2012)), reduce the toxic, carcinogenic, allergic and the detrimental impacts associated with synthetic dyes (Chattopadhya, *et al*., 2008; Yusuf *et al.*, 2015; Mirjalili *et al.*, 2011).

Therefore, the consequences of synthetic dyes and strict environmental standards (Vankar and Bajpai 2006; Purohit *et al.*, 2007) rebirthed the demand of natural dyes (Bose, 2012; Vankar and Bajpai, 2006) all over the world (Bhargava and Jahan, 2013). Nowadays nature lovers (Borah and Phukon, 2009), ecology and health conscious (Kadolph, 2008), environment friendly products manufacturers (Tayade and Adivarekar, 2013) and green minded people started to emphasize natural dyes over synthetic dyes (Freund *et al.*, 1988; Karaboyaci, 2014, Upadhyay and Choudhary, 2014) due to their manifold advantages.

Characteristically, plants based dyes have wide variety. Natural dyes are non-carcinogenic, non-poisonous, biodegradable, and non-hazardous to life (Saravanan *et al.*, 2014; Thiyagarajan *et al.*, 2015). Unlike synthetic dyes, natural dyes are non-toxic (Acquaviva *et al.*, 2010; Goodarzian and Ekrami, 2010; Prabhu *et al.*, 2011; Rehman *et al.*, 2012), non-allergic (Bhuyan and Saikia, 2005; Hwang *et al.*, 2008) , renewable, sustainable, and well known to create soft, subtle, pastel, soothing colours (Onal *et al.*, 2005; Samanta and Agarwal, 2009; Kulkarni *et al.*, 2011; Pervaiz *et al.*, 2016). Natural dyes are neither harmful for human beings nor hazardous for environment (Shahid and Muhammad, 2013; Tayade and Adivarekar, 2013). Natural dyes are enriched with aesthetic properties (Vankar, 2007), helpful to generate employment, safe for ecology (Mahanta and Tiwari, 2005), provide economic benefits through sustainable yield and harvesting of dye bearing plants (Saravanan *et al.*, 2014; Sharma; 2015). On the other side, commercialization of natural dye can help to boost up the economy of the country (Ghorpade *et al.*, 2000; Saravanan *et al.*, 2014; Upadhyay and Choudhary, 2014; Belemkar and Ramachandran, 2015) and have an opportunity to earn carbon credits by reducing consumption of petroleum based synthetic dyes (Aishwarya and Devi, 2014).

Thus, by keeping into account the economic importance of leather industry, growing concerns of eco-safety and impairment of human health, the present study is designed to investigate the indigenous plants of Punjab as a source of natural dyes which is the most diversified province of Pakistan in terms of plant diversity (Zareen and Khan, 2013). In addition, flourishing leather industries of the province have a significant role in the economy of Pakistan (Chattha and Shaukat, 1999; Ghafoor *et al.*, 2012) after textile sector (GOP, 2011). In foot wear, the 90% export is based from Punjab (Rafiq, 2016) and the major exporting countries are Germany, Italy, United Arab Emirates, Saudi Arabia and UK (GOP, 2015). Furthermore, the leather sector contributes significantly by exporting 95% of their saddlery items to international markets and ranks high in employment opportunities (Saif, 2012). In addition, 75% exporters of leather are based in Punjab (Ghafoor *et al.*, 2012) and most of leather production clusters in the province are located in Sialkot, Lahore and Sheikhupura (Ghafoor and Zafar, 2015). This industry also occupies an important place among the top ten GDP contributing sectors of Pakistan (Hassan *et al.*, 2011).

Hence, considering the facts there exist a significant justification for the application and promotion of plants based dyes as they are compatible both for environment and human (Hartl and Vogl 2003; Kumar and Sinha 2004; Kim and Park, 2007). The present study is a comprehensive account of dye bearing plants of Central and Northern Punjab to use the pathway to conserve and manage natural resources by adopting low carbon techniques. Due to production of natural dyes, a step towards green economy can be achieved by eluding environmental risks and ecological scarcities. A wide array of natural dyes is a powerful and efficient tool of sustainable development to mitigate carbon foot prints, improve socio-economic condition of farmers, leather workers, florist and flower exporters to circumvent the hazardous impacts of synthetic dyes.

Consequently, there is utmost need to look for the plant material for dye extraction without disturbing the ecological balance and damaging the environment. The eco-solution of plants waste (Ghorpade *et al.*, 2000; Vankar *et al*., 2009) dyes will not only contribute to reserve natural plant resources but also help to replenish the demand of eco-friendly, non-carcinogenic, non-toxic, non-hazardous and non-poisonous green dyes (Bechtold and Mussak, 2009). In the 21st century, world is conscious and prefer the natural products (Upadhyay and Mahajan, 2014). This study will help researchers who seek information about leather dyeing using natural dyes. This study will also create new opportunities for local dyers, leather merchants, and the leather industry to shift towards eco-friendly natural products and green economy. The dye bearing plants can be used as alternative farming (Borah and Phukon, 2009) which will help to alleviate poverty, empower women of rural areas by home gardening, provide an opportunity for the growth of natural dyes, save our environment and precious planet, the Earth.

AIMS AND OBJECTIVES

Keeping the above points in view, present research was carried out to identify the plants on Central and Northern Punjab for eco-leather dyes. The objectives of the present study were as following:

- To explore the potential of indigenous plants (Central and Northern Punjab) of Pakistan for leather dyeing.
- To provide the non-toxic, non-allergic, non-carcinogenic, non-poisonous, non-hazardous leather to people.
- To improve the socio-economic condition of Pakistan by improving the leather industry of Pakistan.
- To provide the cheapest dyes to local industry of leather within Pakistan.
- To provide the eco-friendly environment for workers of leather industries.

CHAPTER 2

REVIEW OF LITERATURE

Throughout history, dyes have been isolated from plant parts such as roots, stems, barks, leaves, fruit, seeds, berries and flowers (Sanjeeda and Taiyaba, 2014; Biswajit *et al.*, 2015). Natural dyes were mostly used to dye silk, cotton, jute, wool, leather and fur (Cristea and Vilarem, 2006; Lee *et al.*, 2004; Purwar, 2016) for instance *Parkia biglobasa* bark and pods' husk extract were used to dye leather (Campbell-Platt, 1980). In Hellenistic period, kermes dye was evaluated on leather (Koren, 1993). *Carthamus tincotorius*, *Chlorophora tinctoria*, *Cotinus coggygria*, *Haematoxylon campechianum* and *Rubia tinctorum* dyes were found suitable for dyeing leather (Roth and Lindorf, 2013). Moreover, *Tagetes erecta* extract was also analyzed to dye sheep leather (Karolia and Dilawar, 2004).

Adem (1996) selected the onion's skin for dye extraction which is well known for its good dye component. The dye extraction was made using distilled n-hexane and resultant colourant was evaluated on feathered leather, woolen strips and cotton using pre-mordanting and post-mordanting techniques. Results of the study demonstrated that onion's skin dye is effectively and commercially viable for the leather industry.

Samanta *et al*. (2003) carried out research work on cotton fabric. They used myrobolan, turmeric, red sandal wood and madder for the extraction of dyes. Pre-mordanting, simultaneous mordanting and post-mordanting techniques were used with aluminium sulphate as a mordant. Some samples were dyed with a combination of turmeric with madder or red sandal wood. These combinations were used in different proportions. Selected mordanted and dyed samples were afterwards treated with a cationic dyeing fixing agent. Turmeric yielded good result in terms of colour strength both singly and in combination with other dyes. It showed poor wash fastness which was improved to some extent by after treatment with a cationic dye fixing agents. They finally concluded that natural dyes when used simultaneously with dye and mordant yielded better colour fastness. However, myrobolan did not respond well to the post- mordanting method as it did not show a synergistic effect in terms of the observed and calculated Kubelka-Munk equation (K/S) values.

Paul *et al.* (2003) studied the properties of walnut bark as a source of eco-friendly brown colour. He found walnut bark as a good source of brown colour with a variety of fast shades and especially recommended its use for boosting up rural economies. Experiments were carried out on woolen yarns and colour fastness was also tested.

Zhou *et al*. (2003) prepared a list of bio-dyestuffs including insect and tree secretions, and vegetable dyes. The plants providing red, yellow, blue, green and black colours were also listed and the method of extraction detailed. They noted the problems in bio-dyeing. However, they concluded that bio-materials can be used to replace harmful, energy or material-expensive chemical treatments for pre-treatment and finishing.

Agarwal and Gupta (2003) worked on wool with a vegetable dye extracted from the roots of the herb (*Rubia cordifolia*). The dyed samples were tested for fastness to light and washing. The optimum extraction and dyeing time was found to be 5 g per 100 mL of water and the optimum extraction and dying time was found to be 120 minutes and 90 minutes respectively. The simultaneous method of mordanting was found to yield the best results in terms of shine, depth of shade, evenness of the dye and overall appearance.

Rose *et al.* (2004) worked on ornamental mustard (*Brassica juncea*) and extracted a dye which was used most effectively on cotton yarn. Experiments were made to standardize the medium of dye extraction, wave length, extraction time, dye material concentration, dyeing temperature, dyeing time, and dyeing pH. The mustard leaves yielded best colour in the alkaline medium. The results showed that optical intensity increased when extraction time was increased upto 30 minutes. The dyeing absorption was also seen to be related with temperature; it increased with increase in temperature. Dye absorption corresponded with pH and the optimum pH selected was 10. Thus, dye extraction in an alkaline medium with optimum wave length of 360nm, extraction time 30 minutes, dye material concentration 7%, dyeing temperature 100°C, dyeing time 45 minutes, and dyeing pH 10, gave wonderful results for dyeing cotton yarns.

Teli *et al*. (2004) worked on natural dyes such as Madder, Turmeric, Catechu, Henna and Indian Rhubarb on Cellulose Triacetate. Mordanting techniques were studied differently and three different methods of application namely pre-mordanting and meta-mordanting and post-mordanting were used. In each case, contribution of ferrous sulphate, copper sulphate and tannic acid were studied in terms of enhancement in depth of dyeing. It is an established fact that the final shade and tone depends upon dye-fibre mordant system. All the man-made fibres exhibited maximum depth of dyeing using post-mordanting technique. The performance properties varied depending upon the type of the dye, fibre and the mordant used.

Turkmen *et al*. (2004) used plants which were used traditionally to dye carpets and woven matting in the eastern Mediterranean region. The surveys were carried out in Turkey. According to the survey results, 37 species of plants belonging to 29 families were used in natural dye production. The total dyes contents of collected mordants and dye obtained from some of these plants were used to treat the wool and yarn and the dyed items were then tested for their properties.

Lee and Kim (2004) worked on the natural colour extracted from *Cassia tora*. The dyeing worked well and highest K/S values were reached with pH 9. Two different substrates such as cotton and silk were used for dyeing analysis. Results revealed that using ferrous sulphate, copper sulphate gave good light fastness results on silk and cotton specimens moreover aluminium sulfate rendered good light fastness with grade 4 on both selected mordants.

Grover *et al.* (2005) was studied the environment friendly natural dyes. They found that natural dyes were more popular especially with silk fabrics. The natural dyes which were selected for the study included Jatropha, Lantana, Hamelia, Euphorbia, Kilmora, and Walnut. Silk was initially degummed prior to dyeing, to make the fabric free from sericin, which obstructs the penetration of dyestuffs into the fiber. Dye extraction medium was selected after a series of experiments and mordant concentration and methods of mordanting were also worked out. The acidic media exhibited maximum percent absorption for Jatropha, Lantana, Hamelia and Euphorbia dye while Kilmora and Walnut dye showed good results in alkaline medium. A standard recipe was thus evolved for dyeing silk.

Bhuyan and Saikia (2005) identified different natural sources for obtaining natural dyes for replacing synthetic dyes. They studied extracts derived from five different species of Northeastern India. Colored components and their chemical constituents were studied on the basis of chemical and spectroscopy. Anthraquonine was studied in molecules of three species i.e. *Morinda angustifolia Roxb*, *Rubia cordifolia Linn*, *Tectona grandis Linn*, whereas flavonoids was present in the molecules of microscope *elengi Linn.* and *Terminalia arjuna*. With increase in the concentration of dye in dye bath the adsorption of dye on fiber also increased. Dye absorption was found to be related with concentration of dye and it was found to be best when dye concentration was 3%. It was also related to the increase in mordants. Natural dyes of plants can be used as alternative to synthetic on natural silk and cotton.

Sarkar *et al*. (2005) made Marigold flowers the focus of their study. They worked on three varieties of fresh Marigold flowers viz. lemon yellow, golden yellow and maroon-yellow as raw materials for natural dyeing of cotton, wool and silk substrates. Quantity of flower for a certain volume of water and the time needed for extraction were optimized. Best colour intensity was achieved with 30g of flower quantity in 100 ml water with 40 minutes extraction time. In the case of yellow maroon marigold, the time required for extraction was 50 minutes. Three substrates (cotton, silk and wool) were dyed with the extracts from these varieties of Marigold after treating with eight different mordants in all the three cases. Attractive shades were produced by such dyeing. Colour data of different shades as obtained was measured in term of L*, a*, b* values and the same have been mentioned in this paper. The colour fastness property to washing of most of the dyed samples was in the range of 2-3 to 3. Colour fastness to light of the samples dyed was proportionate to the change of mordant and the substrate. Highest rating in case of cotton was found to be 3 and for silk and wool was around 4.

Ke *et al.* (2006) studied extracts from the plant *Rhizoma coptidis* and studied its effects on wool fabric. Colour evaluation was characterized with CIE, L*, a*, b*, C*, h and K/S. Effects of mordant, extraction concentration, pH value of dye bath, and treatment temperature on colour values were studied. Results showed that wool fabrics dyed with mordant, at higher temperature, or in alkali solution showed stronger shades and darker colours. And the wool fabric showed good antibacterial property after dyeing with *R. coptidis* dye.

Mashaly (2006) used both conventional and ultrasonic techniques for extracting the natural dye lac. He found that ultrasonic techniques gave better results than conventional heating at low temperatures. He used the dye extracted for dyeing of nylon fabrics. The extractability of lac dye from natural origin using power ultrasonic was also evaluated in comparison with conventional heating. Dyeing rate constant, half-time of dyeing and affinity and ultrasonic efficiency have been discussed.

Okwuchi (2006) examined the *Khaya senegalensis* (Savanna mahogany), *Bixa orellana* (Annatto), *Allium cepa* (Red Onion), *Mangifera indica* (Mango), and *Hibiscus sabdariffa* (Zobo) natural colourant. Dye was extracted using different solvents such as acetone, ethanol, methanol, water and chloroform. Results of the study showed that the obtained extracts possess colour impacting chromophores and can be successfully used for leather dyeing. Findings of the study indicated the absence of microbial activities in the extracted dye of zobo. With reference to colour fastness to rubbing, the results showed good application of dye on the leather. The percentage of dye adsorption and the yield of dye extracted using different solvents had also reported good results.

Vankar *et al.* (2007) devised a two-step dyeing technique referred to as ultrasonic dyeing. The technique was applied to the dyeing of cotton and silk. He used the natural dyes *Terminalia arjuna*, *Punica granatum*, and *Rheum emodi* and as a first step mixed them with an enzyme treated with tannic acid. This process was considered to be similar to 'one step simultaneous dyeing'. The enzymes protease-analyze, diasterase and lipase were found to be very effective and greatly enhanced the cotton and silk fabrics capacity for dye absorption, much higher than the untreated samples. The enzymes worked equally well with all the three dyes. Laboratory tests confirmed the benefits of enzymatic treatment. This new method of tannic acid – enzyme dye combination gives an environmentally harmless alternative to the metal mordanted natural dyeing and is termed as 'soft chemistry'.

Shanker and Vankar (2007) found that *Hibiscus mutabilis* belonging to the Malvaceae family produced good natural dye which is used for dyeing textiles. Extracts from Gulzuba flowers give shades which have good fastness properties. The dye can be commercially successful for dyeing cotton, silk, and wool yarn to be used for garment and carpet industry. Treatment with metal mordants with 2-4% strength and keeping M:L ratio as 1:40 fabric weight to plant extract is optimum for good results.

Koyuncu (2007) worked on *Rheum ribes* and studied its effects on dyeing wool. The effects of dyeing showed high colour strength values obtained by the later. Dyeing with *R. ribes* roots has proven to be very successful. Colour fastness with respect to washing was fair to good. CIELAB values have also been discussed and evaluated.

Feng (2007) examined the ultraviolet protective characteristics of the fabrics dyed by *Rheum* and *Lithospermum erythrorhizon*. Experimental results proved that the fabrics dyed with natural dyes could absorb about 80% of the ultraviolet rays. It was shown that the Ultra violet (UV) protective effect was strongly dependent on the absorption characteristics of natural dyes for UVR. Natural dyes such as *Rheum* and *L. erythrorhizon* had comparable UV-absorption performance to the common UV-absorber, benzophenone.

Clementi *et al.* (2007) used absorption and emission, UV-viz spectroscopy and chromatography (HPLC-PDA) techniques and applied them on wool textile samples. The purpose was to test the light fastness of the textile samples. The dyeing was done using madder. The principal components were alizarin and purpurin. The time course of ageing was studied using spectroscopic technique. Ageing was studied applying chromatography. The results of the two techniques complemented each other. It was established that purpurin was the principal ingredient giving madder its spectral and chromatic properties. Alum reduced the chances of fading especially when used in the absence of oxygen. UV-vis spectroscopy thus revealed its potential for investigation of dyes on textiles. This technique is also very promising for the study of dyes on works of art.

Bechtold *et al.* (2007) worked on the extract of ash-tree bark (*Fraxinus excelsior*) to study the results of dyeing on wool. Ferrous sulphate mordant was chosen because it had potential for industrial application. Direct addition of FeSO4·7H2O during dye bath with extracts from ash-tree bark showed good results and the shades produced were satisfying. An increase in the mordant above the concentration of 2-3 g did not result in further colour depth. 1-2 g bark was enough to dye 1 g wool yarn to the darkest shade possible. The quality of bark and the method of extraction were considered to be important for colour depth.

Sharma *et al.* (2007) found that *Euptorium adenophorum* yielded green colour which was a good source for dyeing silk yarn. This dyeing had very good fastness properties. Leaves of this plant were taken, dried in shade and crushed into powder form and then packed. Sericin an ingredient in the powder was removed so as not to interfere with dye absorption and luster. Three methods of mordanting were used with four mordants. The optimum dye concentration was discovered by working on several samples. Yellowish green shade was obtained with 10% alum with post mordanting method. With 4% chrome green colour was obtained. Light green and dark green shades obtained with 4% copper sulphate and ferrous sulphate. Very good fastness to light and excellent fastness to washing was shown by dyed silk. Dry and wet crocking samples showed some staining and colour change.

Potsangbam *et al*. (2008) pointed out that in Manipur there were at least 50 plant species the extracts of which have been used for dyeing since ancient times. Chemical dyes were introduced in the state much later. Many tribes of Manipur and the Meitei tribe was famous for dyeing with natural dyes and the most commonly used plants were *Melastoma malabathricum*, *Parkia timoriana*, *Bixa orellana*, *Solanum nigrum*, *Bixaorellana*, *Strobilanthes cusia* and *Tectona grandis*. The compounds isolated from these plants have been identified and the indigenous knowledge of the Manipur people has been reported.

Gahlot *et al.* (2008) experimented with the Jatropha flower and optimized different dyeing variables such as extraction medium, extraction time, dyeing time mordant concentration etc. Different methods of mordanting were studied. Various concentrations of metallic mordants like ferrous sulphate, copper sulphate, alum and chrome were used for mordanting cotton. Optimized dyeing time was worked out to be 60 minutes with 4-6 pH concentration. Various hues of brown, peach and grey were obtained. Results of dyed samples were also good for colour fastness. Various processes involved in the dyeing process were non-hazardous and eco- friendly.

Dayal *et al*. (2008) was successful in isolating a natural dye from the aerial parts of the *Parthenium hysterophorus* weed. The dye was used on cotton fabric. It was extracted by boiling 1 kg weed with 10 liter of water for 60 minutes at 95-98 ºC. Post mordanting method was used and ordinary mordants like copper sulphate, alum and stannous chloride were brought into play. The dyed cotton fabric was dipped in mordant bath for 45 minutes at 95-98 ºC and the M:L ratio was kept at 1:100. A number of attractive shades with good fastness properties were obtained with *P. hysterophorus* dye.

Sivakumar *et al.* (2009) carried out a study to extract natural dye from beetroot and evaluated its dye potential on leather and paper. The ultrasound technique was used to extract dye and has shown significant efficiency to extract dye from beetroot whereas the best dye yield was obtained using 1:1 ethanol–water mixture. Based upon the results it was noticed that 80W ultrasonic power for three hours contact time produced better dye yield. Results of study concluded that obtained natural dye from beetroot was found eco-friendly and potentially viable in 'Green Chemistry.'

Saha and Dutta (2008) recommend the use of unsold marigold flowers for dyeing purposes. They were of the opinion that huge quantities of marigold flowers go waste every day creating problems of disposal and environmental pollution. These unsold flowers can be profitably utilized by the dyeing industry for dyeing cotton fabric and the residual waste could be used as bio-fertilizer. Pre-mordanting technique was employed and cotton was mordanted before dyeing. Low concentration of eco-friendly mordanting agents: Ferrous sulphate, stannous chloride, copper sulphate and alum were used. After dyeing, washing was done at room temperature by using non-ionic soap for ten minutes. The dyed samples were dried in shade. Different mordants yielded different shades. Results were very encouraging as to color fastness, therefore industrial use of these flowers was recommended.

Vankar and Shanker (2008) worked on *Nerium oleander* flower and studied the ultra-sonic dyeing procedure. The fabric was immersed in clean water for 30 minutes before the dyeing process was started. Metal salts such as ferrous sulphate, copper sulphate, tin chloride, potassium dichromate and alum were used as mordants. M:L ratio was kept at 1:30 with pH at 4 and buffer solution was added. The *N. oleander* flowers in aqueous solution gave cream to green purple shades on cotton fabrics. Fastness properties turned out to be good, colour strength was also good and it was especially so for cotton mordanted with stannic chloride. The dye was estimated to be commercially viable.

Sundrarajan *et al.* (2009) studied to improve the colour fastness of natural dyes on silk fabric with the help of mordants. Hibiscus flower, onion skin, and Eucalyptus bark were used for dyeing silk fabric and synthetic mordants were later used to improve fastness. Optimization (dye % and time) was done at 6% dye at 80ºC for 45 minutes. Combinations of different mordants were also used and it was observed that they performed better. It was also understood that pre-mordanted fabrics were good at up taking dyes and producing better fastness, better than the un-mordanted fabric.

Musa *et al.* (2009) analyzed the *Lawsonia ineremis* dye application on leather substrate. *Lawsonia ineremis* is known as henna in subcontinent and belong to the most prominent class of natural colorants which contain (2-hydroxy 1, 4 naphthaquinone and alpha –hydroxylnaphthaquinone). In their study, different shades were produced with the henna dye using aluminium sulphate ferrous sulphate and zinc sulphate mordants. The results of study described that deep shades on leather can be obtained by increasing the amount of henna. However, different shades on leather were obtained with different mordants. The colour fastness to rubbing (dry & wet) and perspiration have shown good results whereas colour fastness to light inferred satisfactory results.

Extraction of natural dye from eucalyptus bark, tea leaves, turmeric rhizomes and walnut bark were studied by Inayat *et al.*, (2010). The extracted dye efficiency was assessed on goat leather. Acetic acid, citric acid and oxalic acid mordants were used to increase the colour fastness of dyed leather using post-mordanting technique. The study of Inayat *et al.*, (2010) concluded that leather dyed with oxalic acid mordant has shown best colour fastness properties in terms of washing, rubbing, and perspiration.

Velmurugan *et al.* (2010) studied the dyeing effects of fungal pigment on wet blue goat leather. They evaluated fungi which have been an important source of anthrquinone, anthraquinone carboxylic acids, and pre-anthraquinones. For the analysis, five different water-soluble pigments were extracted *from Monascus purpureus, Isaria* spp., *Emericella* spp., *Fusarium* spp. and *Penicillium* spp. which were used for dyeing afterwards. They also studied the different parameters such as pH, temperature, exhaustion of dye and colour intensity. The results of their study inferred that fungal pigments can be used as natural dye and would be helpful to reduce the pollution of leather dyeing process.

Kulkarni *et al.* (2011) explored the potential of pomegranate peel for dyeing cotton. Weighed cotton cloth was treated with cupric sulphate (2%) and ferrous sulphate (2%). All the three mordanting techniques were used: pre-mordanting, simultaneous mordanting and post- mordanting with dye concentration 4% and M:L ratio 1:40 . The dyeing process was carried out for 60 minutes at a temperature of 80 ˚C. The dyed fabric was washed with cold water and dries at room temperature. Different shades of black, brown and yellow were obtained. Good fastness was also observed. Good fastness was however a result of the mordants used. All the research established that pomegranate peel could be profitably used for dyeing cotton cloth because it was not only eco-friendly but it was cost effective also.

Kumaresan *et al*. (2011) worked on *Cordia sebestena* and found that this flower can be used for dyeing silk. By using combination of different mordants like myrobolan: aluminium sulphate, myrobolan: nickel sulphate, myrobolan: ferrous sulphate, myrobolan: stannous chloride and myrobolan: potassium dichromate. Wide variety of soft and light brown shades were obtained. The dyed samples were tested for colour fastness to washing and perspiration both in the acidic and alkaline media; the results were excellent. They concluded that *C. sebestena* was a successful choice for dyeing silk.

Boahin *et al.* (2011) evaluated the suede dye on leather sheets which is the local dyestuff of Ghana. For the study purpose, they made three trials of experiments. In the first trial, they examined the suede dye and salt (sodium chloride) results on leather sheet. In the second experiment of study, dye and alum were dissolved in warm water and leather immersed in the solution. In the third trial, two different dyes were mixed separately with alum in warm water and used on leather sheet. In all the trials, leather sheets were immersed left in solutions for 15 minutes for the penetration of dyes. From the results of their study, it has been found that natural dyestuff has good light fastness and can be used for leather dyeing.

Bordingnon *et al.* (2011) analyzed the dyeing capacity of two natural dyes on wet white (chrome free) and wet blue leather. Urucum (*Bixa orellana* L.) and cochineal carmine (*Dactylopius coccus*) were used for dye extraction. It has been observed from the results that leather dyed with selected dyes exhibited good surface coating on leather. Moreover, the dye penetration and exhaustion were also found good with the used dyes. Furthermore, the colour fastness properties of dyed samples exhibited satisfactory results. Findings of the study concluded that natural dyes produced good results on wet blue leather than wet white (chrome free) leather.

Onem *et al.* (2011) studied the 5 year old *Rubia tinctorum* plant roots for dye extraction. The application of dye was tested on chrome and vegetable tanned Iranian sheep leather. Different mordants were used for dyeing analysis viz. potassium aluminium sulphate, copper sulphate and ferrous sulphate. Results of study concluded that chrome tanned leather rendered good colour fastness results as compared to vegetable tanned leather. The study analysis also described that extracted dye was found antioxidant, sustainable, environment friendly and helpful to reduce aquatic pollution.

In 2012, Ersin and his fellows studied the colouring ability of onion skins (*Allium cepa*) on chrome tanned leather. In this research, mordants viz. aluminium sulphate copper sulphate and ferrous sulphate have been used to obtain various colours and to increase the fastness value of dyed leathers. For color measurements, Konica Minolta (CM-3600d) spectrophotometer was used and dyestuff exhaustions have been analyzed by using Shimadzu (UV-1601 PC) UV-Visible spectrophotometer. Colour fastness to rubbing was performed in accordance to TS EN ISO 11640, colour fastness to perspiration was evaluated by TS EN ISO 11641 and colour fastness to light was measured by ISO 105-B02. Findings of the study concluded that colour fastness and dyestuff exhaustion values were varied by mordant type and results of all fastness gave satisfactory output.

Baishya *et al.* (2012) described that the world is increasingly becoming conscious of health hazards and there is an increasing tendency of using natural products. Synthetic dyes are considered to be harmful and there is a tendency of shifting to dyes extracted from plants. The dye which is the subject of the present study was extracted from *Callistemon citrinus* plant. Boiling method was used in its extraction. Scoured cotton cloth was taken and both the autoclaved and non-auto claved dyes were used. Ferrous sulphate and copper sulphate were used as mordants. Dyed samples were tested for fastness and colour strength in terms of K/S value. All types of fastness like light fastness, rub fastness and wash fastness were observed especially in fabric mordanted with ferrous sulphate. Ferrous sulphate was the most successful mordent ensuring colour fastness of the dye.

Mortazavi *et al.* (2012) extracted natural colour from saffron petals and evaluated its results on wool. They evaluated that saffron could be a good and a cheap source because a great quantity of the sepals and petals were wasted after harvesting whereas they could be used as cheap raw material for dyeing. When experimented on wool it was found that different mordants gave different hues ranging from yellow to brown. Sodium dichromate and iron sulphate were the best mordants for improving wash and light fastness. Aluminium sulphate along with oxalic acid was the most effective in promoting light fastness and improving washing durability, besides being cost effective. They did not recommend tin chloride as a mordant because of poor fastness properties.

Pant and Gahlot (2012) studied the natural colourant of cutch (*Acacia catechu)* for dyeing chrome tanned sheep crust leather. Aqueous medium was empolyed for the extraction of dye. They studied the optimum dye extraction time, dyeing and mordanting time and mordants ratio. For comparative analysis, they used natural and synthetic mordants for mordanting leather. Results of their study concluded that different variation of brown shades can be obtained using cutch dye with synthetic and natural mordants. The colour fastness results were also reported fair to good with the used dye.

Singh and Purohit (2012) dyed wool using the flowers of *Erythrina suberosa* using various combinations of mordants such as ferrous sulphate: lemon juice and stannous chloride: lemon juice, in different ratios. All types of mordanting were carried out including pre-mordanting, post-mordanting and simultaneous mordanting. A large variety of shades were obtained because of different ratios of mordants and their combinations. Washing, rubbing, perspiration and light fastness of the dyed samples were rated from fair to excellent grades.

Desphande and Chaturvedi (2012) studied different parts of *Ricinus communis* and extracted the natural dye from these parts. The outer parts of the plant like the fruit coat and leaf turned out to be good sources of natural dye for silk as well as cotton. Different mordants yielded different shades like yellow, green and brown. The dye showed good results as to fastness. With copper sulphate a green shade was observed on cotton cloth. Dye extraction was easy, economically viable and safe, without any hazards.

A comprehensive study was conducted by Mughal *et al.*, (2012) using three different plants for the extraction of natural colourants. Aqueous medium was applied for dye extractions from *Mangifera indica*, *Syzygium cumini* and *Eucalyptus camaldulensis*. The goat leather was used for the assessment of extracted dyes. For the detailed evaluation of dyes, four different mordants *viz.* copper sulphate, ferrous sulphate, potassium permanganate and potash alum were selected. These mordants were used to improve the colour fastness of dyes and for the good dye uptake. Results of their study revealed that excellent colour fastness of dyes was obtained in terms of washing, rubbing, daylight and heat with the selected dyes. Their study also concluded that natural extract with mordants can be successfully applied on leather to get different pleasing shades.

Selvi *et al.* (2013) selected the *Bixa orellana* seeds for the evaluation of natural dye. The dye extraction was carried out using water as solvent. The application of extracted colourant was evaluated on chrome tanned wet blue sheep skins. Results of their study have shown that extracted dye of annatto seeds exhibited uniform shades on grain and flesh side of leather. Moreover, the colour fastness to rubbing (dry & wet) has bestowed good results. Findings of the study concluded that annatto dye has significant characteristics and can be used commercially to replace the hazardous synthetic dyes.

Abba *et al.* (2013) studied the dyeing and colour fastness efficiency of henna and kola nut plants leaves. Dye extraction was carried out using chloroform, acetone and sulphonated and chlorosulfonic acid. The application of sulphonated dyes were evaluated on chrome tanned leather. In their study, they assessed the dye exhaustion, evenness, penetration, fixation of dyes. Comparative analysis of henna and kola nut dyes revealed that better colour fastness results of the sulphonated dyes were observed with henna dye. Results of the study have proved that the use of sulphonation increased the affinity of dyes on leather.

Masure and Patil (2014) studied rose and marigold flowers for dye extraction and used the colour obtained for dyeing silk and cotton. Flower petals were obtained from temples which otherwise would have gone waste. Copper sulphate and ferrous sulphate were used as mordanting agents. The treatment was carried out for 1 hour at 80 degrees centigrade. Varieties of different shades, yellow, brown, olive green were obtained with the use of different mordants. Good fastness was obtained from rose and marigold petals. It was concluded from their study that marigold and rose petals could be used for dye extraction helping to avoid the adverse effects of synthetic dyes.

Uddin (2014) worked on onion outer skin and extracted a dye. Boiling method was used in extraction. Different mordants like tartaric acid, alum, tannic acid, ferrous sulphate, tin were used and premordanting technique was adopted. These mordants alongwith the extracted dye were used in dyeing silk samples. These dyed samples were then compared with samples dyed with the extract from onion skin without the mordants. It was found that better hues were obtained with the use of mordants as compared to the colour shades without the mordants. Ferrous sulphate was found to be the most successful mordant. The colour fastness properties were found to be good and could be improved in certain cases. From fastness results it became evident that these dyes could be used on silk fabric even without the use of mordants.

Amarnath and Radhika (2015) studied leaves of *Indigo tinctoria* L. leaves (Indigo), *Haematoxylon campechianum* L wood of (Logwood) for dye extraction. Application of two different natural dyes was evaluated on wet blue cow leather. Pre-mordanting method was adopted using metallic mordants such as alum, chromium, and ferrous sulphate to improve the colour fastness. The selected raw material was found good source to produce variety of shades such as green, red, brown, and orange on leather. Findings of the study suggested that obtained shades on leather have viable option to promote eco-friendly natural dyes.

Paschal *et al*. (2015) dyed leather, cotton and wool substrates with the extract of *Justicia carner hooker*. The dye was extracted with water and methanol using soxhlet apparatus. Results of the study indicated that the good dye application was observed on all selected substrates. Results also demonstrated that good dye yield i.e. 92.8 % obtained with coupled dye. Hence, the results of colour fastness of coupled dye were recorded viable for leather dyeing.

In 2015, Sundari extracted the natural colourant from *Mucuna pruriens* and analyzed its colouring ability on chrome tanned wet blue goat leather. Ethanolic medium was used for dye extraction. In addition, the dyed leather samples were evaluated by leather experts and they found the satisfactory dye application in terms of dye uniformity. Results of study demonstrated that satisfactory colour fastness properties were obtained with *Mucuna pruriens* dye. Findings of study inferred that several fashion shades were achieved using mordants. Results of study also illustrated that toxic, non-carcinogenic synthetic dyes can be avoided using environment friendly natural dye.

Pervaiz *et al.* (2016a) extracted the dye from waste petals of *Rosa damascena* (rose) and used to dye chrome tanned goat crust leather. Conventional, eco-friendly aqueous method was adopted for dye extraction. Two different methods of mordanting *i.e.* pre-mordanting and post-mordanting were used to dye leather. Results of the study inferred that rose petals have good potential to dye leather with and without mordants. Findings of their study indicated good to very good colour fastness of rubbing whereas colour fastness to light was observed satisfactory. They also performed the cost analysis of dye extraction and results of their study concluded that natural dye obtained from waste rose petals was cost efficient, environmental friendly and viable for industrial application.

In another study of (Pervaiz *et al.*, 2016b), four different varieties of flowers were selected for dye extraction. They analyzed the application of *Celosia cristata, Lantana camara*, *Rosa damascena* and *Tagetes erecta* dyes on goat leather. Eco-friendly dyeing procedure was adopted for dye extraction. Forty shades were developed with ten different mordants using pre-mordanting method and four shades were obtained without mordants. The colour coordinates (CIE L* a* b*) of dyed leather specimens were also studied using Spectrophotometer (Spectraflash SF-650X). The results of their study showed that soft and dark shades were obtained with and without mordant. Findings of the study revealed that floral dyes have remarkable potential in leather dyeing and also an opportunity to promote sustainable fashion development.

Pervaiz *et al.* (2016c) selected the conventional aqueous method for dye extraction using fifteen different plants parts such as araucaria leaves, banana tree bark, banyan tree bark and aerial roots, black plum tree bark, blood leaf leaves, bottle brush flowers and leaves, drumstick leaves, false ashoka leaves, mango bark, mulberry leaves, kaner flower, strawberry leaves and pomegranate fruit peel. The goat crust leather was dyed with liquid extracts, keeping M:L ratio 1:10. Pre-mordanting technique was used for dyeing of leather with oxalic acid. The rubbing and light fastness properties of dyed leather specimens were found in the range of good to very good. They also studied the dye yield of selected plants and maximum yield of dyes were recorded with strawberry leaves and pomegranate fruit peel whereas aerial roots of banyan tree rendered low yield. However, the deep dark shades were obtained with banyan tree’s bark dye. From the results of their study, it was concluded that natural dyes have good tendency for dyeing leather and commercialization of green dyes can help to strengthen the economy of Pakistan.

Pervaiz *et al.* (2016e) extracted the natural colourant from *Rosa damascena, Tagetes erecta, Celosia cristata* and *Bougainvillea glabra* and analyzed its colouring ability on goat leather. Forty different shades were obtained with post-treated leather specimens whereas four shades obtained without mordants. Findings of study inferred that different fashion shades were obtained using mordants. Results of study also demonstrated that natural dyes help to conserve natural resources and an opportunity to improve socio-economic condition through sustainable yield of dye-bearing plants.

CHAPTER 3

MATERIALS & METHODS

The present research was carried out to evaluate the dyes potential of available indigenous plants of Central and Northern Punjab on leather. The extracted dye application was assessed on chrome tanned leather with and without mordant using pre-mordanting and post-mordanting techniques. Moreover, the colour fastness tests were determined in terms of rubbing, mild washing and daylight using standard ISO and BS methods. The complete research was carried out during the year 2014 to 2016 in the Department of Environmental Science, Lahore College for Women University and Pakistan Council of Scientific & Industrial Research (PCSIR).

3.1 Selection of Research Area

Punjab abounds in plant biodiversity which is based on its varied geographical, ecological and climatic conditions (Zareen and Khan, 2012). The province is blessed with unique diverse plant species having great economic prospects and has significant number species of herbs (Zareen and Khan, 2013). In addition, the province’s leather industry is fortunate having abundant raw material of leather and has a distinctive position in export earnings and employment generation. Local availability of raw material for leather sector is having a significant effect on the job market as leather is labour intensive sector. Most of the major leather and tanning related industrial clusters in the province are located in Sialkot, Kasur, Multan, Lahore, Sheikhupura and Gunjranwala. The main leather exports of Punjab are associated with district Kasur and Sialkot and 75% exporters of leather are based in Punjab (Ghafoor *et al.*, 2012). Therefore, considering the fact of Punjab’s exclusive, valuable plant kingdom and rich availability of leather raw material, the province, Punjab has been selected for the present study.

3.2 Study Area

Punjab is the second largest province of Pakistan comprising 205,344 km^2 area. It is located between latitudes 27.42º and 34.02º North and longitudes 69.81º and 75.23º East at the northwestern edge of the geological Indian plate in South Asia (GOP, 1994). Punjab is bordered by the provinces of Khyber Pakhtunkhwa and Balochistan

(Hussain *et al.*, 2003). The province comprises of fertile plains of the mighty Indus River and its tributaries that run from North to South. The landscape is greatly irrigated with a vast network of canals all over the province. Intensity of the weather is noticeable from hot and infertile southern region to cool Himalayan Mountains in the North (GOP, 2009). Physiographically the region is a part of a vast stretch of alluvial deposits laid by the tributary rivers of the Indus. The agricultural lands (predominant land use) are at an elevation of 130 m to 190 m above mean sea level. The variation in temperature and rain fall prevails throughout the year. Central and northern Punjab is quite rich in terms of biodiversity and studies are conducted by many researchers on different aspects of plant species but the natural dyes from plant material are neglected and unexplored in this province no effort has been made to study plants based natural dyes. Thus, for the present study plant samples were collected from the selected area of central and northern Punjab (Fig. 3.1).

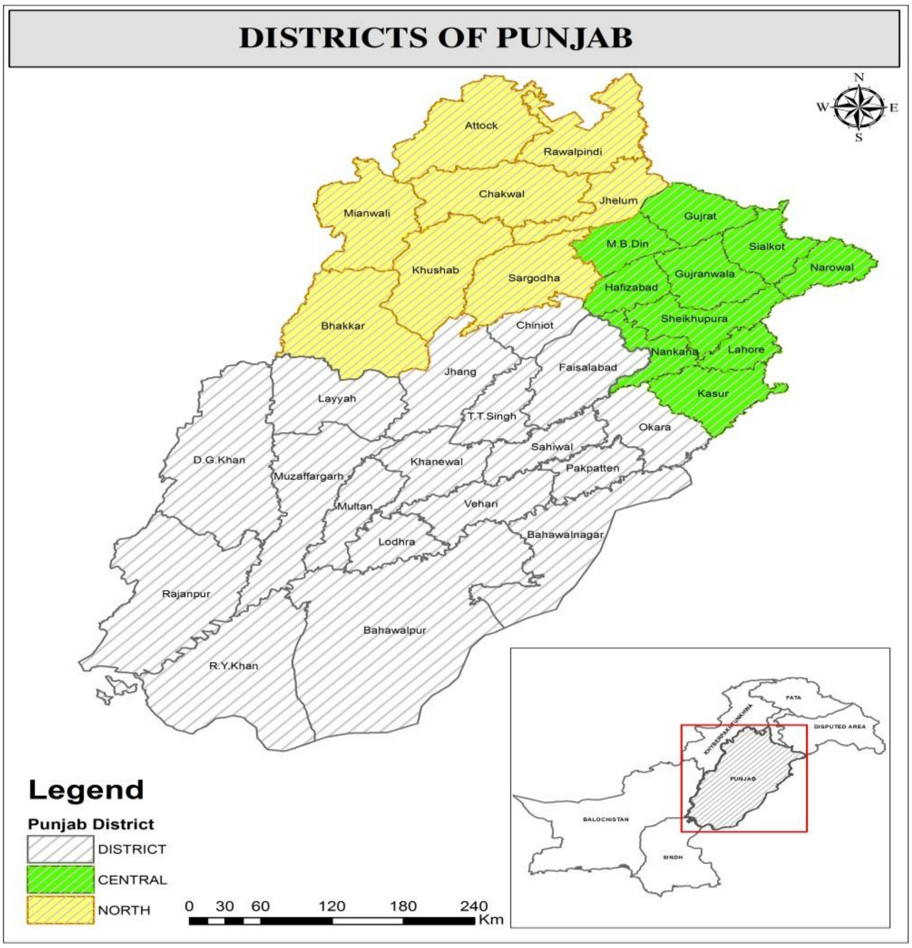


Fig. 3.1 Map of Study Area

3.3 Collection of Plants Material

The plant material consisted of hundred samples such as leaves, barks, aerial roots, waste fruit peel, twigs, seeds and flowers which considered the source of natural dyes (Ahmad *et al.*, 2011) were collected by regular visits of selected area, comprising Central and Northern districts of Punjab using the following criteria:

- Easily available
- Abundant available
- Based on waste product
- Cosmopolitan
- Sustainable to grow in harsh climate
- Compatible with varying type of soil
- Commercial viable

3.3.1 Identification of Plants

All plants were identified by Prof. Dr. Zaheer-ud-din Khan Professor of Botany, Government College University, Lahore. The voucher specimens were deposited in Prem Madan, Herbarium, LCWU, Lahore. The alphabetical arranged plants list with their botanical, local name and parts used are the following (Table 3.1):

Table 3.1 List of Plants Parts

S.#	Botanical Name	Local Name	Family Name	Part used	Collection Site	Voucher No.
1	*Acacia nilotica* (L.) Delile	Kikar	Mimosaceae	Leaves	Jhelum	0022
2	*Albizia lebbeck* (L.) Benth.	Kala shrin	Mimosaceae	Leaves	Jhelum	0152
3	*Albizia procera* (Roxb.) Benth.	Safed shrin	Mimosaceae	Leaves	Faisalabad	0250
4	*Albizia lebbeck*	Siris	Mimosaceae	Leaves	Rawalpindi	0152
5	*Albizia procera*	Peela shareen	Mimosaceae	Leaves	Lahore	0254
6	*Aloe barbadensis* Mill.	Kunwar ghandal	Liliaceae	Stem	Lahore	0221
7	*Alstonia scholaris* (L.) R.Br.	Alstonia	Apocynaceae	Flower	Jhelum	0215
8	*Arbutus unedo* L.	Toot frangi	Rosaceae	Leaves	Lahore	0256
9	*Amaranthus caudatus*	Sag	Amaranthaceae	Leaves	Sheikhupura	0257
10	*Araucaria angustifolia*	Araucaria	Araucariaceae	Leaves	Faisalabad	0258

11	*Avena fatua* Linn.	Jangli jai	Poaceae	Leaves	Faisalabad	0259
12	Azadirachta indica (Linn.) A. Juss.	Neem	Meliaceae	Leaves	Gujranwala	0260
13	*Bauhinia purpurea* L.	Gulabi kachnar	Caesalpiniaceae	Leaves	Rawalpindi	0261
14	*Bellis perennis*	Daisy	Asteraceae	Flower	Lahore	0262
15	*Beta vulgaris* L.	Chukander	Chenopodiaceae	Leaves	Lahore	0263
16	*Bombax ceiba* Linn.	Simbal	Bombacaceae	Flowers	Lahore	0264
17	*Bougainvillea glabra*	Paper flower	Nyctaginaceae	Bracts	Nankana Sahib	0265
18	*Brassica campestris* L.	Sarsoon	Brassicaceae	Shoots	Sheikhupura	0266
19	*Butea frondosa*	Dhak	Papilionaceae	Leaves	Jhelum	0267
20	*Caaesalpinia pulcherrima*	Peacock flower	Caesalpiniaceae	Flower	Lahore	0268
21	*Callistemon citrinus*	Bottle brush	Myrtaceae	Flowers & leaves	Gujranwala	0269
22	*Calotropis procera*	Ak	Asclepiadaceae	Flower	Jhelum	0031
23	*Capparis decidua*	Karein	Capparaceae	Fruit	Faisalabad	0213

24	*Cassia fistula* L.		Caesalpiniaceae	Flower	Jhelum	196
25	*Cassia occidentalis* Linn.	Kasondi	Caesalpiniaceae	Flower	Rawalpindi	270
26	*Catharanthus roseus*	Saada bhar	Apocynaceae	Flower	Lahore	0271
27	*Celtis australis* L.	Kharak	Cannabaceae	Leaves	Rawalpindi	0272
28	*Celosia cristata* Linn.	Kalgha	Amaranthaceae	Flower	Lahore	0283
29	*Cestrum diurnum*	Day jassamin	Solanaceae	Flower	Nankana Sahib	0284
30	*Cordia dichotoma* G. Frost	Lasura	Boraginaceae	Leaves	Lahore	285
31	*Cupressure sempervirens*	Saroo	Cupressaceae	Leaves	Faisalabad	286
32	*Dalbergia sissoo* Roxb.	Shisham	Papilionaceae	Leaves	Jhelum	144
33	*Datura fastuosa* Linn.	Sufaid dtura	Solanaceae	Flower	Rawalpindi	0287
34	*Delonix regia* (Bojer) Raf.	Gul-e-mohr	Papilionaceae	Leaves	Rawalpindi	0288
35	*Dillenia indica* Linn.	Gul-e-must	Dilleniaceae	Leaves	Nankana Sahib	0289
36	*Diospyros malabarica* (Desr.)	Gaab	Ebenaceae	Leaves	Sialkot	0290

	Kostel.					
37	*Dracaena mannii* . Bak	Nkeng	Dracaenaceae	Leaves	Faisalabad	0291
38	*Ehretia acuminata* R. Br.	Jangli kali mirch	Boraginaceae	Leaves	Jhelum	0293
39	*Ehretia obtusifolia*	Chamrror	Boraginaceae	Leaves	Rawalpindi	0294
40	*Eucalyptus camaldulensis* Dehnh.	Sufeda	Myrtaceae	Bark	Attock	0273
41	*Euphorbia tirucalli* L.	Pencil tree	Euphorbiaceae	Twigs/shoots	Jhelum	0295
42	*Ficus auriculata* Lour.	Maxican fig	Moraceae	Leaves	Jhelum	0296
43	*Ficus benghalensis* L.	Bohr	Moraceae	Aerial roots and bark	Lahore	0278
44	*Ficus benjamina* L.	Weeping fig	Moraceae	Leaves	Sialkot	0297
45	*Ficus elastica* Roxb. ex Hornem.	Rubber plant	Moraceae	Aerial roots	Lahore	0298
46	*Ficus palmata* Forssk.	Anjeer	Moraceae	Leaves	Jhelum	0299
47	*Ficus religiosa* L.	Peepal	Moraceae	Leaves	Faisalabad	0182

48	*Foeniculum vulgare* Mill.	Sonf	Apiaceae	Seeds	Chakwal	0148
49	*Gmelina arborea* Roxb.	Kumbar	Lamiaceae	Leaves	Rawalpindi	0300
50	*Grevillea robusta* A. Cunn. ex R. Br.	Silver baloot	Proteaceae	Leaves	Rawalpindi	0302
51	*Hibiscus rosa-sinensis* L.	Shoe flower	Malvaceae	Flower	Lahore	0303
52	*Imperata cylindrica* L.	Seel	Poaceae	Shoot	Sialkot	0304
53	*Iresine paniculata* L.	Blood leaf	Amaranthaceae	Leaves	Lahore	0305
54	*Jacaranda mimosifolia* D. Don.	Nilli gul-e-mohr	Bignoniaceae	Leaves	Rawalpindi	0306
55	*Lantana camara* Linn.	Lantana	Verbenaceae	Flower	Lahore	0307
56	*Leucaena leucocephala* (Lam.) de Wit.	Ipil Ipil	Mimosaceae	Leaves	Faisalabad	0309
57	*Lagerstroemia indica* L.	Lagestomia	Lythraceae	Leaves	Faisalabad	0310
58	*Mangifera indica* L.	Aam	Anacardiaceae	Bark	Gujranwala	0276
59	*Manilkara zapota* (L.) P. Royen	Cheekoo	Sapotaceae	Leaves	Faisalabad	0311

60	*Melia azedarach* L.	Dhrek	Meliaceae	Leaves	Jhelum	0150
61	*Millettia pinnata* (L.)	Sukhchain	Papilionaceae	Leaves	Lahore	0312
62	*Mimosa pudica* L.	Chui mui	Mimosaceae	Flower	Faisalabad	0314
63	*Mimusops elengi* L.	Maulsari	Sapotaceae	Leaves	Rawalpindi	0316
64	*Moringa oleifera* Lam.	Sohanjna	Moringaceae	Leaves	Faisalabad	0317
65	*Morus alba* L.	Safaid toot	Moraceae	Leaves	Lahore	0143
66	*Morus macroura* Miq.	Shah toot	Moraceae	Leaves	Lahore	0225
67	*Morus nigra* L.	Toot siah	Moraceae	Leaves	Lahore	0318
68	*Musa acuminata*	Kela	Musaceae	Bark	Faisalabad	0319
69	*Murraya koenugii* L.	Curry pata	Leguminosae	Leaves	Rawalpindi	0173
70	*Nephelium litchi*	Litchi	Sapindaceae	Leaves/Fruit Peel	Lahore	0324
71	*Nerium oleander*	Kaner	Apocynaceae	Flower	Lahore	0325
72	*Nigella sativa* L.	Kalongi	Apiaceae	Seeds	Jhelum	0326

73	*Ocimum bassilicum* Linn.	Niazbo	Lamiaceae	Flower	Lahore	0327
74	*Papaver rhoeas*	Poppy	Papaveraceae	Flower	Lahore	0328
75	*Parkinsonia aculeata* L.	Vilayati kikar	Fabaceae	Dry leaves	Jhelum	0329
76	*Petunia nyctaginiflora*	Petunia	Solanaceae	Flower	Lahore	0330
77	Pisum sativum L.	Mattar	Papillion	Shell	Faisalabad	0331
78	*Plantago lanceolatum* L.	Ispaghol	Plantaginaceae	Seeds Seed husk	Jhelum	0332
79	*Plumeria obtusa* L.	Gul-e-cheen	Apocynaceae	Leaves	Faisalabad	0333
80	*Polyalthia longifolia* (Sonn.) Thwaites.	Ulta ashok	Annonaceae	Leaves	Lahore	0334
81	*Populus nigra* L.	Poplar	Salicaceae	Leaves	Sialkot	0335
82	*Prosopis cineraria* (L.) Druce	Jand	Mimosaceae	Leaves	Jhelum	0035
83	*Prosopis glandulosa* Torr.	Mesquite	Mimosaceae	Beans	Sialkot	0336

84	*Prosopis juliflora* (Sw.) DC.	Angraizi kikar	Mimosaceae	Leaves	Jhelum	0337
85	*Psidium guajava* L.	Amrood	Myrtaceae	Leaves	Gujranwala	0338
86	*Pterospermum acertifolium* (L.) Willd.	Kanak champa	Malvaceae	Flower	Sheikupura	0339
87	*Punica granatum* L.	Anar	Punicaceae	Fruit peel, twigs and leaves	Gujranwala	0179
88	*Portulaca grandiflora*	Gul dopheri	Portulacaceae	Flower	Lahore	0340
89	*Raphanus sativus* L.	Mooli	Brassicaceae	Leaves	Lahore	0246
90	*Rosa damascena*	Ghulab	Rosaceae	Flower	Lahore	0341
91	*Schinus molle* L.	False pepper	Anacardiaceae	Leaves	Jhelum	0342
92	*Sapindus trifoliatus* L.	Reetha	Sapindaceae	Leaves	Rawalpindi	0343
93	*Syzygium cumini* (L.) Skeels.	Jaman	Myrtaceae	Bark	Lahore	0274
94	*Tamarindus indica* L.	Imli	Caesalpiniaceae	Beans shell	Faisalabad	0344
95	*Tamarix aphylla* (L.) H. Karst.	Khaggal	Tamaricaceae	Leaves	Jhelum	0345

96	*Tagetes erecta* L.	Genda	Asteraceae	Flower	Lahore	0346
97	*Terminalia arjuna* (Roxb. Ex DC.) Wight & Arn.	Arjun	Combretaceae	Leaves	Lahore	0347
98	*Zizyphus jujuba* (L.) Lam.	Shaoo ber	Rhamnaceae	Leaves	Gujranwala	0349
99	*Zizyphus mauritiana* Lam.	Beri	Rhamnaceae	Leaves	Gujranwala	0350
100	*Zizyphus nummularia* (Burm.f.) Whigt. & Arn	Karkinna	Rhamnaceae	Leaves	Sialkot	0351

3.4 Selection of Leather

Goat, sheep, cow and buffalo are the primary sources of skins and hides used for leather articles which were selected for dyeing analysis. The chrome tanned leather was selected on the following basis:

- Easily available
- Durable
- Good affinity and bonding with dyes
- Exhibit good dye uniformity

The potential of dyes was assessed on the selected leather specimens (Fig.3.2).

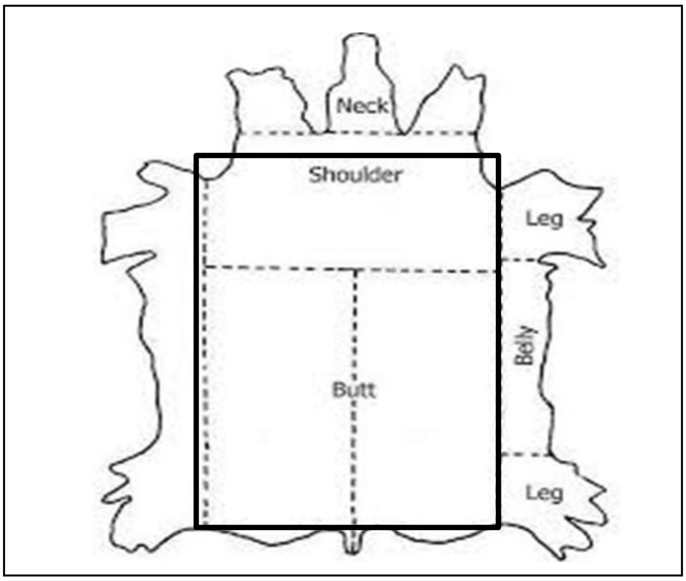


Fig.3.2: Leather Portion used for the Dyes Assessment

3.5 Mordants and Chemicals

For the colour fastness of dye, the mordants were used on the following basis:

- Easily available
- Commercially viable
- Eco-friendly and common mordants

Commercial grade mordants and chemicals such as potash alum $KAl(SO_4)_2$, potassium dichromate ($K_2Cr_2O_7$), copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$), aluminium sulphate ($Al_2(SO_4)_3$), copper acetate ($Cu(CH_3COO)_2$), ferric chloride ($FeCl_3$), acetic acid (CH_3COOH), copper chloride ($CuCl_2$), and tartaric acid ($C_4H_6O_6$), oxalic acid ($C_2H_2O_4$), sodium formate ($HCOONa$), sodium bicarbonate ($NaHCO_3$), sodium hydroxide (NaOH) and formic acid (CH_2O_2) were purchased from the local market.

3.6 Preparation of Sample for Dye Extraction

Plants parts were collected and washed thoroughly with water to remove soil (Win and Swe, 2008; Pervaiz *et al.*, 2016a) and were categorized as following:

3.6.1 Dry Samples

The tree bark, fruit peel, leaves and aerial roots were dried and grinded (Upadhyay and Choudhary, 2012; Haji *et al.*, 2014; Pervaiz *et al.*, 2016c) mechanically from Ashraf, Laboratories, Faisalabad. The samples were stored at dry place in transparent, labeled polythene zip bags (Sharma *et al.*, 2007; Pervaiz *et al.*, 2016c).

3.6.2 Fresh Samples

Over ripen and fresh flowers samples were collected (Patil *et al.*, 2016) from the ground and purchase from the local florist shops. Petals were separated from the plucked flowers, weighed and washed with tap water (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

3.6.3 Waste Plant material

The dried leaves which were shed from the trees were collected from ground. Leaves were weighed, washed, dried and crumbled for use.

3.6.4 Dye Extraction

Dyes extracted from plant material samples were obtained using different solvents as the colour also dependent on solvent selection (Ugochukwu, 2013). Different dye extraction techniques were adopted as per feasibility and as per the requirement of the samples.

3.6.4.1 Steep Extraction

Primitive, conventional, eco-friendly, low cost aqueous method was empolyed for dye extraction with distilled water (Antima *et al.*, 2012; Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b; Pervaiz *et al.*, 2016c). Pre-weighed 100 g of raw material was immersed in 1000 mL distilled water (Grover and Patni, 2011; Pervaiz *et al.*, 2016a) and kept for 36 hours at ambient temperature. In order to obtain maximize dye yield, the steeped flowers petals were heated gently at 40 ˚C for 40 minutes. Afterwards, the dye was left to cool and filtered through Whatman filter paper No.1 (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b; Pervaiz *et al.*, 2016c).

3.6.4.2 Boiling Extraction

Barks and roots samples were steeped overnight (Opoku-Asare *et al.*, 2014; Pervaiz *et al.*, 2016a) in distilled water. The material and water ratio 1:10 was taken for dye extraction and boiled at 90 ˚C for an hour using hot plate. After the dye extraction, the solution was left to cool and filtered through vacuum filtration unit.

3.6.4.3 Soxhlet Extraction

Extraction by soxhlet was carried out with leaves samples. The organic solvents were used such as chloroform, n-hexane, acetone, alcohol and methanol. The sample and solvent ratio1:10 was taken in the thimble and boiled gently in round bottom flask at 40 to 50˚C using heating mental. The process of dye extraction was carried out till the discharge of complete colour then the solvents were evaporated using rotary evaporator (Pervaiz *et al.*, 2016c).

3.7 Leather Dyeing Process

For the assessment of dyes potential, the following procedure was carried out for dyeing leather.

3.7.1 Wetback

The weighed leather was soaked in the tap water for overnight to absorb the maximum moisture content. The soaked leather further processed with the 1% solution of sodium bicarbonate and sodium formate in micro steel drum for 30 minutes for softness and then rinsed with tap water (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

3.7.2 Mordanting

For the current study, mordanting is used in two different ways such as pre-mordanting and post mordanting (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). 1.0 M solution of each mordant was prepared and diluted in 250 mL tap water and used for mordanting (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

3.7.2.1 Without Mordant

The leather was dyed without mordant (Patil *et al.*, 2016; Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

3.7.2.2 Pre-mordanting

Before dyeing, (Adem, 1996; Amarnath and Radhika, 2015, Patil *et al.*, 2016; Pervaiz *et al.*, 2016a) the leather specimens were treated with ten different mordants for an hour (Pervaiz *et al.*, 2016b).

3.7.2.3 Post-mordanting

On contrary to pre-mordanting method, the leather specimens were first dyed and then mordanted (Adem, 1996; Inayat *et al.*, 2010) with each selected mordants for an hour (Pervaiz *et al.*, 2016a).

3.7.2.4 Dyeing

The leather specimens were dyed with liquid extract in two steps. In first step, the leather was dyed with 250 ml liquid extract for 30 minutes. After 30 minutes, the liquid extract pH was adjusted at 3 with formic acid for dye fixation. In the second step, the same process was repeated (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b; Pervaiz *et al.*, 2016c).

3.7.2.5 Drying

The dyed leather samples were spread under shade for drying (Pervaiz *et al.*, 2016a).

3.8 Dye Yield Obtained from Plants Material

The filtered aqueous dye solution was placed in beaker and heated on hot plate at 80^{o}C to get solid dye by evaporating water. Solid dye powder determined after evaporating water using the following equation.

$$W_{dy} = \frac{\text{Weight of beaker after extraction of dye (W1)- Weight of beaker before extraction of dye } (W_0)}{\text{Amount of plant material (g) (W)}} \times 100$$

Where Wdy= percentage dye yield; W1= dye material weight after extraction of dye (g); W_0- weight of beaker before extraction of dye (g). All weighing was carried out on electronic digital balance (Pervaiz *et al.*, 2016c).

3.9 Evaluation of CIE L*a*b* C* & h Values of Dyed Leather Specimens

CIE L* a* b*, C*& h values of dyed and undyed leather specimens were determined by determined through spectrophotometer (Spectraflash SF-650X) According to colour coordinates, L* refers to 100-0 values by presenting light to dark colours. The value of negative a* expresses the green colour and positive a* value shows red colour. Whereas, negative b* value describes the blue colour and positive value of b* denotes yellow colour. The C* shows the chroma by describing the vividness and dullness of colour while h represents hue which expresses the tones of shades (Torskangerpoll and Andersen, 2005; Saravanan *et al.*, 2014; Chung *et al.*, 2015; Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

3.10 Assessment of Colour Fastness

The strength of dye affinity on leather was evaluated by performing colour fastness to rubbing, daylight and mild washing using the following ISO and BS standard methods (Table 3.2):

Table 3.2: Assessment of Colour Fastness of Dyed Leather Specimens

Sr. No.	Assessment of Colour Fastness	ISO and BS Standards
1	Colour Fastness to Rubbing	BS-1006
2	Colour Fastness to Mild Washing	ISO-15703-98
3	Colour Fastness to Daylight	ISO-105-BO1-1999

3.10.1 Colour Fastness to Rubbing

Colour fastness to rubbing of dyed leather specimens was carried out according to SLF-5 (BS-1006) using SATRA rub fastness tester. The dry and wet state of rubbing was determined from the grain side of the dyed leather specimens. Colour fastness of rubbing was evaluated on the following basis:

3.10.1.1 Dry Rubbing

The grain side of the dyed leather specimen was rubbed with a dry circular wool felt pad by setting 512 cycles using weight.

3.10.1.2 Wet Rubbing

For wet rubbing, the circular wool felt pads were soaked and then boiled in water for two minutes. The water was cooled down and the weight of the soaked wool felt pad was adjusted according to the standard method by squeezing the excess water. The specimens were rubbed with the wet wool felt pads by circulating 256 times on the grain side. The wool felt pads were dried and the extent of staining was evaluated using ISO grey scale for staining. The staining and colour change grades were assessed with the ISO grey scales having interpretation range of 1-5 has shown in the Table 3.3 (Paschal *et al.*, 2015; Ado *et al.*, 2015; Pervaiz *et al.*, 2016a).

Table 3.3: Grey Scale Key Interpretation Description for Rubbing

Grey Scale	Fastness Grade	Staining on Adjacent Multifiber	Change in Colour
5	Excellent	No Staining	No change in colour
4	Very good	Very slight staining	Slight change in colour
3	Good	Moderate staining	Appreciable change in colour
2	Poor	Significant staining	Significant change in colour
1	Very Poor	Extensive staining	Extensive change in colour

3.10.2 Colour Fastness to Mild Washing

Colour fastness to mild washing of dyed leather specimens was performed according to ISO 15703:1998. A specimen of leather was taken measuring 100 mm x 36 mm which was representative of the piece of leather for testing. The composite specimen was assembled by placing the piece of adjacent fabric over the leather specimen and stitching them together, for example by inserting two steel staples, at the narrow ends. The adjacent fabric was attached to the flesh side of grain leathers. A suitable quantity of wash liquor was prepared by adding 5,0 g of detergent (Sodium lauryl sulphate) to every liter of water and stirring vigorously until no solids were visible. 100 mL of the washing liquor and 20 PTFE rods were placed in the drum and warmed to 30˚C ± 2˚C. The composite specimen was placed in the drum and rotated at 40 rpm ± 5 rpm for 30 min, maintaining the temperature at 30˚C ± 2˚C. The washing liquor was removed and replaced it with 100 mL of water at 30˚C ± 2˚C (rinsing water). The drum was rotated at 40 rpm ± 5 rpm for 10 min, maintaining the temperature at 30˚C ± 2˚C. Rinsing procedure was repeated once more with fresh rinsing water. The composite specimen was removed from the drum, placed it between sheets of blotting paper, and the blotting paper between glass plates. A weight of 4,5 kg was placed on the upper glass plate and maintained the pressure for 1 min. The composite specimen was taken out, unfastened one narrow end and placed the composite specimen, opened out, on a horizontal grille so that the leather and adjacent fabric are not touching. The composite specimen was dried in air under standard conditions. The change of colour of the grain side of the leather was assessed either visually in accordance with ISO 105 A03. The staining of the adjacent fabric was assessed visually in accordance with ISO 105 A02 using grey scale key interpretation Table 3.4 (Pascal *et al.*, 2015; Ado *et al.*, 2015).

Table 3.4: Grey Scale Key Interpretation Description for Mild Washing

Grey Scale	Fastness Grade	Staining on Adjacent Multifiber	Change in Colour
5	Excellent	No Staining	No change in colour
4	Very good	Very slight staining	Slight change in colour
3	Good	Moderate staining	Appreciable change in colour
2	Poor	Significant staining	Significant change in colour
1	Very Poor	Extensive staining	Extensive change in colour

3.10.3: Colour Fastness to Daylight

Colour fastness to daylight of dyed leather specimens was performed according to ISO 105 B01:1999. An area of the material not less than 10 mm× 100 mm was selected so that each exposed portion was not less than 10 mm× 20 mm. The specimen was a strip of leather mounted on a card and compressed to give a uniform surface and fastened on a card. To facilitate handling, the specimens to be tested and the similar strips of the references were mounted on a card. The specimens to be tested and the blue wool strips of the references were of equal size and shape in order to avoid errors in assessment due to over-rating the visual contrast between exposed and unexposed parts on a larger pattern as against narrower references. This method is used when a large number of specimens have to be tested simultaneously. The basic feature is the control of the exposure periods by inspection of the blue wool references, which allows a number of specimens differing in color fastness to be tested against a single set of blue wool references, thus conserving supplies. The specimens to be tested and the references were arranged, with covers A´B´ and AB each covering one fifth of the total length of each specimen and reference. The specimens and references were exposed to daylight under the conditions described in standard method. The effect of light was followed by lifting cover AB periodically and inspecting the references. When a change in reference 2 was perceived equal to grey scale 3, inspected the specimens and rated their colour fastness by comparing any change that have occurred in references 1, 2 and 3. The cover AB was replaced in exactly the same position and continued to expose until a change in reference 3 was perceived equal to grey scale grade 4; at this point fixed additional cover CD in the position, overlapping the cover AB. Exposure was continued until a change in colour in reference 4 was perceived equal to grey scale grade 4, then fixed the final cover EF in the position, the other covers remaining in position. Exposure was continued until a contrast was produced on reference 7 equal to the contrast illustrated by grey scale grade 4. The assessment of results was carried out with the key interpretation description Table 3.5 (Kiron, 2012; Pervez and Rahman, 2015; Ado *et al.*, 2015).

Table 3.5: Grey Scale Key Interpretation Description for Daylight

Grey Scale	Fastness Grade	Degree of Fading
8	Outstanding	No fading
7	Excellent	Very Slight fading
6	Very good	Slight fading
5	Good	Moderate fading
4	Fairly Good	Appreciable fading
3	Moderate	Significant fading
2	Poor	Extensive fading
1	Very Poor	Very extensive fading

3.11 Economic Sustainability of Produced Liquid Dye

The production cost of liquid dye was estimated by taking into account the raw material, utilities, labour, transportation, packing and overheads (miscellaneous) (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016c).

3.12 Development of Shade Catalogue

The shade catalogue was developed using dyed leather specimens (Pervaiz *et al.*, 2016b). (Annexure, A).

CHAPTER 4

RESULTS

A series of experiments with and without mordants were carried out by keeping in view the above objectives by using different plants parts which were collected from Central and Northern Punjab. During the study, total hundred plant species belonging to fifty one families were documented. Plants reported from the Punjab (Central and Northern) were tabulated according to their botanical name, local name, family name and voucher number (Table 3.1). The selected plants discussed separately are the following:

4.1 *Bellis perennis*

B. perennis waste petals were used for dyeing leather. Twenty one experiments were carried out with and without mordant using pre-mordanting and post mordanting techniques.

4.1.1: General Appearance of Dyed Leather Specimens

From Table 4.1 it can be elucidated that good dye evenness obtained with *B. perennis* dye. The uniformity of dye was observed on both (flesh and grain) sides of the leather specimens. It was also noted from results that un-mordanted leather specimen also produced good dye levelness (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b).

4.1.2: Dye Penetration

The dye penetration level was observed at fair level with and without a mordant. Maximum dye penetration was found with ferrous sulphate, copper sulphate and ferric chloride mordants. Moreover, rest of mordants rendered fair dye penetration (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a) with fair to good surface dye results.

4.1.3: Shade Obtained without Mordant

Results of Table 4.1.1 depicted that without mordant leather specimen produced greyish shade with the extracted pink dye.

4.1.4: Shades Obtained with Pre-mordanting Method

From Table 4.1.1, it was found that variety of grey and greenish grey tones developed with selected mordants. Most of the shades were found in grey range with pre-mordanting method. Besides grey shades eye pleasing greenish grey, elephant brown, sand grey, cumin seed brown and greyish black were observed with selected mordants. Elegant beige shade was developed with potassium dichromate mordant. Copper sulphate exhibited intellectual shade of light grey. Tranquil greenish grey shade was developed with ferrous sulphate. Copper chloride rendered grey shade. Beautiful blackish green shade was produced with ferric chloride mordant. Copper acetate was found with pale brown shade and acetic acid exhibited pale olive shade. Furthermore, the light greyish brown shade was observed with tartaric acid mordant.

4.1.5: Shades Obtained with Post-mordanting Method

On the other side with post mordanting method, the maximum ranges of brown shades were obtained with selected mordants (Table 4.1.1). Light shade of brown was obtained with potash alum, aluminium sulphate, copper sulphate and copper chloride mordants. Comparatively, the dark shade of brown was obtained with ferric chloride mordant. Pale yellow shade was found with potassium dichromate mordant. Dark greyish green shade was developed with ferrous sulphate mordant. Cardamom green shade was developed with copper acetate. Light grey shade was produced with acetic acid and light greyish brown with tartaric acid mordant. Moreover, soft and eye pleasing shades (Kamel *et al.*, 2011; Pervaiz *et al.*, 2016a) were exhibited with copper acetate, acetic acid and tartaric acid.

4.1.6: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

It was observed with *B. perennis* results given in Table 4.1.2 that ferric chloride produced lowest value of L* 38.49 (darkest) whereas copper chloride developed highest L* value 79.28 (lightest). Analyzing a* values, it has been noticed that potash alum developed lowest value of a* -7.72 (most green) while potassium dichromate displayed highest value of a* 3.62 (most red). Similarly, observing b* values, tartaric acid produced lowest value of b* 4.12 whereas potassium dichromate depicted maximum value of b* 21.65 (most yellow).

4.1.7: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Based upon results of *B. perennis* with post mordanting method, it was observed that obtained L* values with the extracted dye using ten different mordants were found very high. Low value of L* 55.61 was obtained with ferric chloride mordant. Observing a* values, it was noticed that minimum value of a* -7.95 (most green) was obtained with copper chloride and maximum value of a* -1.81 was depicted with ferric chloride mordant. In case of b* values, minimum value of b* -5.30 (most blue) was displayed with tartaric acid and maximum value of b* 23.59 (most yellow) was developed with potassium dichromate (Table 4.1.3).

4.1.8: Effects of Mordanting Methods

Mordants play important role to improve the colour fastness of dye. Using different mordants, it was analyzed that deep, dark shades obtained with metal mordants. Analyzing all mordants results, it was found potassium dichromate, ferrous sulphate and ferric chloride mordants rendered dark shades. Comparing results of L* values of pre-mordanting and post-mordanting methods, it was revealed that low lightness values obtained with pre-mordanting method (Fig. 4.1).

4.1.9: Colour Fastness to Rubbing with Pre-mordanting Method

Rub fastness results (dry & wet) of dyed leather specimens as shown in Table 4.1.4. Results of dry rub fastness indicate that excellent (5) results obtained with potash alum, potassium dichromate, aluminium sulphate and ferric chloride mordants. Very good results of dry rub (4-5) were noted with copper sulphate, ferrous sulphate, copper chloride, copper acetate, acetic acid and tartaric acid mordants. Results of wet rubbing elucidated excellent (5) fastness grades which were obtained with potash alum, potassium dichromate, aluminium sulphate and ferric chloride mordants. Moreover very good fastness results (4-5) results observed with copper sulphate, ferrous sulphate, copper chloride, copper acetate and acetic acid whereas (4) rating obtained with tartaric acid mordant. Analyzing results of change in colour, it was noticed that potassium dichromate, aluminium sulphate, and ferric chloride rendered (5) excellent results in dry state while copper sulphate, ferrous sulphate, copper chloride, copper acetate, acetic acid and tartaric developed very good (4-5) results. Excellent change in colour rating in wet state obtained with potassium dichromate, aluminium sulphate and ferric chloride mordants. However, (4-5) very good change in colour results was shown with copper sulphate, ferrous sulphate, copper chloride and copper acetate. In addition, acetic acid and tartaric acid were noted with very good (4) grades.

4.1.10: Colour Fastness to Rubbing with Post-mordanting Method

In case of post-mordanting method, excellent staining grades (5) obtained with potash alum, potassium dichromate, and aluminium sulphate, acetic acid and tartaric acid mordants. Very good staining grades (4-5) were obtained with copper sulphate, ferrous sulphate, copper chloride, ferric chloride and copper acetate mordants. The excellent results (5) of wet rubbing were obtained with potassium dichromate mordant whereas very good (4-5) staining grades were obtained with potash alum, aluminium sulphate, copper sulphate and copper acetate mordants. Excellent (5) change in colour results was observed with potassium dichromate, acetic acid and tartaric acid mordants. Very good (4-5) staining results was obtained with potash alum, aluminium sulphate, copper sulphate and copper acetate mordant. However, (4) rating change in colour observed with ferrous sulphate, copper chloride and ferric chloride mordants. Analyzing results of change in colour in wet state, it revealed that excellent results (5) were obtained with potassium dichromate and acetic acid mordants. Very good results (4-5) was depicted with copper sulphate while potash alum, aluminium sulphate, copper chloride, ferric chloride, copper acetate and tartaric acid mordants exhibited results with (4) rating. In addition, good (3-4) change in colour was noted with ferrous sulphate mordant.

4.1.11: Colour Fastness to Mild Washing with Pre-mordanting Method

Experimental results of wash fastness of dyed leather specimens showed excellent staining results (5) on acetate band. Wash fastness results of Table 4.5 indicated that excellent staining (5) was obtained on cotton whereas very good staining results (4-5) were found with copper sulphate and tartaric acid mordants. Analyzing staining on nylon, it was found that excellent fastness grades (5) obtained with and without mordant except tartaric acid mordant which rendered very good wash fastness result (4). Excellent wash fastness staining (5) were obtained on polyester with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferrous sulphate, copper chloride and copper acetate mordants while acetic acid produced very good wash fastness (4) result. Observing staining on acrylic, it was noted that excellent values (5) produced with all selected mordants whereas tartaric acid mordant gave very good result (4-5). Staining grade on wool was found excellent with potash alum, ferrous sulphate, copper chloride and acetic acid mordants. Very good staining on wool was obtained with potassium dichromate, aluminium sulphate, copper sulphate, ferric chloride and copper acetate. Moreover, excellent results of staining on acetate, cotton, nylon, polyester, acrylic and wool was obtained without mordant. Change in colour was also observed excellent with potassium dichromate whereas very good results were obtained with copper sulphate (4-5), ferrous sulphate (4), copper chloride (4-5), ferric chloride (4-5), copper acetate (4), acetic acid (4) and tartaric acid (4). Whilst very good result change in colour was obtained with un-mordanted dyed specimen.

4.1.12: Colour Fastness to Mild Washing with Post-mordanting Method

B. perennis dye showed good to excellent wash fastness with post-mordanting method. Results of Table 4.1.6 showed that excellent wash fastness grades (5) developed with all selected mordants. Staining results on cotton were found excellent (5) with potash alum, potassium dichromate, aluminium sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid whereas copper sulphate produced very good result (4). Excellent results (5) were noted on nylon with all mordants while copper sulphate produced very good wash fastness grades (4). Specimens post mordanted produced excellent wash fastness grades (5) on polyester with selected mordants except copper sulphate mordant which exhibited very good result. Excellent staining results (5) on wool were obtained with potash alum and potassium dichromate mordants. Very good wash fastness grades (4-5) were obtained with aluminium sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Moreover, very good rating (4) was obtained with copper sulphate. Analyzing results of change in colour with post-mordanting method, excellent result (5) was noted with potassium dichromate. Very good change in colour results (4-5) was observed with ferrous sulphate and ferric chloride. In addition, very good results (4) were obtained with potash alum, copper sulphate, copper chloride, copper acetate and acetic acid. Moreover, aluminium sulphate gave good (3-4) change in colour results. Whilst tartaric acid produced good results with (3) rating.

Comparing results of *B. perennis* wash fastness with pre-mordanting and post-mordanting, it was revealed that negligible staining was observed on acetate, cotton, nylon, polyester and acrylic bands. Moreover good staining results was observed on wool with pre-treated and post-treated leather specimens. Further analyzing change in colour results with both mordanting method, it revealed that very good to excellent results were found with pre-mordanting method.

4.1.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Change in colour of dyed specimens with pre-mordanting method was assessed, after exposing the samples in daylight (Table 4.1.8). Very good (6) change in colour results were observed with ferric chloride mordant. Fairly good (4) results were achieved with potassium dichromate, acetic acid and tartaric acid mordants. Further analyzing results, it was noticed that moderate (3) rating was produced with aluminium sulphate and copper sulphate mordant. While extensive change in colour results was noted with potash alum, ferrous sulphate, copper chloride and copper acetate mordants.

4.1.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

From Table 4.1.9, it was noted that good (5) results observed with acetic acid mordant while moderate rating (3) change in colour evaluated with aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate and tartaric acid mordants. Poor fading results (2) were noted with potash alum, potassium dichromate and un-mordanted dyed leather specimens.

4.1.15: Economic Feasibility of Dye for Green Economy

The production cost of *B. perennis* liquid dye was estimated by taking into account the raw material (waste petals), utilities, labour, transportation, packing and overhead miscellaneous (Table 4.1.10). The extraction cost of liquor dye of 1kg waste petals was 1.71 USD which can be used for dyeing three goat skins and the per skin liquor cost was 0.57 USD. So, *B. perennis* extract from waste petals was not only significant in terms of environmental safety but also economical viable as compared to toxic synthetic dyes (Vankar and Shanker, 2008; Mortazavi *et al.*, 2012; Pervaiz *et al.*, 2016a).

4.2. *Bombax ceiba*

B. ceiba waste flower petals were used for dyeing of leather. Twenty one experiments were carried out with and without mordants using pre-mordanting and post mordanting techniques.

4.2.1: General Appearance of Dyed Leather Specimens

The general appearance of dyed leather specimens can be assessed easily from (Table 4.2.1). It was depicted from the visual inspection that dyed leather specimens exhibited a good levelness of dyes with and without a mordant. Moreover, the significant dye evenness was found good on both sides of leather specimens (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a).

4.2.2: Dye Penetration

The dye penetration level was observed at fair level with and without mordant. In addition, very good dark and soft surface dyes were obtained with *B. ceiba* dye (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a).

4.2.3: Shade Obtained without Mordant

It was clearly observed from the results presented in Table 4.2.1 that un-mordanted dyed leather specimen rendered beautiful pale yellowish shade.

4.2.4: Shades Obtained with Pre-mordanting Method

From Table 4.2.1, it was noted that a variety of dark and light shades obtained with *B. ceiba* floral dye using pre-mordanting method. Biscuit shade was produced with potash alum, aluminium sulphate and copper acetate mordants. Whitish brown shade was produced with acetic acid while ferric chloride mordant rendered camel brown shade. Copper sulphate mordant exhibited beautiful cumin seed shade. However, the elegant brown shade was developed with the ferrous sulphate mordant. Dark mustard shade was developed with potassium dichromate mordant. Tartaric acid developed soft tea pink shade on the leather specimen. Therefore, findings of *B. ceiba* dye showed that super golden dark shade was obtained with potassium dichromate mordant. While medium shade of brown was developed using ferric chloride mordant and ferrous sulphate. Results of obtained shades showed that selected mordants produced satisfactory results.

4.2.5: Shades Obtained with Post-mordanting Method

In post-mordanting method, a wide array of shades was developed with the *B. ceiba* golden dye. From the comparative analysis of all shades, it has been found that super biscuit shade exhibited with potash alum. Elegant golden shade produced with potassium dichromate mordant. Copper sulphate rendered beautiful light camel brown shade. Skin brown shade was developed with aluminum sulphate mordant. Whereas ferrous sulphate and ferric chloride mordants rendered medium walnut brown shades. Copper acetate and tartaric acid mordants exhibited light tea pink shade. Moreover, copper chloride developed super off-white pearl shade.

4.2.6: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

The L* values with *B. ceiba* dye varied from mordant to mordant. Maximum value of L* i.e. 76.56 (lightest) was obtained with un-mordanted dyed specimen whereas minimum value of L* 56.47 (darkest) was developed with ferrous sulphate. Highest value of a* 10.96 (most red) was obtained with potassium dichromate and highest value of b* i.e. 30.66 (most yellow) was also recorded with it. Moreover, analyzing value of a* i.e. 0.90 (lowest red) was recorded with un-mordanted dyed specimen and minimum value of b* 5.80 (lightest yellow) was also produced with un-mordanted dyed leather sample (Table 4.2.2).

4.2.7: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Observing data of Table 4.2.3, it was noticed that maximum value of L* i.e. 77.28 (lightest) was displayed by aluminium sulphate and minimum value of L* i.e. 52.51 (darkest) was observed with ferric chloride. In case of a* values, maximum value of a* i.e. 4.71 (most red) was depicted with tartaric acid mordant and minimum value of a* i.e. -1.63 (most green) was obtained with copper acetate. In case of b* values, maximum value of b* i.e. 32.67 (most yellow) was noted with potassium dichromate mordant and minimum value of b* i.e. 5.80 (least yellow) was displayed with un-mordanted dyed specimen.

4.2.8: Effects of Mordanting Methods

Based upon results of pre-mordanting and post-mordanting methods (Table 4.2.2 and Table 4.2.3), it was noted that all selected mordants developed light and dark shades which is evident from their L* values. Analyzing results (Fig. 4.2.1), it was found that maximum dark and deep shades were obtained with pre-mordanting method whereas ferric chloride and ferrous sulphate mordants developed significant dark shades with post-mordanting method. It was also revealed from the obtained results that metal mordants rendered dark shades with post-mordanting method. Musa *et al.*, (2011) and Bechtold *et al.*, (2009) reported the similar findings with post-mordanting method.

4.2.9: Colour Fastness to Rubbing with Pre-mordanting Method

From Table 4.2.4, it was found that selected mordants exhibited excellent colour fastness to staining and change in colour with *B. ceiba* dye. Leather specimen pre-treated with eco-friendly, potash alum mordant showed excellent grade (5) in dry and wet staining and change in colour. Very good (4-5) to excellent (5) dry and wet staining and colour change grades were obtained with potassium dichromate mordant. Pre-treated leather specimens with aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid exhibited excellent (5) results in dry staining. In wet staining, very good grades (4-5 & 4) were obtained with and without a mordant. In change in colour (dry), very good grades (4-5) were obtained with all selected mordants whereas potash alum showed excellent grade (5). Furthermore, potash alum and potassium dichromate mordants bestowed excellent results (5) in change in colour (wet). In addition, very good grades (4-5 & 4) in change in colour (wet) were recorded with aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Overall comparison of dry and wet rubbing results, it was found that colour fastness to rubbing (dry) rendered excellent results.

4.2.10: Colour Fastness to Rubbing with Post-mordanting Method

From Table 4.2.5, it was clearly seen that very good to excellent results in colour fastness to rubbing (dry and wet) were obtained with the selected *B. ceiba* dye. In dry staining, excellent grade (5) was observed with and without a mordant. Observing results of wet staining, it was noticed that fastness varies with the change in the mordants used. Very good staining (4-5) in wet state was noted with potassium dichromate, aluminium sulphate, copper acetate, acetic acid and tartaric acid mordants whereas copper sulphate mordant exhibited good staining grade (3-4). Similarly, change in colour results also vary with selected mordants. In change in colour (dry), very good results were recorded with all mordants. While analyzing results of change in colour in wet state, very good grades (4) were found with potash alum, potassium dichromate, ferric chloride, copper acetate and acetic acid mordants. Furthermore, aluminum sulphate, copper sulphate, ferrous sulphate, copper chloride and tartaric acid produced good results (3-4) in change in colour (wet).

4.2.11: Colour Fastness to Mild Washing with Pre-mordanting Method

Table 4.2.6 presented staining and change in color results of colour fastness to mild washing with and without a mordant. Analyzing staining results on multifiber, very good to excellent staining grades (4-5 &5) were obtained with and without a mordant. Analyzing change in colour results, it was found that excellent change in colour grades (5) were shown with potash alum, potassium dichromate and copper chloride mordants. While aluminium sulphate, copper sulphate, ferrous sulphate, ferric chloride, copper acetate, acetic acid and tartaric acid mordants gave very good change in colour grades (4-5). Thus, very good to excellent wash fastness results showed that good covalent bonding developed between the dye molecules and the leather.

4.2.12: Colour Fastness to Mild Washing with Post-mordanting Method

Colour fastness to mild washing with post-mordanting method rendered very good to excellent staining grades (4-5& 5) on all bands of multifiber with and without a mordant. Excellent change in colour grade (5) was observed with potassium dichromate and copper chloride mordants while very good colour change (4-5) was noted with potash alum, copper sulphate, acetic acid and tartaric acid mordants. Aluminium sulphate, ferric chloride and copper acetate produced colour change grade (4) while ferrous sulphate mordanted leather specimen displayed good colour change (3-4) (Table 4.2.7).

4.2.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

From Table 4.2.8, it was noticed that excellent change in colour grade (7) was obtained with copper acetate mordant. Fairly good grade (4) was recorded with acetic acid mordant. Aluminium sulphate, copper sulphate and tartaric acid mordants displayed moderate grade (3) of change in colour. Analyzing ferrous sulphate mordant, it was revealed that exposed specimen got darker in shade than the unexposed one whereas potash alum, potassium dichromate, copper chloride and without mordant specimens were noted with poor change in colour grades (2).

4.2.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Colour fastness to daylight with post-mordanting method was shown in Table 4.2.9. Very good change in colour (6) was observed with ferric chloride mordant. Moreover, moderate change in colour (3) was obtained with potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper acetate, acetic acid and tartaric acid mordants. Poor change in colour (2) was evaluated with potash alum and copper chloride mordants.

4.2.15: Economic Feasibility of Dye for Green Economy

The production cost of *B. ceiba* liquid dye was estimated by taking into account the raw material (waste flower petals), utilities, labour, transportation, packing and overheads (miscellaneous) (Table 4.2.10). The total cost of 1kg waste petals was 1.69 USD which can be used for dyeing three goat skins and the per skin liquor cost was 0.563 USD. Thus, *B. ceiba* dye obtained from waste flower petals was not only significant in terms of environmental safety (Anitha and Prasad, 2007), non-toxic but also commercially viable (Vankar and Shanker, 2008; Mortazavi *et al.*, 2012; Pervaiz *et al.*, 2016a) for dyeing leather.

4.3 *Bougainvillea glabra*

B. glabra bracts were analyzed for dyeing leather specimens and twenty one experiments were carried out with and without the use of mordants using pre-mordanting and post-mordanting methods.

4.3.1: General Appearance of Dyed Leather Specimens

From visual inspection of dyed specimens with *B. glabra* dye, it was found that good to very good smooth, equal dyes obtained on both sides of dyed leather specimens with selected mordants (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a) except ferrous sulphate mordant. Furthermore, un-mordanted dyed leather specimen was also analyzed with good dye evenness. Thus, it was concluded from the obtained results that waste bracts dye of *B. glabra* can be used for dyeing leather.

4.3.2: Dye Penetration

Experimental data of tested dye showed the fair to good dye penetration level. Observing result, it was noticed that very good dye penetration obtained with potassium dichromate mordant using post-mordanting method whereas fair level of dye penetration obtained with all dyed specimens (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). In addition, deep, magnificent surface dyes results were observed with and without mordant.

4.3.3: Shade Obtained without Mordant

From Table 4.3.1 it was found that pale yellow shade was produced with un-mordanted dyed leather specimen.

4.3.4: Shades Obtained with Pre-mordanting Method

It was noted from results that different shades obtained with *B. glabra* dye. Pale yellow shades were recorded with potash alum, aluminium sulphate, copper sulphate acetic acid, copper acetate and copper chloride mordants. Chickpea shade was developed with tartaric acid mordant. Potassium dichromate exhibited light biscuit shade. Ferrous sulphate produced brownish shade on flesh side while on grain side the light brown shade was noticed. Super mehndi black shade was developed with ferric chloride mordant (Table 4.3.1).

4.3.5: Shades Obtained with Post-mordanting Method

From results of Table 4.3.1, it was noticed that multiple shades obtained from the bracts dye with post- mordanting method. Potash alum produced light biscuit shade. Cream shade produced with aluminium sulphate. Pale greenish yellow shade developed with copper sulphate, copper chloride, copper acetate mordants. Chickpea shade was noted with tartaric acid mordant. Beige shade produced with potassium dichromate mordant. Biscuit shade produced with ferrous sulphate whereas dark shade of biscuit rendered with ferric chloride mordant. Super eye-pleasing off-white shade was noted with acetic acid. Comparing results of pre-mordanting and post-mordanting, it was revealed that maximum light, soft shades produced with *B. glabra* dye (Kamel *et al.*, 2011; Pervaiz *et al.*, 2016a). Moreover, dark shades obtained with potassium dichromate, ferrous sulphate and ferric chloride mordants.

4.3.6: Colour Coordinates of Dyed Leather Specimens with Pre-Mordanting Method

Results of colour coordinates with pre-mordanting method revealed that minimum lightness (L*) value noted with ferric chloride (42.62) and maximum L* value obtained with aluminium sulphate (78.13). Observing a* values, it was evaluated that lowest value of a* -2.23 (most green) exhibited with copper sulphate and highest value of a* 1.58 (most red) obtained with ferric chloride mordant. In case of b* values, lowest value of b* 8.85 was noted with tartaric acid and highest value of b* 17.08 (most yellow) was recorded with potassium dichromate mordant (Table 4.3.2).

4.3.7: Colour Coordinates of Dyed Leather Specimens with Post-Mordanting Method

Based upon post mordanting results of dyed leather specimens with *B. glabra* dye, the lowest L* value was found with ferric chloride (63.02). Highest value of L* was obtained with aluminium sulphate (79.00). Analyzing a* values, it was observed that minimum value of a* -0.34 (most green) was indicated with aluminium sulphate and maximum value of a* 4.01 (most red) was obtained with tartaric acid. In case of b* values, the minimum value of b* 8.96 (least yellow) was developed with tartaric acid and maximum value of b* 27.95 (most yellow) was recorded with potassium dichromate mordant.

Comparing results of Table 4.3.2 and 4.3.3, it was observed that ferric chloride mordant rendered dark shade with pre-mordanting and post-mordanting techniques. Similarly lowest values of b* were recorded with tartaric acid and highest b* values obtained with potassium dichromate mordants using both mordanting techniques. Moreover, it was evaluated from results that most of obtained h values developed yellow shades

4.3.8: Effects of Mordanting Methods

Lightness (L*) results of dyed leather specimens with *B. glabra* dye using ten different mordants were indicated in Figure 4.3. Results of L* values with pre-mordanting and post-mordanting methods revealed that selected mordants were advantageous for dyeing leather. Pre-treated and post-treated leather specimens gave light to dark shades. Among mordants copper chloride attained dark, deep shade with pre-mordanting technique. On the other hand, with post-mordanting technique, all selected mordants developed the highest values of lightness.

4.3.9: Colour Fastness to Rubbing with Pre-Mordanting Method

The rubbing fastness (dry and wet) with pre-mordanting method presented in Table 4.3.4. Excellent (5) staining results in dry state were obtained with aluminium sulphate, copper sulphate mordants. It was shown from results that very good staining results (4-5) observed with potash alum, potassium dichromate, ferrous sulphate, copper chloride, copper acetate, acetic acid and tartaric acid mordants. Observing staining with wet rubbing, it was revealed that excellent results were produced with potash alum, potassium dichromate, aluminium sulphate, copper acetate, acetic acid and tartaric acid mordants. However, very good results (4-5) of staining obtained with copper sulphate, ferrous sulphate, copper chloride and ferric chloride mordants. From the data of Table 4.3.4, very good results (4-5) in dry state no change in colour was observed with and without mordant. The change in colour in wet state was found excellent (5) with potash alum, potassium dichromate, copper chloride, copper acetate and acetic acid mordants. Moreover, very good change in colour results (4-5) were noted with aluminium sulphate, copper sulphate and ferric chloride mordants. Results of Table (4.3.4) revealed very good to excellent rubbing results (dry and wet) which showed the colour fastness quality of the dye commercially.

4.3.10: Colour Fastness to Rubbing with Post-Mordanting Method

Results of Table 4.3.5 elucidated excellent results (5) of staining in dry state with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, copper acetate, acetic acid and tartaric acid mordants. Very good (4-5) staining results in dry state were analyzed with ferrous sulphate, copper chloride and ferric chloride mordants. Observing staining results in dry state, it was found that similar results in wet state were found with the selected mordants except copper sulphate which was recorded with (4-5) very good results. It was evident from the results (Table 4.3.5) that fastness grades of change in colour with post treated leather specimens showed excellent (5) grade with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, copper acetate and acetic acid mordants. In addition, tartaric acid mordant gave very good (4-5) rating. It was seen from results that similar grades of change in colour recorded with wet state.

4.3.11: Colour Fastness to Mild Washing with Pre-Mordanting Method

Wash fastness results of leather specimens dyed with *g. glabra* dye presented in Table 4.3.6. Results of wash fastness were found encouraging with the selected mordants. No colour staining was observed on acetate strip with and without mordant. Excellent results of staining (5) were observed on cotton, nylon, polyester and acrylic strips with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Excellent result (5) of staining was obtained with copper chloride. Very good results of staining (4-5) was noted with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Change in colour results observed excellent (5) with ferrous sulphate, copper chloride, ferric chloride, copper acetate and acetic acid mordants. Moreover, (4-5) very good results of change in colour found with potash alum, potassium dichromate, aluminium sulphate, copper sulphate mordants except tartaric acid which recorded with (4) grade.

4.3.12: Colour Fastness to Mild Washing with Post-Mordanting Method

Colour fastness to wash results with post-mordanting leather specimens were shown in Table 4.3.7. Excellent staining results (5) were noted on acetate band with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants whereas very good staining result (4-5) obtained with ferrous sulphate. Analyzing staining on cotton band, it was found that excellent result (5) obtained with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper acetate, acetic acid and tartaric acid mordants. Evaluating results of staining on nylon band, it was found that excellent staining grade (5) was noted with potash alum, aluminium sulphate, copper sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Excellent staining grade (5) was obtained on polyester and acrylic bands with all selected mordants. While analyzing colour staining on wool strip, it was observed that excellent results (5) obtained with potash alum, potassium dichromate, aluminum sulphate, copper sulphate mordants whereas (4-5) very good results of staining on wool recorded with ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. On the other side, the change in colour results was also found excellent (5) with potash alum, potassium dichromate, aluminium sulphate and copper sulphate mordant. Very good (4-5) results no change in colour was observed with ferrous sulphate, copper chloride, ferric chloride, acetic acid and tartaric acid mordants. It was evident from obtained results that wash fastness results are supportive to dye leather with *B. glabra* bracts dye.

4.3.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Results of Table 4.3.8 revealed that good to excellent colour fastness (7) found with ferric chloride mordant. Very good (6) result was noted with copper sulphate. Moreover, fairly good change in colour (4) grade was evaluated with ferrous sulphate, copper chloride, copper acetate, acetic acid and tartaric acid mordants.

4.3.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Fairly good colour fastness to daylight was found with potash alum, aluminium sulphate, ferrous sulphate, copper chloride, acetic acid and tartaric acid mordants. Moreover, post treated dyed leather specimens with copper sulphate and ferric chloride dyed leather specimens exhibited dark shade after exposing the samples in sunlight. Furthermore, noticeable poor fading result was found with potassium dichromate mordant (Table 4.3.9). Comparing data of daylight (Table 4.3.8 and Table 4.3.9) with pre-mordanting and post-mordanting methods, it was revealed that maximum dyed leather specimens rendered moderate results of colour fastness to daylight.

4.3.15: Economic Feasibility of Dye for Green Economy

The production cost of *B. glabra* liquid dye was estimated by taking into account the raw material (waste bracts), utilities, labour, transportation, packing and overheads (miscellaneous) (Table 4.3.10). The extraction cost of liquor dye of 1kg waste petals was 1.65 USD which can be used for dyeing three goat skins and the per skin liquor cost was 0.55 USD. Hence, dyeing leather with *B. glabra* waste bracts is commercially viable and also significant in terms of eco safety but also cost effective as compared to hazardous azo dyes (Vankar and Shanker, 2008; Mortazavi *et al.*, 2012; Raja *et al.*, 2012; Pervaiz *et al.*, 2016a).

4.4 *Celosia cristata*

C. cristata flowers were used for dyeing leather. A series of twenty one experiments were carried out with and without mordant using two mordanting methods (pre-mordanting and post-mordanting).

4.4.1: General Appearance of Dyed Leather Specimens

From Table 4.4.1 it has been elucidated that good evenness of dyes obtained with *C. cristata* dye. The uniform dye was observed on both sides of leather specimens (grain and flesh). Un-mordanted leather specimen was also found with good dye levelness. Moreover, all dyed leather specimens with pre-mordanting and post mordanting methods produced good results (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a).

4.4.2: Dye Penetration

The dye penetration level was observed good to very good with and without a mordant (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). Moreover, potash alum, aluminium sulphate, acetic acid with pre-mordanting method rendered excellent surface dye. Furthermore, with post-mordanting method, good to very good surface dyes were found with potassium dichromate and ferric chloride mordants.

4.4.3: Shade Obtained without Mordant

From results of Table 4.4.1 it was found that without a mordant the dye produced pink shade on leather specimen.

4.4.4: Shades Obtained with Pre-mordanting Method

C.cristata dye produced different range of shades on leather with selected mordants (Pervaiz *et al.*, 2016a). Analyzing results, it was observed that a variety of shades were produced with pre-mordanting method Table 4.4.1. Pre-treated dyed leather specimens with potash alum exhibited light brownish yellow shade. Aluminium sulphate produced grey shade. Significant peer green shade was produced with copper sulphate mordant which was also reported on wool (Shanker and Vankar, 2005). Ferrous sulphate mordant was dominant to produce greenish grey shade. Copper chloride was observed with light skin shade whereas camel brown shade recorded with ferric chloride mordant. Acetic acid mordant produced brownish skin shade. The significant snail shell shade was obtained with tartaric acid.

4.4.5: Shades Obtained with Post-mordanting Method

From results of Table 4.4.1, it was noticed that multiple shades obtained with *C. cristata* dye with post-mordanting method. Potash alum produced greenish yellow shade. Potassium dichromate mordant exhibited cardamom green shade. Aluminum sulphate mordant produced light grapes shade. Copper sulphate mordant produced cardamom green shade. Ferrous sulphate mordant gave result of brown shade. Copper chloride mordant was recorded with brownish yellow whereas ferric chloride rendered brownish grey shade. Copper acetate produced light brown shade and acetic acid noted with green shade. While pale green shade was found with tartaric acid mordant. Comparing all results, it was found that *C.cristata* dye developed soft and luster, eye pleasing shades with mordants (Kamel *et al.*, 2011; Pervaiz *et al.*, 2016a).

4.4.6: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Assessing the results of *C. cristata* presented in Table 4.4.2, the lowest value of L* (61.53) produced with copper acetate while the highest value of L* (71.46) developed with potassium dichromate mordant. Assessing results of a*, the lowest value -0.56 (most green) was developed with potassium dichromate whereas highest value of a* 1.20 obtained with acetic acid mordant. Similarly, analyzing results of b*, the lowest value 6.02 was produced with aluminium sulphate mordant whereas highest value of b* 20.18 (most yellow) developed with copper sulphate.

4.4.7: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Based upon results of *C.cristata with* post mordanting, it was analyzed that obtained lightness (L*) values were found lower with ferrous sulphate (51.96), acetic acid (53.37), copper acetate (55.92) and copper sulphate (59.69) mordants. Analyzing a* values, it was noticed that minimum value of a* -1.93 (most green) was obtained with copper sulphate and maximum value of a* 2.35 (most red) was obtained with ferric chloride. In case of b* values, minimum value of b* 9.12 (least yellow) was depicted with acetic acid. Maximum value of b* 22.91 (most yellow) was developed with potassium dichromate, having C* (22.94) and h 87.04. Furthermore, copper sulphate mordant was recorded with a* (-1-93), b* (12.85), C* (12.99) and h (98.56) gave greenish yellow shade. Analyzing ferric chloride mordant the a* (2.35), b* (10.43), C* (10.70) and h (77.32) coordinates showed the shade trend towards brown colour. In addition ferrous sulphate mordant with a*, b*, C* and h coordinates also showed the brownish shade.

4.4.8: Effects of Mordanting Methods

Analyzing all mordants results, it was found that *C.cristata* dye produced soft shades (Pervaiz *et al.*, 2016a) with different mordants. Comparing results of pre-mordanting and post-mordanting methods, it was observed that maximum lightness (L*) values obtained with post-mordanting method whereas dark shade obtained with ferrous sulphate mordant which is the reported quality of the mordant to obtain deep shade (Uddin, 2014). Furthermore, it was noted that *C. cristata* dye rendered dark shades with pre-treated leather specimens (Fig.4.4).

4.4.9: Colour Fastness to Rubbing with Pre-mordanting Method

From Table 4.4.4, it was noted that excellent results (5) dry rub fastness were obtained with and without a mordant. Analyzing results of staining on wet wool felt pad, it was revealed that very good to excellent results obtained with different mordants. Excellent grades (5) with wet testing were found with potash alum, potassium dichromate, aluminum sulphate, copper sulphate while ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid gave (4-5) very good results. Excellent results, no change in colour (5) were obtained with dry testing with potash alum, potassium dichromate, aluminium sulphate, copper sulphate and ferrous sulphate mordants. Moreover, very good results (4-5) change in colour was observed with copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid. In addition, change in colour after wet rubbing observed similar which obtained with dry rubbing. Furthermore, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants were recorded with (4-5) very good rating whereas (4) rating noted with copper acetate mordant. It was found from the results that no colour staining and change in colour were observed with the *C. cristata* dye. Thus, obtained results recommend the dye for commercial purpose.

4.4.10: Colour Fastness to Rubbing with Post-mordanting Method

The evaluation of colour fastness to rubbing with post-mordanting method was presented in Table 4.4.5. The staining and change in colour (dry and wet) results were found (5 to 4-5) with the selected mordants. Analyzing results of colour staining on dry state, it was revealed that excellent results (5) obtained with potash alum, potassium dichromate, copper chloride, acetic acid and tartaric acid mordants. While very good grades (4-5) were obtained with aluminium sulphate, copper sulphate, ferrous sulphate, ferric chloride and copper acetate mordants. Change in colour was observed excellent on dry state using potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride and tartaric acid mordants except copper acetate and acetic acid mordants which observed with very good (4-5) grades. However, the change in colour on wet state with post treated leather specimens showed excellent and very good grades. Excellent grade (5) was observed with potassium dichromate, aluminium sulphate, copper sulphate, ferric chloride and tartaric acid mordants. In addition, very good grade (4-5) was obtained with potash alum, ferrous sulphate, copper chloride, copper acetate and acetic acid mordants. Evaluating results of rubbing it was found that post-treated leather specimens showed excellent to very good grades. No colour staining and change in colour was observed with selected mordants. Thus, it was revealed from results that *C. cristata* dye showed good properties of rubbing.

4.4.11: Colour Fastness to Mild Washing with Pre-mordanting Method

Colour fastness to wash with pre-mordanting method was presented in Table 4.4.6. The leather specimens dyed with *C. cristata* dye showed very good to excellent results with and without mordant. From results, it was noted that excellent results (5) no colour staining observed on adjacent multifiber. Excellent results after washing was recorded on acetate, cotton, nylon, polyester, acrylic and wool with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. While analyzing results of change in colour after washing it was observed that most of post treated leather specimens showed no change in colour (4-5) very good rating with potassium dichromate, aluminium sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants gave. No change in colour was observed with potash alum and copper sulphate with (4) rating results.

4.4.12: Colour Fastness to Mild Washing with Post-mordanting Method

From Table 4.4.7, it was noted that excellent results (5) of no colour staining was observed on acetate strip with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Similar results of no staining grade (5) were observed on cotton, nylon, polyester, acrylic strips. Moreover, no colour staining was observed on wool strip with potash alum, potassium dichromate, aluminium sulphate, ferric chloride and acetic acid mordants while very good results (4-5) no colour staining were recorded with ferrous sulphate, copper chloride, copper acetate and tartaric acid mordants. Analyzing change in colour results was observed excellent (5) with potash alum, potassium dichromate, aluminium sulphate and acetic acid mordants. Very good results of no change in colour (4-5) were shown with ferrous sulphate, copper chloride, ferric chloride, copper acetate and tartaric acid whilst slight change in colour was observed with copper sulphate mordant but with good rating (4). It was revealed from results that pre-mordanting bestowed comparatively most of excellent results. Moreover, the *C. cristata* dye showed very good to excellent wash fastness with pre-treated and post-treated leather specimens. Using *C. cristata* dye almost similar wash fastness results were obtained on wool dyeing (Shanker and Vankar, 2005).

4.4.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Colour fastness to daylight with *C. cristata* dye has shown in Table 4.4.8. Very good (6) change in colour was evaluated with ferric chloride and copper acetate mordants. Good grade (5) change in colour was noted with ferrous sulphate. Aluminium sulphate rendered fairly good change in colour results. Moderate change in colour result was shown with copper sulphate, acetic acid and tartaric acid mordants. While poor change in colour was noticed with potash alum, potassium dichromate and copper chloride mordants.

4.4.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

It was evident from Table 4.4.9 that moderate (3) change in colour results obtained with aluminium sulphate and copper sulphate mordants. Ferrous sulphate and ferric chloride observed with dark shade after exposing in sunlight. Moreover, extensive fading results were observed with rest of mordants.

4.4.15: Economic Feasibility of Dye for Green Economy

C. cristata waste petals were purchased at low price. One kg extracted dye cost was 1.69 USD which can be used to dye 300g leather. *C. cristata* dye also reported inexpensive and free of pollutants by (Shanker and Vankar, 2005). Thus, results of study concluded that obtained dye is economical to use (Table 4.4.10).

4.5 *Lantana camara*

L. camara florets were used for dye extraction. Twenty one experiments were carried out including and excluding mordants by adopting pre-mordanting and post-mordanting methods.

4.5.1: General Appearance of Dyed Leather Specimens

From Table 4.5.1 it was elucidated that good uniformity of dyes obtained with *L. camara* brown-yellowish dye. The levelness of dye was observed good to very good on both sides (grain and flesh) of leather. Furthermore, good dye levelness was also noticed with un-mordanted dyed leather specimen. Moreover, all dyed leather specimens shown good results of dye evenness with pre-mordanting and post-mordanting methods (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016b).

4.5.2: Dye Penetration

The dye penetration level was recorded fair to good with and without mordant (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). Analyzing results, it was found that good penetration of dye was observed with pre-mordanting method instead of post-mordanting method. Whereas, good to very good surface dye results were found with all dyed specimens using *L. camara* dye. Findings of results showed that *L. camara* was suitable for the yellow and greenish-yellow surface dyes.

4.5.3: Shade Obtained without Mordant

From Table 4.5.1, it was noted that beautiful cardamom green shade was produced with *L. camara* dye.

4.5.4: Shades Obtained with Pre-mordanting Method

It was revealed from results (Table 4.5.1) that significant cardamom green shade developed with potash alum. Beige shade was produced with potassium dichromate mordant. Greenish-yellow shade was recorded with aluminium sulphate. Copper sulphate produced pale green shade. Peer green shade was produced with acetic acid. Moreover, ferrous sulphate and ferric chloride exhibited light brown shade. Pale yellowish-green shade was noted with copper chloride and acetic acid mordants whereas tartaric acid rendered greyish green shade. Furthermore, similar different reported shades were observed on cotton (Saravanan *et al.*, 2014).

4.5.5: Shades Obtained with Post-mordanting Method

Analyzing Table 4.5.1, it was revealed that golden shade was obtained with potassium dichromate and aluminium sulphate mordants. Light golden shade was observed with copper sulphate mordant. Copper chloride and acetic acid mordants produced light green shade. Light yellow shade was recorded with copper acetate mordant. Ferrous sulphate produced light brown shade whereas ferric chloride exhibited dark shade of brown. It was noted from pre-mordanting and post-mordanting method, the golden and greenish shade can be developed with *L. camara* dye.

4.5.6: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

It was observed with *L. camara* results given in Table 4.5.2 that highest value of (L*) (71.59) being lightest one was obtained with copper chloride mordant and lowest value of L* (55.23) being darkest one was developed with ferric chloride mordant. Analyzing a* coordinates, it was found that highest value of a* (3.65) most red developed with potassium dichromate mordant while acetic acid mordant developed lowest value of a* (-4.98) most green. Analyzing b* coordinates, it was observed that maximum value of b* (24.84) obtained with potassium dichromate mordant whereas the minimum value of b* (5.58) produced with potash alum mordant. Observing all coordinates of a* and b*, it was noticed that maximum results were found in yellowish green shades except ferrous sulphate which displayed a* (-1.86), b* (13.01), h (98.13) and ferric chloride which displayed a* (-0. 55), b* (13.96) and h (92.26) produced medium brown shade

4.5.7: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

From (Table 4.5.3) it was observed that highest L* value (82.68) was obtained with potash alum being lightest whereas lowest value of L* (61.39) being darkest obtained with ferric chloride. Analyzing a* coordinates, it was observed that minimum value of a* (-16.41) was developed with copper acetate being most green and maximum value of a* (-1.82) was recorded with acetic acid being most red. In case of b* coordinates, the minimum value of b* (10.46) was developed with ferric chloride being lightest yellow and maximum value of b* 27.95 recorded with potassium dichromate mordant being most yellow.

Evaluating results of Table 4.5.2 and Table 4.5.3, it was noted that potassium dichromate mordant is significantly used to ascertain golden yellow shade.

4.5.8: Effects of Mordanting Methods

Analyzing results of Table 4.5.2 and 4.5.3, it was revealed that most of the dark shades were obtained with pre-mordanting method (Fig. 4.5).

4.5.9: Colour Fastness to Rubbing with Pre-mordanting Method

From Table (4.5.4), it was found that excellent staining grades (5) were observed in dry state with and without mordant whereas acetic acid produced very good staining (4-5). *L. camara* dye was recorded with very good staining (4-5) in wet stated with and without mordant. Analyzing results of change in colour, it was noted that potassium dichromate and acetic acid mordants rendered excellent results grades (5) in dry state. While other mordants and un-mordanted dyed specimens produced very good staining grades (4-5). Change in colour result in wet state showed similar behavior as in change in dry state. Thus, results of rubbing (dry and wet) with pre-mordanting method were found valuable regarding industrial point of view.

4.5.10: Colour Fastness to Rubbing with Post-mordanting Method

Measured values of rubbing with post-mordanting method were presented in Table 4.5.5. From results, it was observed that excellent staining results (5) were obtained with potash alum, potassium dichromate, copper acetate and tartaric acid mordants in dry state. In addition, un-mordanted dyed leather specimen also produced excellent staining results (5) in dry state. Further analysis of staining in wet state revealed that very good staining results (4-5) were noted with and without mordant. Change in colour results in dry state was found excellent (5) with potassium dichromate and copper acetate mordants. While other mordants produced very good change in colour results (4-5) in dry state. Furthermore, change in colour in wet state was found with excellent results (5) with potassium dichromate and copper acetate mordants. Analyzing change in colour in wet state, very good change in colour results (4-5) were noted with potash alum, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, acetic acid and tartaric acid mordants. Results of colour fastness to rubbing with pre-mordanting and post-mordanting showed that *L. camara* dye suitable for commercial dyeing.

4.5.11: Colour Fastness to Mild Washing with Pre-mordanting Method

L. camara dye showed excellent staining (5) on acetate, cotton, nylon, polyester and acrylic strips. While staining on wool was found excellent (5) with potash alum, potassium dichromate, aluminum sulphate mordants. Very good staining results (4-5) were observed with copper sulphate, ferrous sulphate, copper chloride, ferric chloride, acetic acid and tartaric acid mordants. Excellent change in colour grade (5) was recorded with potash alum, potassium dichromate and ferric chloride mordants. Furthermore, very good change in colour grades (4-5) were observed with aluminium sulphate, copper sulphate, ferrous sulphate, ferric chloride, copper acetate, acetic acid and tartaric acid mordants.

4.5.12: Colour Fastness to Mild Washing with Post-mordanting Method

Colour fastness to mild washing results with post-mordanting method were showed in Table 4.5.7. Results of staining on acetate were found excellent (5) with and without mordant. While excellent staining (5) on cotton was found with potash alum, potassium dichromate, aluminium sulphate, ferrous sulphate and tartaric acid mordants. Hence, very good staining (4-5) on cotton was obtained with copper chloride and copper acetate mordants. Excellent staining (5) on wool was found on nylon, polyester and acrylic with and without mordant. Excellent staining (5) on wool was noted with potassium dichromate, aluminium sulphate, acetic acid and tartaric acid mordants. Further, analyzing staining on wool, it was found that very good staining (4-5) was obtained with potash alum, ferrous sulphate, copper chloride and copper acetate mordants. Good staining (4) on wool was obtained with copper sulphate and ferric chloride mordant. Further analyzing results of change in colour, it was revealed that excellent results (5) were observed with potash alum, potassium dichromate, aluminium sulphate, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. In addition very good results (4-5) were noted with copper sulphate and copper chloride mordants. From the result of Table 4.5.7, it was observed that *L. camara* dye possess good commercial dye qualities.

4.5.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Results of Table 4.5.8, highlighted that the colour fastness to daylight was moderate with change in colour grade (3) with the maximum mordants. Whereas poor change in colour grade (2) was observed with potash alum and un-mordanted dyed leather specimens.

4.5.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Data in Table 4.5.9 showed that dyed leather specimen with aluminium sulphate rendered fairly good change in colour result (4). Seven out of ten mordants were recorded moderate change in colour grade result (3). Besides, poor change in colour results (2) were observed with copper sulphate and copper acetate and un-mordanted leather specimens.

4.5.15: Economic Feasibility of Dye for Green Economy

The production cost of *L. camara* liquid dye was carried out by taking into account the raw material (florets), utilities, labour, transportation, packing and overheads (miscellaneous) (Table 4.5.10). The extraction cost of liquor dye of 1kg florets was 1.78 USD which can be used for dyeing three goat skins and the per skin liquor cost was 0.59 USD. Thus, *L. camara* dye was not only significant in terms of environmental safety but also commercially viable (Rawat *et al.*, 2004; Vankar and Shanker, 2008; Mortazavi *et al.*, 2012) for dyeing leather (Pervaiz *et al.*, 2016a)

4.6 *Papaver rhoeas*

P. rhoeas waste petals were used for dyeing analysis. Twenty one experiments were carried out with and without mordant.

4.6.1: General Appearance of Dyed Leather Specimens

From Table 4.6.1, the general appearance of dyed leather specimens dyed with *P. rhoeas* dye can be observed. It was inferred from results that dyed leather specimens rendered very good to excellent dye levelness with pre-mordanting and post-mordanting techniques (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a). In addition, the un-mordanted leather specimen was also gave very good results of dye levelness.

4.6.2: Dye Penetration

Excellent dye penetration results were obtained with the pre-mordanting and post-mordanting methods with all selected mordants. It was also observed from the results that un-mordanted leather specimen also found with very good dye penetration (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). The good penetration of dye revealed that *P. rhoeas* dye can be used successfully to dye leather. Not only this dye produced very good to excellent surface dyes results but also exhibited good dye penetration level.

4.6.3: Shade Obtained without Mordant

It was elucidated from Table 4.6.1, that beautiful greyish blue shade was obtained with un-mordanted dyed leather specimen.

4.6.4: Shades Obtained with Pre-mordanting Method

From Table 4.6.1, it was observed that pink shade developed with potash alum and copper sulphate. Potassium dichromate produced yellow shade. Application of ferrous sulphate, aluminium sulphate and acetic acid mordants exhibited blue shade. Dark biscuit shade was the dominant shade developed with ferric chloride mordant. Sand grey shade was obtained with copper acetate mordant while light grey shade noted with copper chloride mordant.

4.6.5: Shades Obtained with Post-mordanting Method

Analyzing shades with post-mordanting method, it was found that potash alum produced bluish grey shade. Yellow shade was obtained with potassium dichromate whereas bluish grey shade produced with aluminium sulphate. Ferrous sulphate was recorded with bluish pink shade. Pink shade was elucidated with copper sulphate whereas sand grey shade obtained with copper chloride mordant. Super sand grey shade was noted with copper acetate mordant. Ferric chloride was recorded with biscuit shade. Greyish blue shade was obtained with acetic acid whereas pale purple shade was recorded with tartaric acid mordant. Furthermore, different similar reported shades were observed on silk and cotton (Merdan *et al.*, 2012b; Gedik *et al.*, 2013).

4.6.6: Colour Coordinates of Dyed Leather Specimens with Pre-Mordanting Method

Table 4.6.2 showed L*, a*, b*, C* & h values of dyed leather specimens. It was observed from results that highest values of L* (74.76) obtained with potassium dichromate mordant and the darkest L* value observed with ferrous sulphate mordant. Highest value of a* (8.02) most red recorded with potash alum and lowest value a* (-2.35) presented with acetic acid mordant. Analyzing results, the maximum value of b* (19.15) was obtained with potassium dichromate whereas minimum value of b* (-12.28) recorded with acetic acid mordant.

4.6.7: Colour Coordinates of Dyed Leather Specimens with Post-Mordanting Method

Table 4.6.3 presented the colour coordinates of the post-treated leather specimens dyed with *P. rhoeas* dyes. All obtained coordinates presented the variety of shades with selected mordants. Highest L* (68.82) obtained with copper chloride mordant and lowest (57.91) recorded with ferrous sulphate mordant. Minimum value of a* (-4.30) most green obtained with copper chloride mordant. Maximum value a* (11.60) most red obtained with tartaric acid while potassium dichromate exhibited yellow shade with b* coordinate (18.42) and h (95.68). In addition, bluish shade rendered with aluminium sulphate having a* (6.93), b* (-3.17) and h (335.41).

4.6.8: Effects of Mordanting Methods

From Fig. 4.6.1, it was clearly seen that selected mordants produced numerous dark shades. Moreover, dyed leather specimens were found in dark deep shades with post-mordanting method.

4.6.9: Colour Fastness to Rubbing with Pre-Mordanting Method

Results of rubbing with pre-mordanting method presented in Table 4.6.4. It was evident from results that excellent staining (5) results were obtained in dry state with and without mordant. Assessing results of staining in wet state, it was revealed that very good staining (4-5) results obtained with potash alum, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate and tartaric acid. While un-mordanted dyed leather specimen also noted with very good staining results (4-5) in wet state. In case of change in colour result, it was found that very good results (4-5) in dry state developed with potash alum, potassium dichromate, ferrous sulphate, copper chloride, ferric chloride, copper acetate. Meanwhile good change in colour (3-4) observed with aluminium sulphate, copper sulphate, acetic acid mordants. Observing change in colour in wet state, it was analyzed that very good results (4) obtained with potassium dichromate and ferric chloride mordants. Good change in colour results were noted with ferrous sulphate, copper chloride, copper acetate and acetic acid mordants. While very poor results (1) change in colour in wet state observed with potash alum, aluminium sulphate, copper sulphate and tartaric acid mordants. Finding of results showed that mordants with very poor results of change in colour were not commercially viable.

4.6.10: Colour Fastness to Rubbing with Post-Mordanting Method

Analyzing results of Table 4.6.5, it was noted that excellent (5) staining results found with and without mordant except ferric chloride which produced (4-5) very good results. Staining results in wet state found very good with potash alum, potassium dichromate, aluminum sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate and acetic acid whereas un-mordanted specimen also rendered the similar results. While only tartaric acid recorded with excellent result of staining in wet state. Furthermore, the change in colour in dry state found good very good with all selected mordants whereas un-mordanted specimen noted with good result. Very good change in colour results in wet state obtained with copper acetate mordants. In addition, good results of change in colour observed with copper sulphate, ferrous sulphate, copper chloride, ferric chloride, acetic acid and tartaric acid mordants. Moreover, very poor results of change in colour were noted with potash alum and un-mordanted dyed leather specimens. Comparing results of pre-mordanting and post-mordanting method, it was found that change in colour in wet state in encouraging with maximum mordants.

4.6.11: Colour Fastness to Mild Washing with Pre-Mordanting Method

P. rhoeas dye showed excellent staining results (5) on acetate strip with and without mordant. Excellent results (5) of colour staining on cotton, nylon, polyester, acrylic were found with potash alum, potassium dichromate, aluminum sulphate, copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. On wool strip, (4-5) very good staining results were obtained with all selected mordant. Analyzing results of mild washing, it was found that very good ratings (4-5) change in colour obtained with copper sulphate and ferric chloride mordant. Good results of change in colour were observed with aluminium sulphate, copper chloride, copper acetate and acetic acid mordants. On the other hand, analyzing results with potash alum, copper sulphate, ferrous sulphate and tartaric acid mordant poor results (1) change in colour were noted. Similarly, good fastness results were reported on yarn with poppy flower petals dye (Ghasemi, 2015).

4.6.12: Colour Fastness to Mild Washing with Post-Mordanting Method

Based upon Table 4.6.7 results of wash fastness with post-mordanting method, excellent results (5) of staining on acetate band were obtained with all selected mordants. Excellent (5) results of staining were also obtained with all mordants on cotton band whereas (4-5) very good staining was noted with tartaric acid mordant. Furthermore, on nylon band, excellent wash fastness (5) were obtained with copper sulphate, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid and tartaric acid whereas very good staining results on nylon band were obtained with potash alum and aluminium sulphate mordants. Excellent staining was found on polyester and acrylic bands with all mordants. Analyzing colour staining on wool, it was noted that excellent results (5) observed with potassium dichromate and ferric chloride mordants. While (4-5) very good rating analyzed with potash alum, aluminium sulphate, ferrous sulphate, copper acetate, acetic acid and tartaric acid mordants. In addition, good staining result (3-4) was recorded with copper chloride. Analyzing change in colour, it was revealed that excellent (5) grade was obtained with potassium dichromate. Very good rating of (4-5) change in colour was obtained with ferric chloride and copper acetate mordant. While poor rating change in colour was obtained with copper sulphate and acetic acid. Furthermore, very poor (1) change in colour results was recorded with potash alum, aluminium sulphate and tartaric acid mordants. Analyzing results of wash fastness using pre-mordanting and post-mordanting techniques, it was revealed that very good to excellent staining results were obtained with *P. rhoeas* dye. Moreover, the change in colour was observed commercially viable with potassium dichromate, ferric chloride and copper acetate with post-mordanting method whereas with pre-mordanting method, potassium dichromate and ferric chloride rendered good results.

4.6.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Colour fastness to daylight was shown in Table 4.6.8. It was noted from results that *P. rhoeas* produced very good (6) result with ferric chloride mordant. Moderate grade (3) was obtained with potassium dichromate whereas potash alum, aluminium sulphate, copper sulphate, copper chloride, acetic acid and tartaric acid recorded with extensive fading results. In addition, similar results were obtained in the earlier study reported by Merdan *et al.*, (2012a) for dyeing wool.

4.6.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

From Table 4.6.9, it was evaluated that moderate fastness obtained with copper chloride, copper acetate and tartaric acid mordants. Results of colour fastness to daylight with ferric chloride have shown dark as compared to original dyed specimens after exposing in sunlight. In addition, potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper acetate, acetic acid and tartaric acid mordants were observed with extensive colour fading results.

4.6.15: Economic Feasibility of Dye for Green Economy

P. rhoeas waste petals were purchased at very low price. Therefore, 1 kg extracted dye cost was 1.78 USD which found economically sound regarding industrial point of view (Table 4.6.10). In addition, *P. rhoeas* natural dye is non- toxic than synthetically produced hazardous dyes.

4.7 *Rosa damascena*

R.damascena waste petals were used for dyeing analysis. Twenty one experiments were carried out with and without mordant.

4.7.1: General Appearance of Dyed Leather Specimens

The general appearance of dyed leather specimens can be assessed easily from Table 4.7.1. It was found from the visual inspection that dyed leather specimens exhibited good to very good levelness of dye with pre-mordanting and post-mordanting techniques whereas without mordant dyed specimen also exhibited good dye evenness (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a).

4.7.2: Dye Penetration

The dye penetration level was observed at fair level with and without mordant (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). On the other side, it was revealed that excellent surface dye results exhibited with and without mordants using *R. damascena* dye.

4.7.3: Shade Obtained without Mordant

From Table 4.7.1 it was found that without mordant a dark grey shade produced on leather specimen. Furthermore, the analysis of results given in Table 4.7.1 also exhibited shade without mordant due to the chrome tanning attribute (Eitel *et al.*, 1984).

4.7.4: Shades Obtained with Pre-mordanting Method

Analyzing Table 4.7.1, it was noticed that the application of mordants produced 20 varieties of colours. Moiz *et al.*, (2010) carried out a study regarding dyeing of leather with henna also reported the different shades were obtained with different mordants. With pre-mordanting method, it was also noticed that all produced shades were found deep in colour except potash alum mordant. Potash alum produced greenish yellow shade. Beautiful beige shade developed with potassium dichromate. Copper sulphate mordant exhibited peer green reported shade (Masure and Patil, 2014). Olive green shade was developed with aluminium sulphate mordanted sample. The ferrous sulphate mordanted dyed specimens were found in greyish black shade. While ferric chloride mordant was also produced dark greyish black shade. Moreover, copper acetate was found in greenish yellow tone. Acetic acid and tartaric acid mordants were found in the range of brown shade.

4.7.5: Shades Obtained with Post-mordanting Method

With post-mordanting method, the dark, deep shades obtained with the reported selected technique (Bechtold *et al*., 2009). Comparing with pre-mordanting method, dark beige shade obtained with potassium dichromate. Aluminum sulphate is dominant to produce pleasing grape shade whereas copper chloride and copper sulphate were found in the shade range of greenish yellow. Acetic acid mordant developed pale greenish shade and the tartaric acid produced greyish shade. Table 4.7.1 also demonstrated that ferrous sulphate which is a well-known mordant and considered for grey to black shades gave one of the significant colour strength (Bhanawat and Mohta, 2014).

4.7.6: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Analyzing the results of *R. damascena* in Table 4.7.2, it was found that low L* values were obtained with ferrous sulphate (47.55), ferric chloride (41.73), copper chloride (58.56), tartaric acid (55.41) and the without mordant, it was recorded (49.05). Observing a* values, it was noticed that minimum value of a* -4.15 (most green) was obtained with potash alum and maximum value of a* 2.31 (most red) was depicted with tartaric acid. In case of b* values, minimum value of b* -2.21 (most blue) was displayed with ferric chloride and maximum value of b* 24.77 (most yellow) was developed with potassium dichromate (Table 4.7.2).

4.7.7: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

From results of *R. damascena* in Table 4.7.3, it was found that low L* values were obtained with ferrous sulphate (37.38), ferric chloride (42.34) and copper sulphate (58.87). Observing a* values, it was noticed that minimum value of a* -6.70 (most green) was obtained with potash alum and maximum value of a* 3.53 (most red) was depicted with potassium dichromate. In case of b* values, minimum value of b* -2.25 (most blue) was displayed with ferrous sulphate and maximum value of b* 24.55 (most yellow) was developed with potassium dichromate.

4.7.8: Effects of mordanting methods

Analyzing pre-mordanting and post-mordanting results, it was found that colour coordinates were better obtained with the post-mordanting technique. The low values of L* were obtained with post-mordanted method except with acetic acid mordant. Ferrous sulphate was dominant of all mordants in post-mordanting method having lower value of L* 37.38 and the ferric chloride was the second highest mordant to produce dark shade having 42.34 L* results with the post-mordanting method. Moreover, potassium dichromate evaluated in deep shade as compared to alum, acetic acid, copper chloride and tartaric acid. It was also elucidated from the results of pre-mordanting and post-mordanting results that depth of shade obtained with post-mordanting method. The results of earlier study of Musa *et al.*, (2009) also concluded that the post-mordanting method characteristically bestowed better results on leather specimens as compared to pre-mordanting method as in post mordanting technique the dye is absorbed on the substrates and followed by the formation of an insoluble complex with metal ion (Fig. 4.7.1).

4.7.9: Colour Fastness to Rubbing with Pre-mordanting Method

Results of rubbing with pre-mordanting method were presented in Table 4.7.4. Analyzing results, it was noticed that very good staining observed in dry state with and without mordant. Very good staining results in wet state was found with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, copper chloride, copper acetate, acetic acid and without mordant. While ferrous sulphate and ferric chloride rendered good staining results with wet rubbing. Observing change in colour results, it was revealed that excellent grade (5) obtained with potash alum whereas rest of mordants gave very good results including without mordant. Further analyzing change in colour in wet state, very good results obtained with and without mordant.

4.7.10: Colour Fastness to Rubbing with Post-mordanting Method

Table 4.61 shows rubbing fastness of dyed specimens with and without mordant. It was observed from results that good rubbing fastness obtained with *R. damascena* dye. The similar results of dry rubbing with rose petals dye reported on cotton (Masure and Patil, 2014). Staining grades of colour fastness to rubbing revealed that the good values were obtained with pre-mordanting method. Comparatively, it was also noticed from the results obtained from both mordanting techniques that colour fastness to rubbing in dry state produced better results than the colour fastness to rubbing in wet state. Besides the rubbing in dry state, the good staining grades (4-5) were also obtained in rubbing (wet) with alum, copper sulphate, aluminium sulphate and tartaric acid in pre-mordanting and with copper acetate and tartaric acid in post-mordanting. The results of wet rubbing with pre- and post-mordanting methods showed that majority of the mordants had good staining grades in the range of 4-5 and 4. Moreover, overall results of colour fastness to rubbing were found good to very good with both mordanting techniques which is also reported by Ekrami *et al.*, (2011) on wool.

4.7.11: Colour Fastness to Mild Washing with Pre-mordanting Method

Colour fastness to wash with pre-mordanting method has shown in Table 4.7.6. Excellent rating (5) was observed on acetate strip with and without mordant except tartaric acid which recorded with (4-5) grade. Excellent staining on cotton strip was evaluated with potash alum, potassium dichromate, copper chloride, acetic acid and without mordant. Moreover very good staining results on cotton strip was observed with aluminium sulphate, copper sulphate, ferrous sulphate, copper acetate and tartaric acid mordants. Analyzing results of staining on nylon strip, it was found that excellent grade observed with copper chloride and without mordant whereas rest of mordants rendered very good grade (4-5). In addition, on polyester and acrylic strips excellent results were obtained with and without mordant except aluminium sulphate which presented very good rating (4-5). Results of staining on wool strip, depicted excellent rating with potash alum, ferrous sulphate, copper chloride, ferric chloride, copper acetate, acetic acid, tartaric acid mordants whereas rest of mordants rendered good results. Moreover, very good change in colour results obtained with and without mordant.

4.7.12: Colour Fastness to Mild Washing with Post-mordanting Method

Observing results of colour fastness to mild washing with post-mordanting method (Table 4.7.12), it was revealed that similar results of laundering evaluated with pre-mordanting method. Very good change in colour results was also obtained with and without mordant. In addition, similar Furthermore, the dyed leather specimens' results similarly confirmed the findings on wool (Ekrami *et al.*, 2011). Comparing results of wash fastness with pre-mordanting, post-mordanting and without mordant, it was evident that *R. damascena* dye is commercially viable to dye leather.

4.7.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

The results of colour fastness to daylight with pre-mordanting method were observed moderate to very good (Table 4.7.9). Very good change in colour (6) was obtained with copper chloride mordant. Application of ferrous sulphate and ferric chloride mordants also produced good change in colour results. Moderate results of daylight exposure were obtained with tartaric acid which is acceptable level of light. Potassium dichromate gave poor colour change results whereas alum produced moderate colour change. Moderate to good light results on cotton were also reported with rose petals dye (Masure and Patil, 2014).

4.7.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Results of colour fastness to light with post-mordanting methods were observed moderate to very good. Very good results were observed with aluminium sulphate and copper chloride mordants. Application of mordants potash alum, potassium dichromate rendered moderate change in colour results. Change in colour (4) observed fairly good with copper sulphate, ferrous sulphate, ferric chloride, copper acetate, acetic acid and tartaric acid mordants. Similarly, moderate to good daylight fastness results on wool were also reported with rose petals dye (Ekrami *et al.*, 2011).

4.7.15: Effects of Aqueous Dye Extraction and the Significance of Floral Dyeing

The results of study revealed that aqueous method is effective for the extraction of floral dye (Deshpande and Chaturvedi, 2014) and economical (Ibrahim *et al.*, 1997). Moreover, it has been analyzed from results that pink reported (Kalsy and Srivastava, 2016) water soluble dye extracted from steeped petals within 36 hours produced good results. Furthermore, the obtained results demonstrated that dyed specimens found fragrant after dyeing which is reported dynamic quality of floral dyeing (Singh and Srivastava, 2015; Kalsy and Srivastava, 2016).

4.7.16: Economic Feasibility of Dye for Green Economy

The production cost of liquid dye was estimated by taking into account the raw material (waste petals), utilities, labour, transportation, packing and overhead miscellaneous (Table 4.7.10). The extraction cost of liquor dye of 1kg waste petals was 1.86 USD which can be used for dyeing three goat skins and the per skin liquor cost was 0.62 USD. So, *R. damascena* extract from waste petals was not only significant in terms of environmental safety but also economical viable as compared to toxic synthetic dyes.

4.8 *Tagetes erecta*

T .erecta waste flowers were used for the extraction of dye and the efficiency of yellow dye was evaluated with and without a mordant.

4.8.1: General Appearance of Dyed Leather Specimens

The general appearance of dyed leather specimens can be visualized from Table 4.8.1. It was noticed from the visual inspection that dyed leather specimens produced a good levelness of dye with and without mordants. A fair levelness of dye was obtained with ferrous sulphate and ferric chloride mordants using pre-mordanting method whereas; with the post-mordanting method, fair to good fair dye uniformity was observed with all selected mordants (Selvi *et al.*, 2013; Pervaiz *et al.*, 2016a).

4.8.2: Dye Penetration

The dye penetration level was observed fair to good with and without mordant (Musa *et al.*, 2009; Pervaiz *et al.*, 2016a). Moreover, alum, aluminium sulphate, acetic acid with pre-mordanting method rendered excellent surface dye. Furthermore, with post-mordanting method, the good to very good surface dyes were found with potassium dichromate and ferric chloride mordants.

4.8.3: Shade Obtained without Mordant

It was clearly observed from the results presented in Table 4.8.1 that un-mordanted dyed leather specimen rendered beautiful pale yellowish shade with the extracted yellow dye which was the reported shade of *T.erecta* (Verghese, 1998; Jothi, 2008; Pervaiz *et al.*, 2016b; Singh and Swami, 2016).

4.8.4: Shades Obtained with Pre-mordanting Method

From Table 4.8.1, it was found that soft pleasing shades obtained with *T.erecta* dye. Most of the shades were found in light yellow range with pre-mordanting method. Besides yellow shades beautiful variety of cardamom green, yellowish green, and light brown were exhibited with different mordants. Shade of yellow developed with aluminum sulphate which was the reported shade on cotton and silk (Jothi, 2008). Moreover, similar reported result of light yellow shade obtained on cotton with copper sulphate mordant (Kanchana *et al.*, 2013). Whilst ferrous sulphate produced light brownish shade which similarly reported observation analyzed on cotton (Jothi, 2008; Chavan and Ghosh, 2015). Moreover, potash alum, copper acetate produced light yellow, ferric chloride developed light brown and acetic acid exhibited bright yellow shades.

4.8.5: Shades Obtained with Post-mordanting Method

In post-mordanting method, an assortment of pale yellow shades was developed with the *T.erecta* yellow dye (Ratnapandian *et al.*, 2012; Sadi *et al.*, 2016). From the comparative analysis of all shades, it has been revealed that most of obtained shades were in range of light and soft with potash alum, copper sulphate, aluminium sulphate (Kamel *et al.*, 2011). Furthermore, with ferric chloride mordant the brownish shade obtained with selected dye (Khattak *et al.*, 2011).

4.8.6: Colour Coordinates of Dyed Leather Specimens with Pre-Mordanting Method

Combination of dark and light values was obtained with selected mordants. Assessing the results of *T. erecta* in Table 4.8.2, it has been revealed that minimum value of L* 58.66 (darkest) was obtained with copper chloride and maximum value of L* 79.00 (lightest) was recorded with ferric chloride. Observing a* values, minimum value of a* -5.60 (most green) was found with aluminium sulphate and maximum value of a* 0.80 (most red) was reported with copper chloride. Analyzing b* values, minimum value of b* 9.78 was observed with ferric chloride whereas maximum value of b* 23.97 (most yellow) was achieved with aluminium sulphate whereas acetic acid (23.96) ranked second and potash alum (23.88) ranked third in yellow shade. It was evident from results that significant yellow shades were obtained with potash alum having b* value (23.88), C* (24.45) and h 102.33 which confirmed the results of yellow. On the other hand, aluminium sulphate recorded with the b* value (23.97) while the a* value was found in (-5.60) and the h 103. 15 depicted yellow shade. In addition acetic acid was rendered b* coordinate of 23.96 with a* coordinate -4.00 and the h angle recorded with 99.48. Comparing all results of pre-mordanting, it was found that L* values were found high except with ferrous sulphate and ferric chloride mordants.

4.8.7: Colour Coordinates of Dyed Leather Specimens with Post-Mordanting Method

Based upon results of *T.erecta* with post-mordanting method (Table 4.8.3), it was observed that obtained L* values with the extracted dye using ten different mordants were found very high. Observing a* values, it was noticed that minimum value of a* 0.77 (most green) was obtained with ferrous sulphate and maximum value of a* -3.77 (most red) was depicted with copper chloride. In case of b* values, minimum value of b* -8.31 (most blue) was displayed with ferrous sulphate and maximum value of b* 24.47 (most yellow) was developed with potassium dichromate. Experimental results of post-mordanting revealed that potassium dichromate mordant developed beautiful yellow shade with b* coordinate (24.56) and the h angle was 94.91. Analyzing further Table 4.8.3, copper chloride mordant was noted with b* coordinate 21.96, C* (22.28) and the h (99.75). Moreover, ferrous sulphate mordant gave results with a* (0.77) and b* (8.31) depicted light brown shade. In addition, ferric chloride mordant recorded with brownish shade.

4.8.8: Effects of Mordanting Methods with Pre-Mordanting and Post-Mordanting Method

Mordants played significant role to fix the dye on substrate (Bose and Nag, 2012). From the obtained results, it was analyzed that dark shades were obtained with metal mordants. Analyzing all mordants results, it was found that ferric chloride mordant produced dark reported shade (Khattak *et al.*, 2014; Pervaiz *et al.*, 2016b). In addition, dark shade was also observed with ferrous sulphate (Jothi, 2008) which is reported quality of metal mordant to make coordination with the dye (Ratnapandian, 2013) and in the present research, it developed good bonding with the *T. erecta* dye. Besides ferrous sulphate mordant, potash alum was also found in dark shade (Khattak *et al.*, 2014). Aluminium sulphate mordant was found significant to develop yellow shade. Moreover, beautiful range of yellow shades was developed with the maximum selected mordants.

4.8.9: Colour Fastness to Rubbing with Pre-Mordanting Method

Colour fastness to rubbing of dyed leather specimens was found excellent (5) to very good (4-5). In case of dry rubbing, the grey scale reading 5 was obtained with and without mordant whereas the excellent (5) wet rubbing grade was obtained with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride and copper acetate mordants. Moreover, very good (4-5) wet rubbing results were found with ferric chloride, acetic acid and tartaric acid mordants. Results of Table 4.8.4 revealed that excellent results (5) of no change in colour were obtained with dry rubbing. Furthermore, the change in colour with wet rubbing also showed excellent results (5) with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, copper chloride and copper acetate mordants. Comparatively, it was also noticed from the results obtained from rubbing (dry and wet) with pre-mordanting technique that colour fastness to rubbing in dry and wet state produced very good to excellent results (Table 4.8.4). Moreover, change in colour results with pre-mordanting method bestowed better results than post-mordanting method.

4.8.10: Colour Fastness to Rubbing with Post-mordanting Method

Based upon results of Table 4.8.5, it was found that excellent (5) dry rub fastness was obtained with and without mordant. Besides the rubbing in dry state, excellent results (5) of wet rubbing were recorded with potash alum, potassium dichromate, copper sulphate, copper chloride, ferric chloride, copper acetate, acetic acid, tartaric acid mordants whereas very good result of rubbing (4-5) was observed with ferrous sulphate mordant. Aluminium sulphate mordant was recorded with good result of (4). Furthermore, excellent results (5) of change in colour were obtained with and without mordant in dry state. Results of change in colour in wet rubbing showed excellent results (5) with potash alum, copper sulphate, copper chloride, ferric chloride, copper acetate and acetic acid mordant. In addition, very good (4-5) change in colour results observed with potassium dichromate, ferrous sulphate and tartaric acid.

4.8.11: Colour Fastness to Mild Washing with Pre-mordanting Method

Leather specimens dyed with selected mordants showed very good to excellent tendency with the *T.erecta* dye. Wash fastness results of Table 4.8.6 indicated that excellent staining results were obtained on acetate, with potash alum, copper chloride, copper acetate and acetic acid mordants. Excellent result (5) staining on cotton was recorded with potash alum, aluminum sulphate, ferrous sulphate, copper acetate and tartaric acid mordant. Staining on nylon was observed excellent (5) with and without mordant. Moreover excellent (5) staining results were also recorded with and without mordant on acrylic except acetic acid mordant which gave very good results with the grade (4-5). Staining on wool showed excellent results (5) with and without a mordant. Whilst (4-5) very good staining on wool was observed with potash alum and acetic acid. Good staining (4) on wool was developed with copper acetate. Change in colour results with and without mordant showed the slight change in shade after washing the dyed specimens. Excellent result (5) change in colour was noted with potassium dichromate. Very good results of (4-5) were recorded with aluminium sulphate, copper sulphate, copper sulphate, ferrous sulphate, copper chloride, copper acetate, and acetic acid mordants. Good results of change in colour (3-4) were noted with potash alum and ferric chloride mordants. Poor result of change in colour (2) was noted with tartaric acid mordant (Table 4.8.6).

4.8.12: Colour Fastness to Mild Washing with Post-mordanting Method

T.erecta dye showed excellent staining grade (5) on acetate with ferric chloride, acetic acid and tartaric acid mordant. Very good (4-5) and (4) staining on acetate was found with potash alum, potassium dichromate, copper sulphate, ferrous sulphate and copper acetate. Good staining grade (3-4) was noted with aluminium sulphate mordant. Excellent staining rate (5) on cotton was observed with aluminium sulphate, copper chloride and tartaric acid mordants. Very good staining results (4-5) on cotton was recorded with potash alum, potassium dichromate, copper sulphate, ferrous sulphate, ferric chloride, copper acetate and acetic acid. Very good results of staining on nylon were observed with all mordants. Staining on polyester was noted excellent (5) with ferric chloride, copper acetate, acetic acid and tartaric acid mordant and without mordant except acetic acid which is recorder with very good staining results (4-5). Excellent results (5) of staining on acrylic were found with potash alum, potassium dichromate, aluminium sulphate, copper sulphate, ferrous sulphate, ferric chloride and tartaric acid mordants while copper chloride observed with (4-5) result. Staining on wool was observed excellent with potassium dichromate, ferric chloride, copper acetate and acetic acid. Very good results of staining on wool were obtained with potash alum, copper sulphate, ferrous sulphate, copper and tartaric acid mordants. Excellent results (5) of change in colour were noted with potash alum and potassium dichromate. Whereas very good results in terms of change in colour (4-5) were recorded with aluminium sulphate, copper chloride, acetic acid and tartaric acid mordant. Good results (3-4) of change in colour were developed with ferrous sulphate and ferric chloride mordants. Comparing pre-mordanting and post-mordanting wash fastness results, it was revealed that excellent staining results were obtained with pre-mordanted dyed specimens. On the other hand, analyzing results of change in colour with pre- mordanting and post mordanting method, it was observed that post-mordanting specimens gave very good to excellent results (Table 4.8.7).

4.8.13: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

From Table 4.8.8, moderate to very good daylight fastness values were observed with *T.erecta* dye. Very good results (6) were exhibited with acetic acid and tartaric acid mordants. Fairly good rating (4) of change in colour was noted with potassium dichromate and aluminum sulphate mordants. Analyzing results of copper sulphate and ferric chloride, it was revealed that after sunlight exposure the dyed leather specimens shade became darker as compared to original dyed specimens. Application of ferrous sulphate, potash alum and copper acetate exhibited moderate change in colour results whereas copper chloride and un-mordanted dyed leather specimen recorded with poor (2) rating.

4.8.14: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Observing Table 4.8.8, it was found that very good (6) change in colour result was recorded with tartaric acid. In addition, fairly good rating was obtained with potassium dichromate, aluminium sulphate, copper sulphate, copper acetate and acetic acid. Comparing results of ferrous sulphate and ferric chloride mordants, it was noticed that both sample which exposed in sunlight exhibited dark shade than actual dyed specimens.

4.8.15: Economic Feasibility of Dye for Green Economy

Distilled water was used to extract dye from marigold flower petals (Islam *et al.,* 2016) as it is considered cost effective (Ali *et al.*, 2016). In addition, *T. erecta* waste garlands were purchased at low price. Therefore, the cumulative estimated cost of 1kg extracted dye from the *T. erecta* floral waste taking into consideration utilities, labor, transportation, overheads and miscellaneous 1.78 USD which was found to be quite economical and commercially viable to dye 300g of leather (4.8.10).

4. *Bellis perennis*

Bellis perennis waste petals were used to dye leather with various mordants. Twenty different shades were elucidated with *B. perennis* dye using ten selected mordants whereas without mordant also exhibited shade (Table 4.1.1). Colour coordinates of dyed leather specimens were also evaluated with pre-mordanting and post-mordanting methods as given in Table 4.1.2 and 4.1.3 respectively.

Table 4.1.1: Shades Obtained on Dyed Leather Specimens with and without Mordants

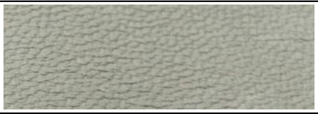
Without Mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.1.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	70.39	-7.70	6.97	10.39	136.87
Potash alum	71.38	-7.72	6.98	10.41	137.88
Potassium dichromate	54.70	3.62	21.65	21.95	80.51
Aluminium sulphate	73.11	-6.83	6.53	9.45	136.31
Copper sulphate	74.37	-6.32	9.39	11.32	123.93
Ferrous sulphate	60.34	-4.60	8.48	9.64	118.47
Copper chloride	79.28	-3.45	8.90	9.54	111.17
Ferric chloride	38.49	-2.21	8.15	8.44	105.19
Copper acetate	74.15	-6.64	10.92	12.78	121.32
Acetic acid	72.10	-6.30	7.48	9.78	130.08
Tartaric acid	74.44	-2.08	4.12	4.62	116.73

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.1.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	70.39	-7.70	6.97	10.39	136.87
Potash alum	79.46	-7.15	10.40	12.62	124.51
Potassium dichromate	71.76	-2.72	23.59	23.74	96.57
Aluminium sulphate	76.82	-5.84	6.51	8.75	131.87
Copper sulphate	78.41	-7.68	12.13	14.36	122.33
Ferrous sulphate	62.73	-5.46	9.63	11.07	119.53
Copper chloride	79.35	-7.95	12.46	14.78	122.53
Ferric chloride	55.61	-1.81	8.50	8.69	102.01
Copper acetate	78.31	-6.19	9.55	11.38	122.94
Acetic acid	78.49	-6.09	7.31	9.51	129.78
Tartaric acid	76.71	-3.42	5.30	6.31	122.84

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Colour fastness results of rubbing (dry & wet) were evaluated with pre-mordanting method. The colour staining and change in colour results are presented in Table 4.1.4. The quality of the dyed leather specimens were evaluated by rubbing (dry & wet) colour fastness test. The colour staining and change in colour with pre-mordanting method has been presented in Table 4.1.4. Results of colour fastness to rubbing (dry & wet) with post-mordanting method were also evaluated and tabulated in Table 4.1.5.

Table 4.1.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/Without mordant	**Pre-Mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	4-5	4	4	3-4
Potash alum	5	5	4-5	4
Potassium dichromate	5	5	5	5
Aluminium sulphate	5	5	5	5
Copper sulphate	4-5	4-5	4-5	4-5
Ferrous sulphate	4-5	4-5	4-5	4-5
Copper chloride	4-5	4-5	4-5	4-5
Ferric chloride	5	5	5	5
Copper acetate	4-5	4-5	4-5	4-5
Acetic acid	4-5	4-5	4-5	4
Tartaric acid	4-5	4	4-5	4

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.1.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/Without mordant	**Post-Mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	4-5	4	4	3-4
Potash alum	5	4-5	4-5	4
Potassium dichromate	5	5	5	5
Aluminium sulphate	5	4-5	4-5	4
Copper sulphate	4-5	4	4-5	4-5
Ferrous sulphate	4-5	4	4	3-4
Copper chloride	4-5	4-5	4	4
Ferric chloride	4-5	4-5	4	4
Copper acetate	4-5	4-5	4-5	4
Acetic acid	5	4-5	5	5
Tartaric acid	5	4-5	5	4

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness values to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been evaluated in Table 4.1.6 and 4.1.7 respectively.

Table 4.1.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4	4-5	4-5	4-5	1
Potash alum	5	5	5	5	5	5	4
Potassium dichromate	5	5	5	5	5	4-5	5
Aluminium sulphate	5	5	5	5	5	4-5	3
Copper sulphate	5	4-5	5	5	5	4-5	4-5
Ferrous sulphate	5	5	5	5	5	5	4
Copper chloride	5	5	5	5	5	5	4-5
Ferric chloride	5	5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	4
Acetic acid	5	5	5	5	5	5	4
Tartaric acid	5	4-5	4	4-5	4-5	4-5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.1.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/Without mordant	**Post-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4	4-5	4-5	4-5	1
Potash alum	5	5	5	5	5	5	4
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	4-5	3-4
Copper sulphate	5	4	4-5	4-5	4-5	4	4
Ferrous sulphate	5	5	5	5	5	4-5	4-5
Copper chloride	5	5	5	5	5	4-5	4
Ferric chloride	5	5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	4
Acetic acid	5	5	5	5	5	4-5	4
Tartaric acid	5	5	5	5	5	4-5	3

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are illustrated in Table 4.1.8 and 4.1.9.

Table 4.1.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	4
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	2
Copper chloride	3
Ferric chloride	6
Copper acetate	2
Acetic acid	4
Tartaric acid	4

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.1.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	2
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	3
Ferric chloride	3
Copper acetate	3
Acetic acid	5
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

In order to know about the economic and commercial importance of dye a comprehensive survey was carried out in the present study to and the results have been presented in Table 4.1.10.

Table 4.1.10. Feasibility Study of *B. perennis* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste petals)	0.10
2	Utilities	0.58
3	Labour	0.41
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.71 USD

4.2 *Bombax ceiba*

B. ceiba waste petals were used to dye leather. Different shades were developed with *B. ceiba* dye with and without a mordant (Table 4.2.1). Furthermore, colour coordinates of dyed leather specimens were also evaluated with pre-mordanting and post-mordanting methods as given in Table 4.2.1 and 4.2.3 respectively.

Table 4.2.1: Shades Obtained on Dyed Leather Specimens with and without Mordant

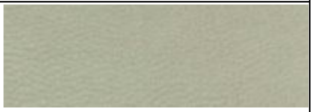
Without mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.2.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	76.56	0.90	5.80	5.87	81.15
Potash alum	66.16	5.93	20.49	21.33	73.86
Potassium dichromate	59.66	10.96	30.66	32.56	70.33
Aluminium sulphate	71.25	2.46	16.03	16.21	81.29
Copper sulphate	69.84	1.02	13.99	14.02	85.83
Ferrous sulphate	56.47	2.50	17.81	17.98	81.99
Copper chloride	73.76	1.88	9.13	9.32	78.36
Ferric chloride	57.94	2.38	18.73	18.89	82.75
Copper acetate	71.60	2.28	14.83	15.00	81.26
Acetic acid	63.35	4.32	22.19	22.60	78.98
Tartaric acid	74.14	4.42	8.76	9.81	63.21

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.2.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	76.56	0.90	5.80	5.87	81.15
Potash alum	76.90	0.06	10.20	10.20	89.67
Potassium dichromate	64.60	5.71	32.67	33.16	80.08
Aluminium sulphate	77.28	3.55	9.66	10.30	69.82
Copper sulphate	74.55	1.15	13.45	13.50	85.13
Ferrous sulphate	62.19	-0.76	10.85	10.88	93.98
Copper chloride	74.71	2.77	15.58	15.83	79.91
Ferric chloride	52.51	2.23	14.33	14.50	81.15
Copper acetate	76.05	-1.63	9.14	9.28	100.14
Acetic acid	75.38	2.40	9.80	10.09	76.26
Tartaric acid	76.44	4.71	12.60	13.45	69.50

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Results of colour fastness to rubbing (dry & wet) with pre-mordanting and post-mordanting methods were determined in order to check the quality of dyed leather specimens and have been tabulated in Table 4.2.4 and 4.2.5.

Table 4.2.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4	3-4
Potash alum	5	5	5	5
Potassium dichromate	5	4-5	4-5	5
Aluminium sulphate	5	4-5	4-5	4-5
Copper sulphate	5	5	4-5	4
Ferrous sulphate	5	4-5	4-5	4-5
Copper chloride	5	4-5	4-5	4-5
Ferric chloride	5	4	4-5	4
Copper acetate	5	4-5	4-5	4-5
Acetic acid	5	4-5	4-5	4
Tartaric acid	5	4-5	4-5	4

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.2.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4	3-4
Potash alum	5	4-5	4-5	4
Potassium dichromate	5	4-5	4-5	4
Aluminium sulphate	5	4-5	4	3-4
Copper sulphate	5	4	4	3-4
Ferrous sulphate	5	3-4	4	3-4
Copper chloride	5	4	4	3-4
Ferric chloride	5	4	4-5	4
Copper acetate	5	4-5	4-5	4
Acetic acid	5	4-5	4-5	4
Tartaric acid	5	4-5	4	3-4

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been presented in Table 4.2.6 and 4.2.7.

Table 4.2.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	5	3
Potash alum	5	5	5	5	5	5	5
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	4-5
Copper sulphate	5	5	5	5	5	4-5	4-5
Ferrous sulphate	5	5	5	5	5	4-5	4
Copper chloride	5	5	5	5	5	4-5	5
Ferric chloride	5	5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	4
Acetic acid	5	5	5	5	5	4-5	4-5
Tartaric acid	5	4-5	5	5	5	4-5	4

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.2.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/Without mordant	Pre-mordanting						Change in Colour
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	5	3
Potash alum	5	5	5	5	5	5	4-5
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	4
Copper sulphate	5	5	5	5	5	4-5	4-5
Ferrous sulphate	5	4-5	5	5	5	4-5	3-4
Copper chloride	5	5	5	5	5	4-5	5
Ferric chloride	5	4	5	5	5	4-5	4
Copper acetate	5	5	5	5	5	4-5	4
Acetic acid	5	5	5	5	5	4-5	4-5
Tartaric acid	5	4-5	5	5	5	4-5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Colour fastness results to daylight of dyed leather specimens with pre-mordanting and post-mordanting methods have been tabulated in Table 4.3.8 and 4.3.9.

Table 4.2.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting method

Mordants/ Without mordant	Change in Colour
Without mordant	2
Potash alum	2
Potassium dichromate	2
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	2
Ferric chloride	3
Copper acetate	7
Acetic acid	4
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.2.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	3
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	2
Ferric chloride	6
Copper acetate	3
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

A comprehensive survey was carried out to estimate the dye cost. The results of present study have been tabulated in Table 4.2.10.

Table 4.2.10. Feasibility Study of *B. ceiba* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste flower petals)	0.10
2	Utilities	0.58
3	Labour	0.39
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.69 USD

4.3 *Bougainvillea glabra*

B. glabra bracts were used to dye leather with various mordants. Twenty different shades were elucidated with *B. glabra* dye using ten selected mordants whereas un-mordanted dyed leather specimen also exhibited elegant shade (Table 4.3.1). Colour coordinates of dyed leather specimens were also evaluated with pre-mordanting and post-mordanting methods as given in Table 4.3.2 and 4.3.3 respectively.

Table 4.3.1 Shades Obtained on Dyed Leather Specimens with and without Mordant

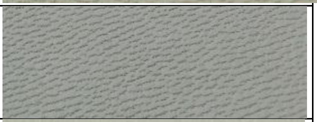
Without mordant		
Mordants	**Pre-mordanting**	**Post- mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.3.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	77.18	0.38	10.82	10.82	87.98
Potash alum	75.91	-0.26	16.27	16.27	90.93
Potassium dichromate	68.69	0.78	17.08	17.10	87.38
Aluminium sulphate	78.13	-1.03	13.28	13.332	94.42
Copper sulphate	77.47	-2.23	13.77	13.95	99.20
Ferrous sulphate	67.13	-0.57	12.65	12.67	92.57
Copper chloride	74.24	-0.95	12.98	13.01	94.18
Ferric chloride	42.62	1.58	13.34	13.43	83.26
Copper acetate	76.01	-2.15	11.19	11.40	100.87
Acetic acid	72.81	0.96	12.49	12.52	85.62
Tartaric acid	77.27	-0.29	8.85	8.85	91.86

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.3.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	77.18	0.38	10.82	10.82	87.98
Potash alum	74.57	-1.13	14.35	14.40	94.50
Potassium dichromate	63.90	3.16	27.95	28.13	83.56
Aluminium sulphate	79.00	-0.34	10.30	10.31	91.90
Copper sulphate	76.51	-2.88	13.50	13.81	102.06
Ferrous sulphate	66.51	2.00	12.98	13.13	81.25
Copper chloride	75.15	-2.20	13.37	13.55	99.32
Ferric chloride	63.02	3.68	10.92	11.53	71.39
Copper acetate	78.50	-2.81	12.89	13.19	102.32
Acetic acid	76.91	3.08	10.86	11.29	74.17
Tartaric acid	73.48	4.01	8.96	9.82	65.91

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

The quality of the dyed leather specimens was evaluated by rubbing (dry & wet) fastness test. The colour staining and change in colour with pre-mordanting method presented in Table 4.3.4. Results of colour fastness to rubbing (dry & wet) with post-mordanting method were also assessed and have been tabulated in Table 4.3.5.

Table 4.3.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4-5	4
Potash alum	4-5	5	4-5	5
Potassium dichromate	4-5	5	4-5	5
Aluminium sulphate	5	5	4-5	4-5
Copper sulphate	5	4-5	4-5	4-5
Ferrous sulphate	4-5	4-5	4-5	4
Copper chloride	4-5	4-5	4-5	5
Ferric chloride	4	4-5	4-5	4-5
Copper acetate	4-5	5	4-5	5
Acetic acid	4-5	5	4-5	5
Tartaric acid	4-5	5	4-5	4

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.3.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4-5	4
Potash alum	5	5	5	5
Potassium dichromate	5	5	5	5
Aluminium sulphate	5	5	5	5
Copper sulphate	5	4-5	5	5
Ferrous sulphate	4-5	4-5	5	5
Copper chloride	4-5	4-5	5	5
Ferric chloride	4-5	4-5	5	5
Copper acetate	5	5	5	5
Acetic acid	5	5	5	5
Tartaric acid	5	5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness values to mild washing of dyed leather specimens with pre-mordanting and with post-mordanting methods have been described in Table 4.3.6 and 4.3.7 respectively.

Table 4.3.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	3-4
Potash alum	5	5	5	5	5	4-5	4-5
Potassium dichromate	5	5	5	5	5	4-5	4-5
Aluminium sulphate	5	5	5	5	5	4-5	4-5
Copper sulphate	5	5	5	5	5	4-5	4-5
Ferrous sulphate	4-5	5	5	5	5	4-5	5
Copper chloride	5	5	5	5	5	5	5
Ferric chloride	5	5	5	5	5	4-5	5
Copper acetate	5	5	5	5	5	4-5	5
Acetic acid	5	5	5	5	5	4-5	5
Tartaric acid	5	5	5	5	5	4-5	4

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.3.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	3-4
Potash alum	5	5	5	5	5	5	5
Potassium dichromate	5	5	4-5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	5
Copper sulphate	5	5	5	5	5	5	5
Ferrous sulphate	4-5	5	4-5	5	5	4-5	4-5
Copper chloride	5	4-5	5	5	5	4-5	4-5
Ferric chloride	5	4-5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	4-5
Acetic acid	5	5	5	5	5	4-5	4
Tartaric acid	5	5	5	5	5	4-5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are illustrated in Table 4.3.8 and 4.3.9.

Table 4.3.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	3
Aluminium sulphate	3
Copper sulphate	6
Ferrous sulphate	4
Copper chloride	4
Ferric chloride	7
Copper acetate	4
Acetic acid	4
Tartaric acid	4

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.3.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	4
Potassium dichromate	2
Aluminium sulphate	4
Copper sulphate	4
Ferrous sulphate	3
Copper chloride	4
Ferric chloride	3
Copper acetate	3
Acetic acid	4
Tartaric acid	4

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

In order to know about the economic and commercial importance of *B. glabra* dye a comprehensive survey was carried out to estimate the dye cost. A result of produced liquid dye cost has been presented in Table 4.3.10.

Table 4.3.10. Feasibility Study of *B. glabra* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste petals)	0.10
2	Utilities	0.58
3	Labour	0.35
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.65 USD

4.4 *Celosia cristata*

C. cristata waste petals were used to dye leather. Twenty-one different shades were produced with and without mordant (Table 4.4.1). The colour coordinates data of dyed leather specimens with pre-mordanting and post-mordanting methods have been illustrated in Table 4.4.2 and 4.4.3 respectively.

Table 4.4.1: Shades Obtained on Dyed Leather Specimens with and without Mordant

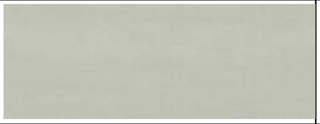
Without mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.4.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/Without mordant	L*	a*	b*	C*	h
Without mordant	65.62	5.00	2.09	5.42	22.71
Potash alum	67.82	1.93	6.00	6.31	72.14
Potassium dichromate	71.46	-0.56	14.08	14.09	92.26
Aluminium sulphate	68.74	1.50	6.02	6.02	76.03
Copper sulphate	70.27	-5.72	20.18	20.98	105.83
Ferrous sulphate	66.93	-0.52	9.75	9.76	93.07
Copper chloride	68.77	1.30	9.74	6.29	71.16
Ferric chloride	64.83	1.06	13.84	13.88	85.61
Copper acetate	61.53	-0.08	6.77	6.77	90.64
Acetic acid	65.58	1.20	9.87	9.94	83.09
Tartaric acid	69.14	-0.22	9.46	9.46	91.32

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.4.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	65.62	5.00	2.09	5.42	22.71
Potash alum	69.51	-0.18	14.18	14.18	90.71
Potassium dichromate	66.20	1.19	22.91	22.94	87.04
Aluminium sulphate	76.71	0.29	9.24	9.25	88.18
Copper sulphate	59.69	-1.93	12.85	12.99	98.56
Ferrous sulphate	51.96	1.32	11.95	12.02	83.70
Copper chloride	71.31	-0.57	14.70	14.71	92.21
Ferric chloride	57.37	2.35	10.43	10.70	77.32
Copper acetate	55.92	-0.84	11.61	11.64	94.13
Acetic acid	53.37	-0.21	9.12	9.12	91.33
Tartaric acid	67.34	1.20	14.29	14.35	85.19

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Colour fastness of dyed leather specimens were evaluated in terms of dry and wet rubbing to check the quality of the dye using pre-mordanting and post-mordanting methods (Table 4.4.4 and Table 4.4.5).

Table 4.4.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4-5	4-5
Potash alum	5	5	5	5
Potassium dichromate	5	5	5	5
Aluminium sulphate	5	5	5	5
Copper sulphate	5	5	5	5
Ferrous sulphate	5	4-5	5	4-5
Copper chloride	5	4-5	4-5	4-5
Ferric chloride	5	4-5	4-5	4-5
Copper acetate	5	4-5	4-5	4
Acetic acid	5	4-5	4-5	4-5
Tartaric acid	5	4-5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.4.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	4-5	4-5
Potash alum	5	4-5	5	4-5
Potassium dichromate	5	4-5	5	5
Aluminium sulphate	4-5	5	5	5
Copper sulphate	4-5	4-5	5	5
Ferrous sulphate	4-5	4-5	5	4-5
Copper chloride	5	4-5	5	4-5
Ferric chloride	4-5	4-5	5	5
Copper acetate	4-5	4-5	4-5	4-5
Acetic acid	5	4-5	4-5	4-5
Tartaric acid	5	5	5	5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness results to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been presented in Table 4.4.6 and 4.4.7 respectively.

Table 4.4.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4-5	5	5	4-5	3-4
Potash alum	5	5	5	5	5	5	4
Potassium dichromate	5	5	5	5	5	5	4-5
Aluminium sulphate	5	5	4	5	5	5	4-5
Copper sulphate	5	5	5	5	5	5	4
Ferrous sulphate	5	5	5	5	5	5	4-5
Copper chloride	5	5	5	5	5	5	4-5
Ferric chloride	5	5	5	5	5	5	4-5
Copper acetate	5	5	5	5	5	5	4-5
Acetic acid	5	5	5	5	5	5	4-5
Tartaric acid	5	5	5	5	5	5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.4.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4-5	5	5	4-5	3-4
Potash alum	5	5	5	5	5	5	5
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	5
Copper sulphate	5	5	5	5	5	4	4
Ferrous sulphate	5	5	5	5	5	4-5	4-5
Copper chloride	5	5	5	5	5	4-5	4-5
Ferric chloride	5	5	5	5	5	5	4-5
Copper acetate	5	5	5	5	5	4-5	4-5
Acetic acid	5	5	5	5	5	5	5
Tartaric acid	5	4	5	5	5	4-5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Colour fastness results to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are documented in Table 4.4.8 and 4.4.9.

Table 4.4.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	2
Aluminium sulphate	4
Copper sulphate	3
Ferrous sulphate	5
Copper chloride	2
Ferric chloride	6
Copper acetate	6
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.4.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	3
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	2
Ferric chloride	3
Copper acetate	2
Acetic acid	2
Tartaric acid	2

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

A survey was carried out in order to analyze the economic and commercial importance of *C. cristata* dye. A result of produced liquid dye cost has been presented in Table 4.4.10.

Table 4.4.10. Feasibility Study of *C. cristata* Liquid Dye

Sr. No.	Description	Dollars
1	Raw Material (1 Kilogram waste petals)	0.10
2	Utilities	0.58
3	Labour	0.39
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.69 USD

4.5 *Lantana camara*

Twenty one different shades were exhibited using *L. camara* dye with and without a mordant (Table 4.5.1). Moreover, colour coordinates values of dyed leather specimens were also determined with and without a mordant (Table 4.5.2 and 4.5.3).

Table 4.5.1: Shades Obtained on Dyed Leather Specimens with and without Mordant

Without mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.5.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	67.14	-4.12	15.27	15.82	105.09
Potash alum	65.94	-4.15	5.58	6.85	126.61
Potassium dichromate	60.92	3.65	24.84	25.11	81.63
Aluminium sulphate	65.08	-3.58	13.94	14.39	104.39
Copper sulphate	71.04	-3.71	12.91	13.43	106.03
Ferrous sulphate	57.81	-1.86	13.01	13.14	98.13
Copper chloride	71.59	-4.06	17.73	18.19	102.91
Ferric chloride	55.23	-0.55	13.96	13.98	92.26
Copper acetate	71.36	-4.09	16.68	17.18	103.78
Acetic acid	69.99	-4.98	15.28	16.07	108.04
Tartaric acid	66.03	-3.03	10.62	11.05	105.90

L* - the lightness coordinate (0= white, 100= black)
a* - the red/green coordinate, (+a*= red, and -a* = green)
b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)
C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).
h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.5.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	67.14	-4.12	15.27	15.82	105.09
Potash alum	82.68	-15.76	19.20	24.84	129.37
Potassium dichromate	71.54	-12.52	28.00	30.67	114.09
Aluminium sulphate	76.97	-14.78	22.92	27.27	122.81
Copper sulphate	79.43	-14.61	21.48	25.98	124.22
Ferrous sulphate	64.47	-11.39	15.29	19.07	126.69
Copper chloride	70.57	-1.86	11.12	11.27	99.49
Ferric chloride	61.39	-3.81	10.46	11.14	109.99
Copper acetate	82.35	-16.41	17.44	23.95	133.25
Acetic acid	69.91	-1.82	11.26	11.41	99.17
Tartaric acid	68.89	-1.81	11.24	11.39	99.14

L* - the lightness coordinate

a* - the red/green coordinate, with +a* indicating red, and -a* indicating green.

b* - the yellow/blue coordinate, with +b* indicating yellow, and -b* indicating blue.

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Results of colour fastness of rubbing (dry and wet) with pre-mordanting and post-mordanting methods were tabulated in Table 4.5.4 and Table 4.5.5 which showed the quality of dyed leather specimens.

Table 4.5.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without Mordant	5	4-5	4	4
Potash alum	5	4-5	4-5	4-5
Potassium dichromate	5	4-5	5	5
Aluminium sulphate	5	4-5	4-5	4-5
Copper sulphate	5	4	4-5	4-5
Ferrous sulphate	5	4-5	4-5	4-5
Copper chloride	5	4-5	4-5	4-5
Ferric chloride	5	4-5	4-5	4-5
Copper acetate	5	4-5	5	5
Acetic acid	4-5	4	4-5	4-5
Tartaric acid	5	4-5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.5.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without Mordant	5	4-5	4	4
Potash alum	5	4-5	4-5	4-5
Potassium dichromate	5	4-5	5	5
Aluminium sulphate	4-5	4-5	4-5	4-5
Copper sulphate	4-5	4	4-5	4-5
Ferrous sulphate	4-5	4-5	4-5	4-5
Copper chloride	4-5	4	4-5	4
Ferric chloride	4-5	4	4-5	4-5
Copper acetate	5	4-5	5	5
Acetic acid	4-5	4	4-5	4-5
Tartaric acid	5	4-5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness data to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods with *L. camara* dye have been recorded in Table 4.5.6 and 4.5.7 respectively.

Table 4.5.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	5	4
Potash alum	5	5	5	5	5	5	5
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	4-5
Copper sulphate	5	5	5	5	5	4-5	4-5
Ferrous sulphate	5	5	5	5	5	4-5	4
Copper chloride	5	5	5	5	5	4-5	5
Ferric chloride	5	5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	4
Acetic acid	5	5	5	5	5	4-5	4-5
Tartaric acid	5	4-5	5	5	5	4-5	4

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.5.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without Mordant	5	5	5	5	5	5	4
Potash alum	5	5	5	5	5	4-5	5
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	5	5	5	5	5
Copper sulphate	5	4	5	5	5	3	4-5
Ferrous sulphate	5	5	5	5	5	4-5	4
Copper chloride	5	4-5	5	5	5	4	4-5
Ferric chloride	5	4	5	5	5	3-4	5
Copper acetate	5	4-5	5	5	5	4-5	5
Acetic acid	5	4	5	5	5	5	5
Tartaric acid	5	5	5	5	5	5	5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are given in Table 4.5.8 and 4.5.9.

Table 4.5.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	Change in Colour
Without mordant	2
Potash alum	2
Potassium dichromate	3
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	3
Ferric chloride	3
Copper acetate	3
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.5.9: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	3
Aluminium sulphate	4
Copper sulphate	2
Ferrous sulphate	3
Copper chloride	3
Ferric chloride	3
Copper acetate	2
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

In order to evaluate the economic and commercial importance of *L. camara* dye, a survey was carried out to estimate dye yield cost. Result of present study has been shown in Table 4.5.10.

Table 4.5.10. Feasibility Study of *L. camara* Liquid Dye

Sr. No.	Description	Dollars
1	Raw Material (1 Kilogram florets)	0.10
2	Utilities	0.58
3	Labour	0.48
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.78 USD

4.6 *Papaver rhoeas*

Papaver rhoeas waste petals were used to dye leather. Various beautiful shades were obtained with selected mordants whereas un-mordanted dyed leather specimen also rendered elegant shade. Results of colour coordinates of dyed leather specimens with the selected dye have also been evaluated and tabulated in Table 4.6.2 and Table 4.6.3.

Table 4.6.1. Shades Obtained on Dyed Leather Specimens with and without Mordants

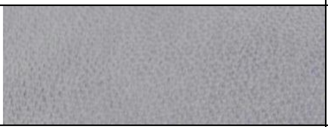
Without mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.6.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	66.30	0.28	-4.24	4.25	273.77
Potash alum	64.34	8.02	-7.40	10.91	317.33
Potassium dichromate	74.76	-3.21	19.15	19.42	99.51
Aluminium sulphate	54.54	1.97	-12.25	12.41	279.13
Copper sulphate	63.60	5.53	-3.00	6.30	331.50
Ferrous sulphate	57.13	1.88	-2.17	2.87	310.89
Copper chloride	63.62	-1.15	0.96	1.49	140.18
Ferric chloride	65.43	5.35	11.27	12.47	64.63
Copper acetate	63.87	-1.31	-1.88	2.29	235.19
Acetic acid	57.72	-2.35	-12.28	12.51	259.15
Tartaric acid	58.84	3.68	-8.60	9.36	293.17

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.6.3 Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	66.30	0.28	-4.24	4.25	273.77
Potash alum	60.46	2.43	-7.87	8.24	287.13
Potassium dichromate	67.76	-1.83	18.42	18.51	95.68
Aluminium sulphate	64.51	6.93	-3.17	7.62	335.41
Copper sulphate	64.16	0.16	-3.58	3.58	272.48
Ferrous sulphate	57.91	1.12	-11.34	11.39	275.64
Copper chloride	68.82	-4.30	-0.25	4.31	183.31
Ferric chloride	60.35	4.36	12.21	12.97	70.33
Copper acetate	68.36	-5.26	2.42	5.79	155.33
Acetic acid	65.11	-1.16	-5.84	5.96	258.76
Tartaric acid	60.92	11.60	-0.15	11.61	359.26

L* - the lightness coordinate (0= white, 100= black)
a* - the red/green coordinate, (+a*= red, and -a* = green)
b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)
C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).
h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Colour fastness of dyed leather specimens was determined with dry and wet rubbing tests. Results of colour staining and change in colour with pre-mordanting and post-mordanting methods have been presented in Table 4.6.4 and 4.6.5.

Table 4.6.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	3-4	1
Potash alum	5	4	4	1
Potassium dichromate	5	3-4	4	4
Aluminium sulphate	5	4	3-4	1
Copper sulphate	5	4	3-4	1
Ferrous sulphate	5	4	4	3-4
Copper chloride	5	4-5	4	3-4
Ferric chloride	5	4	4	4
Copper acetate	5	4	4	3-4
Acetic acid	5	3-4	3-4	3
Tartaric acid	5	4	3	1

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.6.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	4-5	3-4	1
Potash alum	5	4-5	4	1
Potassium dichromate	5	4-5	4-5	4
Aluminium sulphate	5	4-5	4	1
Copper sulphate	5	4-5	4	3-4
Ferrous sulphate	5	4-5	4	3
Copper chloride	5	4	4	3
Ferric chloride	4-5	4-5	4	3-4
Copper acetate	5	4-5	4	4
Acetic acid	5	4-5	4	3
Tartaric acid	5	5	4	3

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been shown in Table 4.6.6 and 4.6.7 respectively.

Table 4.6.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4-5	4-5	5	4-5	1
Potash alum	5	5	5	5	5	4-5	1
Potassium dichromate	5	5	5	5	5	4-5	4-5
Aluminium sulphate	5	5	5	5	5	4-5	3
Copper sulphate	5	5	5	5	5	4-5	1
Ferrous sulphate	5	5	5	5	5	4-5	1
Copper chloride	5	5	5	5	5	5	3
Ferric chloride	5	5	5	5	5	4-5	4-5
Copper acetate	5	5	5	5	5	4-5	3-4
Acetic acid	5	5	5	5	5	4-5	3
Tartaric acid	5	5	5	5	5	4-5	1

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.6.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	4-5	4-5	5	4-5	1
Potash alum	5	5	4	5	5	4-5	1
Potassium dichromate	5	5	5	5	5	5	5
Aluminium sulphate	5	5	4-5	5	5	4-5	1
Copper sulphate	5	5	5	5	5	4	2
Ferrous sulphate	5	5	5	5	5	4-5	3
Copper chloride	5	5	5	5	5	3-4	3-4
Ferric chloride	5	5	5	5	5	5	4-5
Copper acetate	5	5	5	5	5	4-5	4-5
Acetic acid	5	5	5	4	5	4-5	2-3
Tartaric acid	5	4-5	5	5	5	4-5	1

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are illustrated in Table 4.6.8 and 4.6.9.

Table 4.6.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	3
Aluminium sulphate	2
Copper sulphate	2
Ferrous sulphate	2
Copper chloride	2
Ferric chloride	6
Copper acetate	2
Acetic acid	2
Tartaric acid	2

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.6.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	2
Aluminium sulphate	2
Copper sulphate	2
Ferrous sulphate	2
Copper chloride	3
Ferric chloride	3
Copper acetate	3
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

In order to assess the commercial importance of produced dye cost, a survey was carried out and the result of *P. rhoeas* produced dye has been presented in Table 4.6.10.

Table 4.6.10: Feasibility study of *P. rhoeas* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste petals)	0.10
2	Utilities	0.58
3	Labour	0.48
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.78 USD

4.7. *Rosa damascena*

Rosa damascena waste petals were used to dye leather with and without mordant. Experimental study revealed that twenty-one different shades were obtained with the *R. damascena* dye (Table 4.7.1). Moreover, the colour coordinates of dyed leather specimens were also determined with and without mordant as described in Table 4.7.2 and 4.7.3 respectively.

Table 4.7.1: Shades Obtained on Dyed Leather Specimens with and without Mordants

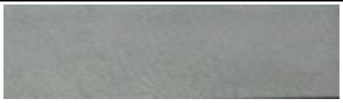
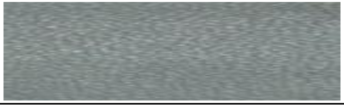
Without Mordant		
Mordants	**Pre-mordanting**	**Post mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.7.2: Colour Coordinates of Dyed Leather Specimens with Pre-Mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	49.05	-0.85	2.45	2.59	109.18
Potash alum	65.94	-4.15	5.58	6.95	126.61
Potassium dichromate	65.51	1.30	24.77	24.81	87.01
Aluminium sulphate	65.08	-3.58	13.94	14.39	104.39
Copper sulphate	62.66	-2.85	13.39	13.69	102.03
Ferrous sulphate	47.55	-1.36	7.50	7.62	100.31
Copper chloride	58.56	-1.43	5.72	5.90	104.01
Ferric chloride	41.73	-1.14	-2.21	2.54	243.26
Copper acetate	67.55	-2.53	8.91	9.26	105.83
Acetic acid	65.73	-2.39	8.87	9.91	105.11
Tartaric acid	55.41	2.31	5.72	6.17	68.05

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.7.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	49.05	-0.85	2.45	2.59	109.18
Potash alum	66.33	-6.70	12.99	14.62	117.28
Potassium dichromate	60.82	3.53	24.55	24.90	81.86
Aluminium sulphate	66.39	-5.72	13.43	14.60	113.06
Copper sulphate	58.87	-2.96	13.41	13.74	102.44
Ferrous sulphate	37.38	-1.52	-2.25	2.72	235.95
Copper chloride	63.07	-1.65	16.93	17.01	95.57
Ferric chloride	42.34	-0.62	0.57	0.84	137.37
Copper acetate	64.00	-2.10	19.96	20.07	96.01
Acetic acid	71.30	-3.39	12.03	12.50	105.76
Tartaric acid	65.73	-2.68	9.82	10.18	105.29

L* - the lightness coordinate (0= white, 100= black)
a* - the red/green coordinate, (+a*= red, and -a* = green)
b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)
C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).
h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

The colour fastness quality of dyed leather specimens were evaluated using dry and wet rubbing. The colour staining and change in colour results with pre-mordanting and post-mordanting methods have been presented in Table 4.7.4 and Table 4.7.5.

Table 4.7.4: Colour Fastness to Rubbing of Dyed Leather Specimens

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	4	4	4-5	4-5
Potash alum	4-5	4-5	5	4-5
Potassium dichromate	4-5	4	4-5	4-5
Aluminium sulphate	4	4-5	4-5	4-5
Copper sulphate	4-5	4-5	4-5	4-5
Ferrous sulphate	4	3-4	4	4
Copper chloride	4-5	4	4-5	4
Ferric chloride	4	3-4	4	4
Copper acetate	4-5	4	4	4
Acetic acid	4-5	4	4-5	4-5
Tartaric acid	4-5	4-5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.7.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	4	4	4-5	4-5
Potash alum	4	3-4	5	4-5
Potassium dichromate	4	4	4-5	4-5
Aluminium sulphate	4-5	4	4-5	4-5
Copper sulphate	4-5	4	4-5	4-5
Ferrous sulphate	3-4	3-4	4	4
Copper chloride	4-5	4	4-5	4-5
Ferric chloride	4	4	4-5	4-5
Copper acetate	4	4-5	4-5	4-5
Acetic acid	4	3-4	4-5	4
Tartaric acid	4-5	4-5	4-5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness values to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been evaluated and presented in Table 4.7.6 and 4.7.7 respectively.

Table 4.7.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	4-5
Potash alum	5	5	4-5	5	5	5	4
Potassium dichromate	5	5	4-5	5	5	4-5	4
Aluminium sulphate	5	4-5	4-5	4-5	5	4-5	4
Copper sulphate	5	4	4-5	5	5	4-5	4-5
Ferrous sulphate	5	4-5	4-5	5	5	5	4
Copper chloride	5	4-5	5	5	5	5	4
Ferric chloride	5	5	4-5	5	5	5	4
Copper acetate	5	4-5	4-5	5	5	5	4
Acetic acid	5	5	4-5	5	5	5	4-5
Tartaric acid	4-5	4	4-5	5	5	5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.7.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting (Staining)**						**Change in Colour**
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	4-5
Potash alum	5	5	4-5	5	5	5	4-5
Potassium dichromate	5	5	4-5	5	5	4-5	4
Aluminium sulphate	5	4-5	4-5	4-5	5	4-5	4
Copper sulphate	5	4	4-5	5	5	4-5	4
Ferrous sulphate	5	4-5	4-5	5	5	5	4
Copper chloride	5	4-5	5	5	5	5	4
Ferric chloride	5	5	4-5	5	5	5	4
Copper acetate	5	4-5	4-5	5	5	5	4-5
Acetic acid	5	5	4-5	5	5	5	4-5
Tartaric acid	4-5	4	4-5	5	5	5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are illustrated in Table 4.7.8 and 4.7.9.

Table 4.7.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	2
Potassium dichromate	2
Aluminium sulphate	3
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	4
Ferric chloride	3
Copper acetate	3
Acetic acid	3
Tartaric acid	3

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.7.9: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	3
Aluminium sulphate	6
Copper sulphate	4
Ferrous sulphate	4
Copper chloride	6
Ferric chloride	4
Copper acetate	4
Acetic acid	4
Tartaric Acid	4

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

A comprehensive survey was carried out to evaluate the economic and commercial importance of *R. damascena* dye and the produced liquid dye cost has been presented in Table 4.7.10.

Table 4.7.10. Feasibility Study of *R. damascena* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste petals)	0.19
2	Utilities	0.58
3	Labour	0.48
4	Transportation	0.38
5	Packing	0.13
6	Overheads (Miscellaneous)	0.10
Total Cost		1.86 USD

T. erecta waste petals were used to dye leather with various mordants. Results presented in Table 4.8.1 indicated that different shades obtained after dyeing leather with *T. erecta* dye. Colour coordinates of dyed leather specimens were evaluated with pre-mordanting and post-mordanting methods are given in Table 4.8.2 and 4.8.3 respectively.

Table 4.8.1: Shades Obtained on Dyed Leather Specimens with and without Mordant

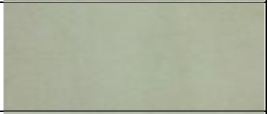
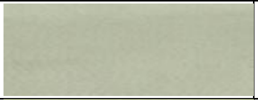
Without mordant		
Mordants	**Pre-mordanting**	**Post-mordanting**
Potash alum		
Potassium dichromate		
Aluminium sulphate		
Copper sulphate		
Ferrous sulphate		
Copper chloride		
Ferric chloride		
Copper acetate		
Acetic acid		
Tartaric acid		

Table 4.8.2: Colour Coordinates of Dyed Leather Specimens with Pre-mordanting Method

Mordants/Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	74.06	-3.34	18.10	18.40	100.45
Potash alum	78.06	-5.22	23.88	24.45	102.33
Potassium dichromate	75.50	-1.23	16.38	16.43	94.29
Aluminium sulphate	78.59	-5.60	23.97	4.62	103.15
Copper sulphate	75.42	-3.83	16.06	16.51	103.40
Ferrous sulphate	58.67	-1.34	10.52	10.61	97.28
Copper chloride	58.66	0.80	10.46	10.14	105.35
Ferric chloride	79.00	-2.68	9.78	10.49	85.60
Copper acetate	76.89	-3.69	15.09	15.53	103.74
Acetic acid	75.11	-4.00	23.96	24.30	99.48
Tartaric acid	75.65	-2.82	13.63	13.92	101.68

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

Table 4.8.3: Colour Coordinates of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**L***	**a***	**b***	**C***	**h**
Without mordant	74.06	-3.34	18.10	18.40	100.45
Potash alum	81.66	-2.89	11.29	11.65	104.39
Potassium dichromate	75.31	-2.10	24.47	24.56	94.91
Aluminium sulphate	81.03	-3.20	12.65	13.05	104.19
Copper sulphate	80.71	-3.62	11.17	11.74	107.96
Ferrous sulphate	66.59	0.77	8.31	8.34	84.73
Copper chloride	74.24	-3.77	21.96	22.28	99.75
Ferric chloride	67.63	3.20	9.69	10.20	71.73
Copper acetate	75.75	-2.05	16.45	16.58	97.11
Acetic acid	75.87	-2.46	18.53	18.69	97.55
Tartaric acid	78.61	-2.22	6.88	7.23	107.89

L* - the lightness coordinate (0= white, 100= black)

a* - the red/green coordinate, (+a*= red, and -a* = green)

b* - the yellow/blue coordinate,(+b*= yellow, and -b* = blue)

C* - the chroma coordinate, the perpendicular distance from the lightness axis (more distance being more chroma).

h* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°.

The quality of the dyed leather specimens was evaluated by rub (dry & wet) fastness tests. The colour staining and change in colour with pre-mordanting method presented in Table 4.8.4. Results of colour fastness to rub (dry & wet) with post-mordanting method were also assessed and have been tabulated in Table 4.8.5.

Table 4.8.4 Colour Fastness to Rubbing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	5	4-5	4
Potash alum	5	5	5	5
Potassium dichromate	5	5	5	5
Aluminium sulphate	5	5	5	5
Copper sulphate	5	5	5	5
Ferrous sulphate	5	5	5	5
Copper chloride	5	5	5	5
Ferric chloride	5	4-5	5	4-5
Copper acetate	5	5	5	5
Acetic acid	5	4-5	5	4-5
Tartaric acid	5	4-5	5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.8.5: Colour Fastness to Rubbing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**			
	Staining		**Change in Colour**	
	(Dry)	(Wet)	(Dry)	(Wet)
Without mordant	5	5	4-5	4
Potash alum	5	5	5	5
Potassium dichromate	5	5	5	4-5
Aluminium sulphate	5	4	4-5	4
Copper sulphate	5	5	5	5
Ferrous sulphate	5	4-5	5	4-5
Copper chloride	5	5	5	5
Ferric chloride	5	5	5	5
Copper acetate	5	5	5	5
Acetic acid	5	5	5	5
Tartaric acid	5	5	5	4-5

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

The colour fastness values to mild washing of dyed leather specimens with pre-mordanting and post-mordanting methods have been evaluated in Table 4.8.6 and 4.8.7 respectively.

Table 4.8.6: Colour Fastness to Mild Washing with Pre-mordanting Method

Mordants/ Without mordant	**Pre-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	3-4
Potash alum	5	5	5	5	5	4-5	3-4
Potassium dichromate	4-5	4-5	5	5	5	5	5
Aluminium sulphate	4-5	5	5	5	5	5	4-5
Copper sulphate	4-5	4	5	5	5	5	4
Ferrous sulphate	4-5	5	5	5	5	5	4-5
Copper chloride	5	4-5	5	5	5	4	4
Ferric chloride	4-5	4-5	5	5	5	5	3
Copper acetate	5	5	5	5	5	4	4-5
Acetic acid	5	4	4	4-5	4-5	4-5	4
Tartaric acid	4-5	5	5	5	5	5	2

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Table 4.8.7: Colour Fastness to Mild Washing with Post-mordanting Method

Mordants/ Without mordant	**Post-mordanting**						**Change in Colour**
	Staining on Multifiber*						
	CA	**CO**	**PA**	**PES**	**PAN**	**WO**	
Without mordant	5	5	5	5	5	4-5	3-4
Potash alum	4-5	4-5	4-5	4	5	4-5	5
Potassium dichromate	4-5	4-5	4-5	4	5	5	5
Aluminium sulphate	3-4	5	4-5	4-5	5	3-4	4
Copper sulphate	4-5	4-5	4-5	4	5	4-5	5
Ferrous sulphate	4-5	4-5	4-5	4	5	4-5	3-4
Copper chloride	4	5	4-5	4-5	4-5	4-5	4-5
Ferric chloride	5	4-5	4	5	5	5	3-4
Copper acetate	4-5	4-5	4	5	5	5	5
Acetic acid	5	4-5	4-5	5	5	5	4-5
Tartaric acid	5	5	4-5	5	5	4-5	4-5

***Multifiber**

CA=Acetate, CO= Cotton, PA= Nylon, PES= Polyester, PAN= Acrylic, WO= Wool

Fastness Grades

5= Excellent, 4= Very Good, 3= Good, 2= Poor, 1= Very Poor

Results of colour fastness to daylight with pre-mordanting and post-mordanting methods of dyed leather specimens are illustrated in Table 4.8.9 and 4.8.10.

Table 4.8.8: Colour Fastness to Daylight of Dyed Leather Specimens with Pre-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	4
Aluminium sulphate	4
Copper sulphate	3
Ferrous sulphate	3
Copper chloride	2
Ferric chloride	3
Copper acetate	3
Acetic acid	6
Tartaric acid	6

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

Table 4.8.9: Colour Fastness to Daylight of Dyed Leather Specimens with Post-mordanting Method

Mordants/ Without mordant	**Change in Colour**
Without mordant	2
Potash alum	3
Potassium dichromate	4
Aluminium sulphate	4
Copper sulphate	4
Ferrous sulphate	5
Copper chloride	4
Ferric chloride	4
Copper acetate	2
Acetic acid	4
Tartaric acid	6

Fastness Grades

8= Outstanding, 7= Excellent, 6= Very Good, 5= Good, 4= Fairly Good

3= Moderate, 2= Poor, 1= Very Poor

To evaluate the commercial importance of extracted dye from *T. erecta* waste petals, a comprehensive survey was carried out and the results of present study of obtained liquid dye have been presented in Table 4.8.10.

Table 4.8.10. Feasibility Study of *T. erecta* Liquid Dye

Sr. No.	**Description**	**Dollars**
1	Raw Material (1 Kilogram waste petals)	0.10
2	Utilities	0.58
3	Labour	0.48
4	Transportation	0.38
5	Packing	0.14
6	Overheads (Miscellaneous)	0.10
Total Cost		1.78 USD

The lightness values (L*) of dyed leather specimens were obtained with *B. perennis* dye shown in Fig. 4.1.

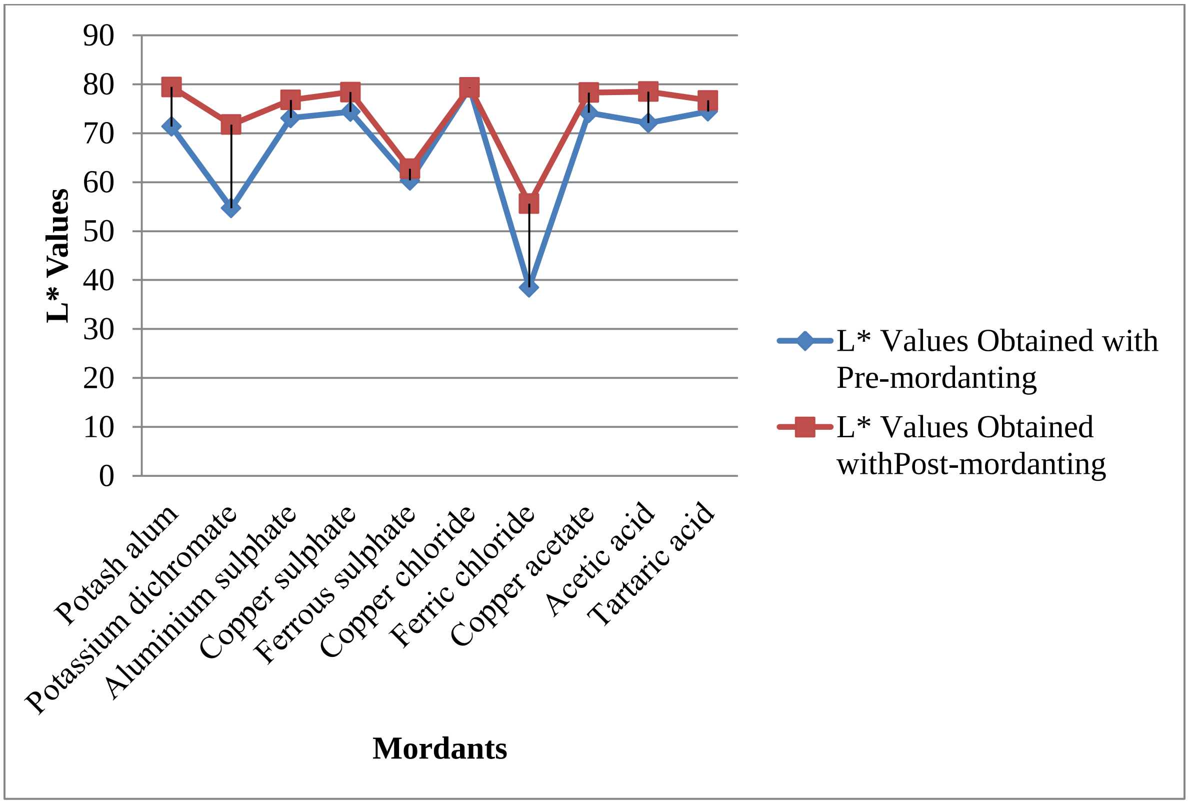


Fig. 4.1 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Figure 4.2 indicated the lightness values (L*) obtained with *B. ceiba* dye using pre-mordanting and post-mordanting methods.

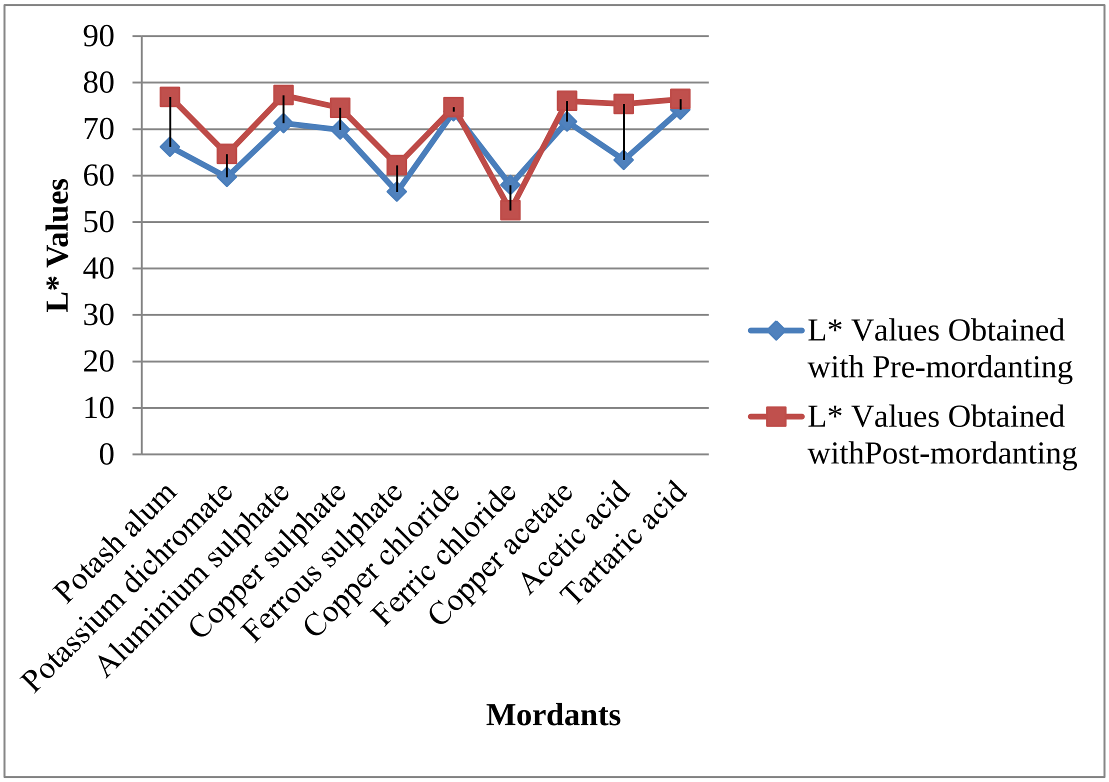


Fig. 4.2 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Results of Fig.4.3 elucidated the L* values produced with pre-mordanting and post-mordanting techniques using *B. glabra* dye.

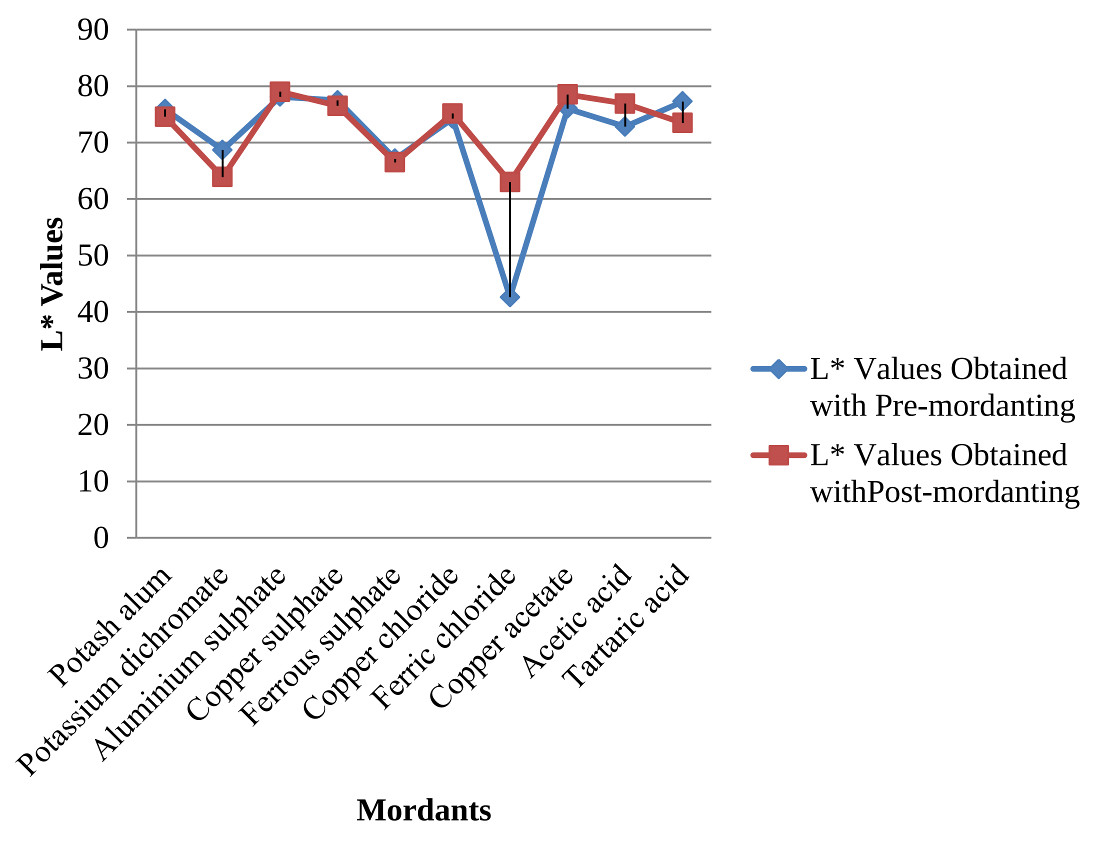


Fig. 4.3 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Figure 4.4 showed the lightness values (L*) obtained with pre-mordanting and post-mordanting methods using *C. cristata* dye.

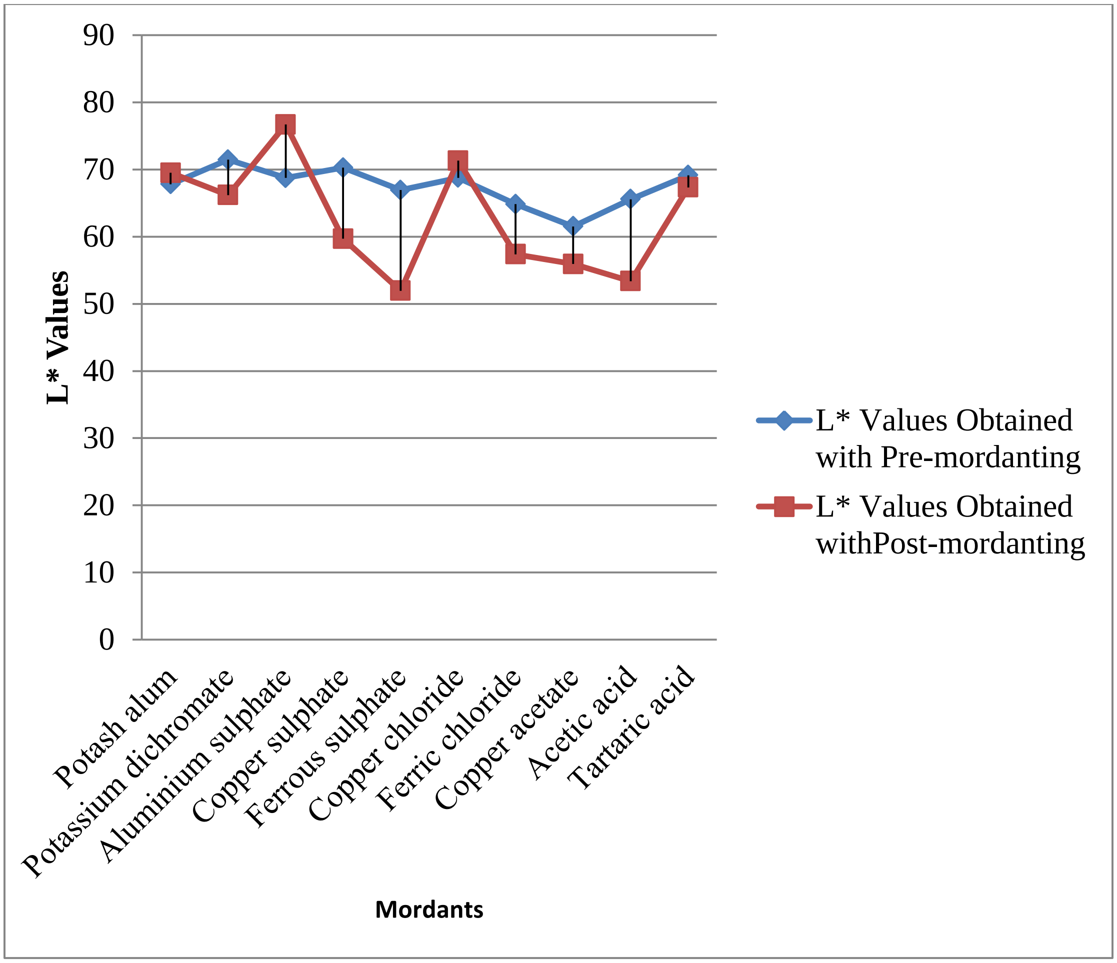


Fig. 4.4 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

The lightness values (L*) obtained with *L. camara* dye is illustrated in Fig. 4.5.

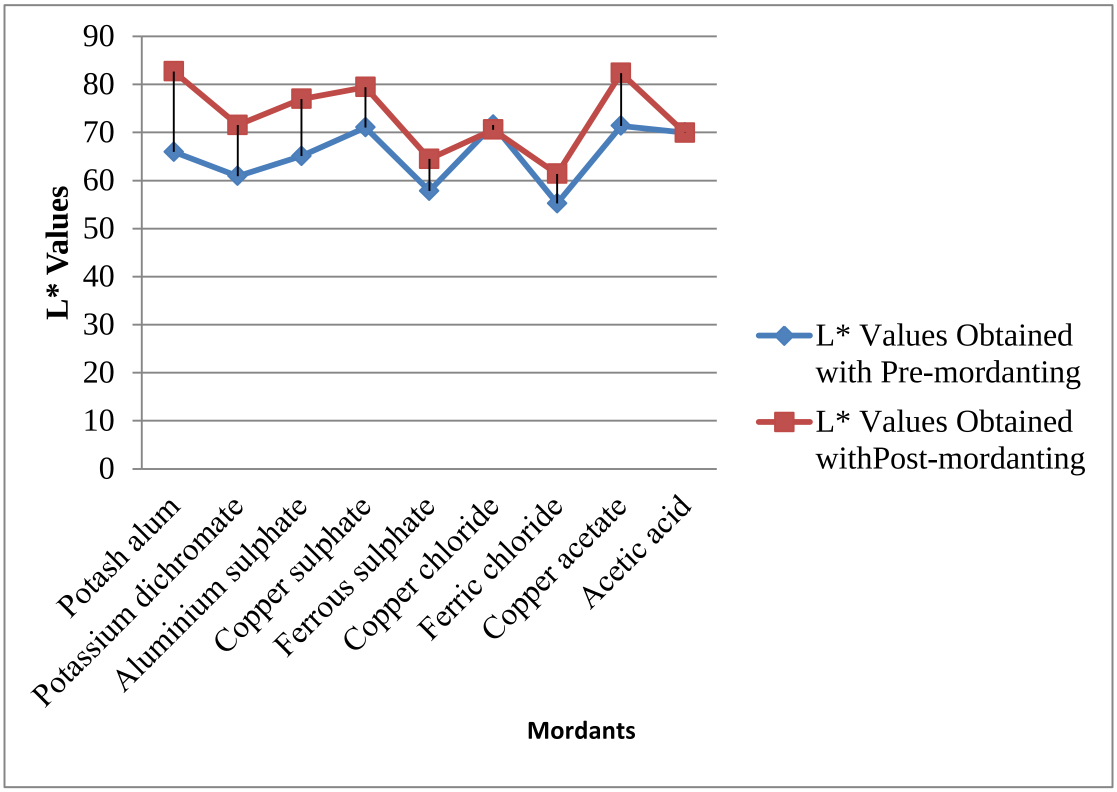


Fig. 4.5 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Figure 4.6 indicated the lightness values L* obtained with *P. rhoeas* dye using pre-mordanting and post-mordanting methods.

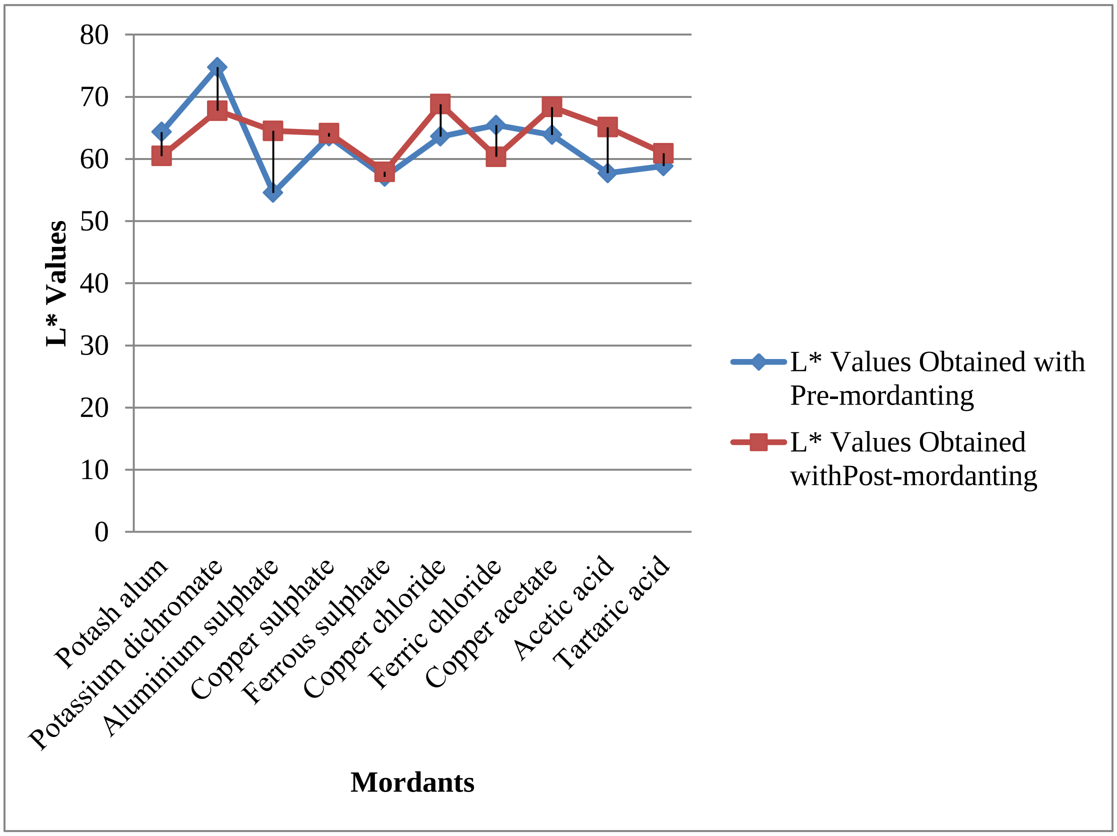


Fig. 4.6 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Figure 4.7 presented the lightness values (L*) obtained with pre-mordanting and post-mordanting methods using *R.damascena* dye.

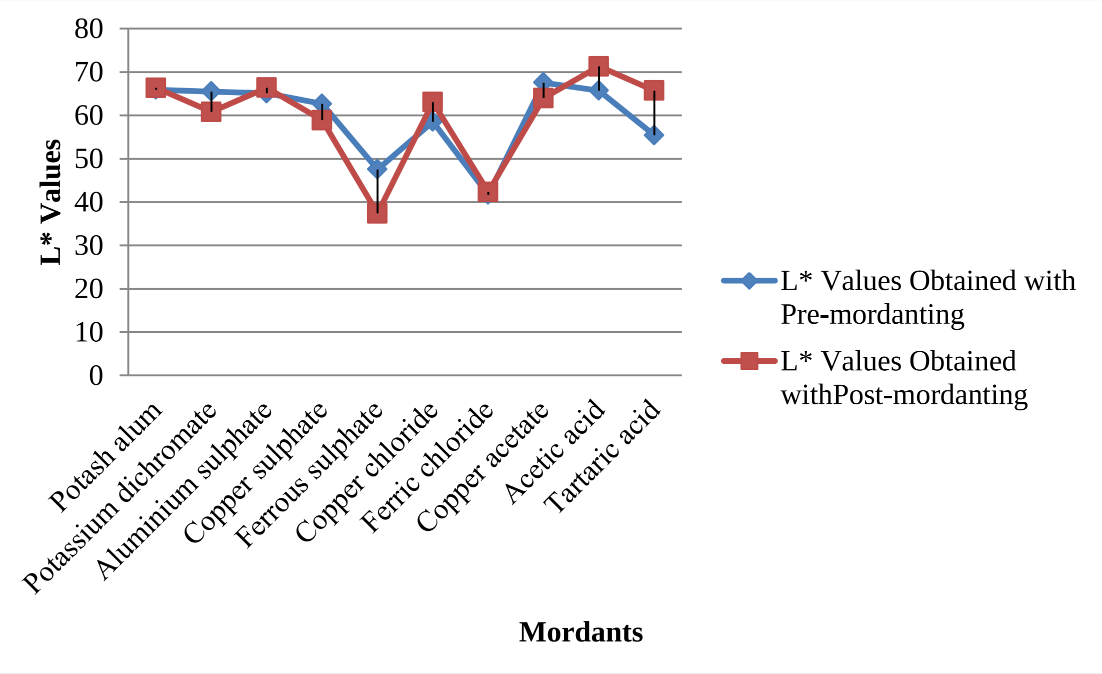


Fig. 4.7 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

Results of Fig. 4.8 illustrated the lightness values (L*) obtained with *T. erecta* dye using pre-mordanting and post-mordanting techniques.

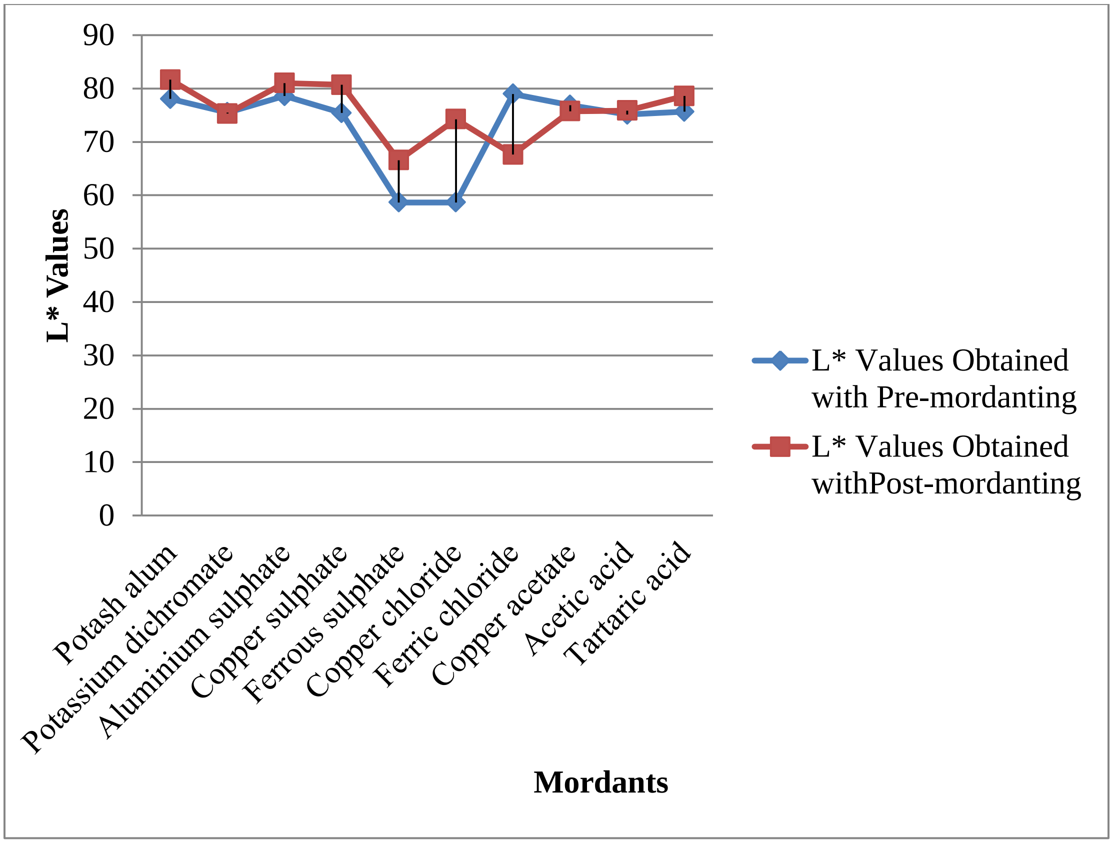


Fig. 4.8 L* Values of Dyed Leather Specimens Obtained with Pre-mordanting and Post-mordanting Methods

CHAPTER 5

DISCUSSION

Punjab, province of Pakistan is richly endowed with natural reserves and blessed with a wide range of biodiversity (Zareen *et al.*, 2012; Pervaiz, 2015). In addition, the province is diversified in environmental, ecological, agricultural and industrial perspectives. The dynamic province is the hub of the leather sector which is the key source of employment generation, having huge share and contribution in the Pakistan's economy. On the other side, the significant non-timber forest products are the income generating source in rural areas. In current scenario of Punjab, several studies have been reported on available plant resources but no study has been conducted earlier to dye leather with herbal dyes.

Globally, azo dyes are used for leather colouration which is the major environmental and health concern. Greenhouse gas (GHGs) emissions during synthetic dyes production, is one of the biggest source of climate change and a major threat to sustainable development. Thus, there is dire need to reduce the consumption of highly pollutant synthetic dyes being used for leather dyeing. Therefore, by keeping into account the economic importance of leather and carcinogenic impacts of synthetic dyes, this study has been carried out for the first time in Punjab to extract natural dye from the indigenously available plants which are the sustainable renewable source to reduce GHG's emissions. Environment friendly, natural dyes indeed play an important role towards green economy to improve human well-being and social equity, while significantly reducing environmental risks and ecological scarcities using socially inclusive, resource efficient, low carbon techniques (EEA, 2013; Zoboli *et al.*, 2013) and chiefly relate to the principles of sustainable development (Pearce *et al.*, 1989). Thus, eco-friendly, natural dyes are helpful to reduce toxic side effects of synthetic dyes as they are non-poisonous, non-carcinogenic and non-hazardous. Dye-bearing plants not only mitigate climate change and strengthen economy but also improve the socio-economic condition of local rural people (Paul *et al.*, 2003; Choudhary *et al.*, 2012; Soaga *et al.*, 2014; Pervaiz *et al.*, 2016d).

After carrying out a comprehensive study, it was investigated that considerable, dye yielding plants are available in central and northern Punjab. Initial screening of plant material results showed that more than 40% of tested dyeing achieved acceptable results while readily available plant material for dye extraction i.e. flower was found to meet the local industrial demand, having easy transportability, manageability of raw material at operation level and most importantly to avoid de-forestation, non-exploitation of available plant resources and found most sustainable way to reuse plant material. Moreover, obtained environment friendly dye is low cost, non-poisonous, non-hazardous and non-toxic which is the significant quality to meet the objectives of the present study.

The present study showed that selected flowers have great significant potential of exclusive colours. Therefore, the future of natural dyes looks very bright. Considering the facts of available natural dye raw material, present study showed that selected flowers can be used for dyeing leather as they are found to be the most suitable source of natural dye. Obtained dyes from flowers (Masure and Patel, 2014; Pervaiz *et al.*, 2016a) are environment friendly (Grover, 2005; Onem *et al.*, 2011; Jadhao and Rathod, 2013; Singh and Swami, 2016; Pervaiz *et al.*, 2016a; Patil *et al.*, 2016) cost efficient (Naqvi, 1980; Ibrahim *et al.*, 1997; Saha and Dutta, 2008; Vankar and Shanker, 2008; Mortazavi *et al.*, 2012; Selvi *et al.*, 2013; Jadhao and Rathod, 2013; Singh and Swami, 2016; Pervaiz *et al.*, 2016a; Patil *et al.*, 2016). Readily available flower material for dye extraction is sustainable. Dye extraction from flowers is relatively easy and fast (Annapoorani and Sundarraj, 2014; Pervaiz *et al.*, 2016a). Obtained dye from flowers is commercially successful for dyeing cotton, silk, wool (Shanker and Vankar, 2007) and leather (Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b; Patil *et al.*, 2016). Furthermore, the obtained results demonstrated that dyed specimens found fragrant after dyeing which is a reported dynamic quality of floral dyeing (Singh and Srivastava, 2015; Kalsy and Srivastava, 2016; Pervaiz *et al.*, 2016a). Similar findings of experimental results of the present study were also reported with China rose, Bixa flowers (Gokhale *et al.*, 2004; Mahanta and Tiwari, 2005; Siva, 2007; Gaur, 2008; Raja *et al.*, 2012).

Mordants are used with natural dyes to fix the dye firmly and to improve the colour fastness of dyed substrates as the natural dye alone might fade or wash out. Mordants develop the co-ordination bonds with the dye molecule, help to last the dye for a long time and make them insoluble in water (Mongkholrattanasit *et al.*, 2011). Furthermore, the variation in colour shades is also dependent on the use of mordants and mordanting methods/techniques. Regarding environmental perspective, the use of metallic mordants is less sustainable with eco-friendly dyes. Therefore, eco-friendly mordants such as ferrous sulphate, copper sulphate and potash alum (Saha and Dutta, 2008; Mahangade *et al.*, 2009; Uddin, 2014; Pervaiz *et al.*, 2016a) and without mordant were considered in the present study. Moreover, the dye efficiency of selected flowers was also assessed with other common mordants. In addition, low concentration of mordants (Saha and Dutta, 2008; Pervaiz *et al.*, 2016a; Pervaiz *et al.*, 2016b) were used with the dyes to minimize the negative environmental impacts. Musa *et al.*, (2009) studied *Lawsonia ineremis* dye application on leather substrate. Different shades were produced with the henna dye using aluminium sulphate ferrous sulphate and zinc sulphate mordants. Similarly, Ersin *et al.*, (2012) studied the colouring ability of onion skins on chrome tanned leather. In their research, mordants viz. aluminium sulphate, copper sulphate and ferrous sulphate have been used to obtain various colours. In another study of Amarnath and Radhika, 2015, natural dyes were extracted from indigo and logwood. The dye potential was evaluated on cow leather. Ferrous sulphate, alum, chromium sulphate and sodium carbonate exhibited different shades on leather. Thus, in the present study, ten different mordants were used for pre-treatment of leather. Results of the study showed that different shades can be obtained with the same plant dye which is supported results by Raghava *et al.*, (2008), Musa *et al.*, (2009), Onem *et al.*, (2011) and Ersin *et al.*, (2012). Furthermore, the similar results of shades were obtained on different substrates such as cotton, silk and wool (Kar and Borthakur, 2008).

In addition, mordanting methods *viz.* pre-mordanting, post-mordanting and simultaneously mordanting also play key role to ascertain dark and light shades (Yaqub *et al.*, 2014; Pervaiz *et al.*, 2016a). In the present work, leather specimens were pre-treated with different mordants. Maximum values of L* were noted with selected dyes. Findings of research work of Onem *et al.*, (2011) to dye leather are in accordance with the obtained results of present work.

Current study further reveals that low values of L* were obtained with post-treated leather samples. It was further noted from the post-mordanting results that lowest values of L* were obtained with ferrous sulphate and ferric chloride mordants. Musa *et al.*, (2011) and Bechtold *et al.*, (2009) proved that post-mordanting method is an ideal method to produce dark shades. Similar findings are also obtained with cotton and silk using post-mordanting method. In the present investigation, ferrous sulphate and ferric chloride rendered similar results with the selected dyes (Pervaiz *et al.*, 2016a).

Medium of dye extraction is one of the most important variables. Aqueous dye extraction is conventional, low cost and eco-friendly process (Ibrahim *et al.*, 1997; Deshpande and Chaturvedi, 2014). Moreover, previous study of Singh and Swami, 2016 reported the extraction of water soluble dye from steeped petals. Similarly, in the present experiments, superior dye extraction was observed from the selected flowers through aqueous method (Pervaiz *et al.*, 2016a).

In the present investigation, nice aroma of extracted dyes was assessed throughout the dye extraction span. Moreover, the dyed leather specimens were evaluated fragrant with floral dyeing. Previous study of Banupriya and Maheshwari (2013), Singh and Srivastava, (2015) and Kalsy and Srivastava, (2016) reported the dynamic quality of floral dyeing. Observing results, it was noticed that *R. damascena* presented super aroma results whereas *L. camara* ranked second highest significant results.

Results of previous study showed that different plants parts produced different percentage of dye yield. In the study of Kulkarni *et al.*, (2011) 19.2% dye obtained with *Punica granatum* peel while in 2010 Goodarzian and Ekrami, extracted 22.5% amount of dye with the same plant part. In the current study, the percentage dye yield was found more than 30% from pomegranate peel (Pervaiz *et al.*, 2016c). Furthermore, in the current study, it was inferred that maximum dye yield was obtained with the selected flower of *L. camara* dye (11.6g) and the lowest amount of dye yield was recorded with *C. cristata* (2.7g). In addition, it was revealed from the obtained results that *R. damascena* extracted dye (5.8g) rendered best leather dyeing results. Whereas *P. rhoeas* dye yield (4.2g) was found dominant in all selected flowers to produce elegant shades.

The obtained dye yield from the selected plants gave different results with mordants. Selected ratio of gave satisfactory results. Moreover, with the selected ratio of raw material soft shades were produced with *B. perennis* and *C. cristata.* While ferrous sulphate and ferric chloride mordants chelated good coordination with selected dyes and produced dark shades. It has been concluded from the results that dye yield is found suitable to achieve desirable results. Moreover, the increase ratio of raw material would be helpful to obtain more dark shades.

In the present work, very good to excellent results of surface dyes were obtained with all selected dyes. Soft shades were recorded with *B. perennis* and *C. cristata* dyes. Moreover, rest of the selected flowers gave dark and light shades with and without mordants. These results are also supported by the published work done on leather dyeing with henna (Musa *et al.*, 2009) and urucum (Bordingnon *et al.*, 2011).

The current study further reveals that very good dye penetration level was obtained with *P. rhoeas* dye which is also the reported result of the previous study of Musa *et al.*, (2009). Moreover, *B. perennis*, *B. ceiba*, *B. glabra*, *C. cristata*, *L. camara*, *R. damascena* and *T. erecta* produced fair to good dye penetration level.

Selvi *et al.*, (2013) studied the aqueous extract of *B. orellana* seeds. Wet blue sheep skins have been dyed using the aqueous medium. Uniform shade was observed on both grain and flesh sides of the leather. Results of their study clearly indicated that obtained dye can be used for dyeing of leather. Similarly, in the present study good to very good uniform dye results were observed on both sides of leather (grain and flesh) with all selected dyes except ferrous sulphate and ferric chloride mordants which rendered fair dye evenness with *T. erecta* dye using pre-mordanting method (Pervaiz *et al.*, 2016b).

Present investigation of current study revealed that maximum hues for all the selected plants were recorded towards yellow colour. The values of L* were noted very high for all the dyed leather specimens which varies from plant to plant. Moreover, ferrous sulphate and ferric chloride mordants produced the lowest L* values with all the selected flowers. In addition, lowest L* values were recorded with *P. rhoeas* dye while potassium dichromate mordant rendered highest value of b* with the selected dyes.

Comparing present results of colour fastness to rubbing with reported earlier study (Musa *et al.*, 2009; Onem *et al.*, 2011; Erisen *et al.*, 2012; Selvi *et al.*, 2013; Sundari, 2015), it was found that selected dyes showed commercially viable output. Moreover, significant findings regarding change in colour gave good to very good results almost with all selected plants except *P. rhoeas* dye which showed unsatisfactory change in colour results with potash alum and aluminium sulphate mordants (Pervaiz *et al.*, 2016a).

Furthermore, colour fastness to washing was highlighted in current work. Results of laundering were recorded good to very good in terms of staining and change in colour (Pervaiz *et al.*, 2016). Results of previous studies showed the similar output with the natural dyes (Musa *et al.*, 2009; Inyat *et al.*, 2010; Onem *et al.*, 2011; Selvi *et al.*, 2013; Sundari, 2015).

Good fastness to daylight is one of the desirable commercial properties of dyed leather. Analyzing results of colour fastness to day light of present study demonstrated that dyed specimens showed fair results of light as reported by (Sundari, 2015). Moreover, results with ferrous sulphate and ferric chloride mordants were recorded in dark shade, which is contrary to reported results by Musa *et al.*, 2009; Onem *et al.*, 2011; Erisen *et al.*, 2012; Selvi *et al.*, 2013; Sundari, 2015). However, rest of the results were found in acceptable range regarding market point of view (Musa *et al.*, 2009; Onem *et al.*, 2011; Erisen *et al.*, 2012; Selvi *et al.*, 2013; Sundari, 2015).

CONCLUSION

This study is the first one in Punjab to investigate the application of floral dyes on chrome tanned leather. In Punjab, the abundantly available flowering plants can be served as a major source of eco-friendly dyeing agents and have great potential of using non-toxic dyes for leather dyeing. The findings of the study show that flowers possess good potential of dye.

Furthermore, results of the study revealed that liquid dye produced different soft and dark shades with and without mordants. It is also notable from the obtained findings that aqueous dye extraction process is eco-friendly and economically viable which provides effective utilization of natural resources in current situation of global environmental concern. Beside this, a use of natural dyes from waste petals was found economical according to industrial point of view. It was concluded from the results that natural dyes are found environment friendly, low cost, non-carcinogenic, non- hazardous and very useful for leather dyeing.

Hence, there is a good scope for Pakistan's leather industry to use natural dyes to meet the fundamental requirement of European Union, to earn carbon credits by reducing the use of synthetic dyes and to improve the socio-economic condition of farmers by yielding and exporting dye bearing plants. Overall, commercialization of natural dyes has good scope to boost up the green economy of Pakistan and have great opportunity to earn carbon credits by adhering clean development mechanism (CDM) philosophy.

Conclusively, from the findings that the produced floral dyes from selected flowers are well suited for leather dyeing and the developed shade catalogue is a new addition in eco-friendly leather dyes to promote sustainable fashion development.

Moreover, detailed studies and technical investigations of natural dyes are yet to be made from the same plants available in different regions of the world and propagate the plant species having maximum dye yield percentage for leather dyeing.

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