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# Ecological dyeing of Woolen yarn with *Adhatoda vasica* natural dye in the presence of biomordants as an alternative copartner to metal mordants

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ABSTRACT

Introduction of natural dyes into modern dye houses is very promising green chemistry concept which should be popularized more and more to reduce the dependency of wool dyeing on some toxic and non-biodegradable synthetic dyes (Azo and benzidine dyes). In the present study, an attempt has been made to investigate the possibility of wool dyeing with *Adhatoda vasica* extract as a natural dye. A beautiful color palette of shades of varied hue and tone were obtained by using different mordants. The effect of various metal salts (ferrous sulphate, alum and stannous chloride) and natural tannin extracts (gallnut, pomegranate peel and babool bark) as mordants on color and fastness properties of dyed wool samples was comparatively evaluated. Dyeing experiments were performed with and without mordants, using pre-mordanting technique. The color of dyed woolen yarn was investigated in terms of CIELab (L*, a* and b*) and K/S values; and fastness properties were determined as per ISO and AATCC standard test methods. As confirmed by exhaustion studies, a substantial portion of metal salts remained in residual mordant baths. The results of using biomordants for wool dyeing were comparable with that of the metallic mordants in terms of color strength and fastness characterisctics. Biomordants produced quite different color gamuts as expected from a mordant and thus offer full potential to replace metal salts in wool dyeing.



## 1. Introduction

A revived interest in the use of natural dyes in textile and food coloration has been growing since last few decades and there is an urgent need for availability of natural dye yielding plants for fulfilling the purpose. Recently discovered properties of natural dyes such as insect repellent [1], deodorizing [2], flame retardant [3], UV protection [4], fluorescence [5,6], and antimicrobial activity [7–9], besides being biocompatible, biodegradable, renewable, and non-toxic have revolutionized all industrial sectors especially textile industry for producing more appealing and highly functional value-added textiles [10,11]. This is a result of ecological concerns related with the use of 118 of the azo and benzidine synthetic dyes with 24 carcinogenic aromatic amines as their primary photolytic degradation products, which have motivated researchers all over the globe to explore new eco-friendly substitutes for minimizing their negative environmental impacts [12]. In the application of natural dyes, different dyeing and mordanting techniques and post-treatment were used to improve color fastness properties. As a result, optimization of the dyeing conditions with regard to the type of natural dye is quite common and a broad set of variations in the dyeing recipes is given in the literature [13,14]. The numerous variations of dyes from plant sources and dyeing processes make an introduction of natural dyeing into full-scale technical dyeing processes rather difficult. The rapid changes in trends, fashion and the demand for good fastness properties on different substrates requires a basic database describing possible applications of natural dyes, otherwise too much parallel optimization work has to be done by each dyehouse.

But intrinsic lower light fastness, poor shade reproducibility, non-standardization of raw material and complexity of process involved in natural dyeing restricts their use in textile applications,

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besides many advancements have been taken into consideration for modifying color characteristics of dyed textile materials [15–17]. Mordants are essential components of natural dyeing processes in terms of achieving broad spectrum of colors of various patterns and special performance characteristics on wide range of natural as well as synthetic textile materials [18–21]. Chemical nature of mordant and fiber-mordant-dye interactions greatly modifies the color characteristics of dyed textile. Most common mordants in natural dyeing used to alter the colorimetric parameters and fastness properties of dyed textile materials are aluminium, potassium dichromate, copper sulphate, ferrous sulphate, and stannous chloride [19]. Use of rare earth metals have been successfully employed as mordants for increasing dyeing performance of ramie fabrics [22]. Although, significant amounts of metal ions remains unexhausted in residual mordant baths which eventually are discharged in waste waters, thereby posses ecological concerns and negative impact on public health [20]. The amount of metal ion discharged from textile industries is strictly banned beyond a certain limit [22–24]. Advancements in mordanting processes and selecting new, safe and ecofriendly mordants to replace traditional heavy metal ions has been an important part in the development of natural dyeing processes [25].

The textile industry is one of the biggest consumers of water, so extensive data about the effluent production have been collected and are available from the literature [15]. Thus, depending on the extent of after treatments relating to the release of effulents produced from dye houses, waste water from the dyeing step is diluted more or less to reduce the load of toxic chemicals. Use of natural mordants (Biomordants) in place of metallic salt mordants has been advised by researchers in terms of an effective and safe alternative considering environmental aspects of pollution and their biodegradable nature, hence can be discharged to the environment without any chemical or physical treatment (e.g. precipptation or filtration) [26–28]. Mordants from natural origin such as myrabolan (*Terminalia chebula*), pomegranate rinds (*Punica granatum*), tannin, tannic acid, tartaric acid, guava and banana leaves ash have been utilized for mordanting purpose [29]. Recently, lot of research finding have been done regarding use of biomordants as an alternative and safe substitute to metal mordants and encouraging results have been achieved [30–33]. Biomordants are biological natural materials having metal ion(s), tannins etc. mostly come from vegetable sources and act as mordant in natural dyeing processes. Some plants and plant parts with high tannin or metal content may present mordanting effect to various extents depending on their chemical structure and amount of metal present in them [34].

In continuation to our earlier studies [35] of thermodynamics and kinetic investigation on wool dyeing with the evaluation of colorimetric and fluorescence characteristics with *A. vasica* natural dye, present study was undertaken in order to investigate dyeing properties of *A. vasica* dye alone (Control dyeing) and in conjunction with small amounts of metal mordants and alternative biomordants. Additionally, comparison between metal mordanted and biomordanted woolen yarn samples were also done with the aim of making this research a viable alternative for non-biodegradable metal mordants with ecofriendly, biodegradable and nontoxic biomordants.

## 2. Materials and methods

### 2.1. Materials

100% pure New Zealand Semi worsted woolen yarn (60 counts) was procured from MAMB Woolens Ltd. Bhadohi, S R Nagar Bhadohi (U.P.), India. Powdered *Adhatoda vasica* leaves extract and biomordants (extract of gallnut, pomegranate rind and babool) were purchased from Sir Biotech India Ltd. Kanpur (U.P.), India. Metallic mordants iron II sulphate, alum and tin II chloride used were of laboratory grade. Sodium acetate and sodium hydrogen carbonate buffer were purchased from Merck.

#### 2.1.1. Dye component

*Adhatoda vasica* (L.) Nees (Family Acanthaceae), a well known shrub found throughout Indian peninsula up to an altitude of 1300 m, possesses an imperative place in Ayurvedic and Unani medicine for the treatment of various diseases and disorders, particularly respiratory tract ailments [36]. It is a fast growing plant with unknown (unreported) annual production but coppices well. The main chemical component present in *A. vasica* is a bitter quinazoline alkaloid Vasicine in addition to vasicinone, vasicinol, adhatodine, adhatonine, adhavasinone, anisotine, and peganine [37,38]. It is well known that *Adhatoda vasica* contains 2-pyridyl methyl amine and gives yellow color with alum, light yellow with copper sulfate and gray with ferrous sulfate [39]. Besides possessing varied and high therapeutic potential researchers have tried to explore dyeing properties of *A. vasica* and introduce it in textile industry as a potential finishing agent. However, very little information is available related its dyeing potential [35,39].

#### 2.1.2. Biomordants

*Quercus infectoria* (Gallnut/Aleppo oak) belongs to family Fagaceae is indigenous to Greece, Asia Minor, Syria, and Iran. The galls of *Q. infectoria* contain mixture of gallotannins, gallic acid, and ellagic acid as principal constituents (50–70%) and find extensive application in tanning, mordanting, dyeing, and manufacturing of ink. The main coloring component in gallnut extract is ellagic acid, which has an affinity for dyeing substrates due to the presence of −OH (auxochrome group) [8,40].

Ellagic acid is the main coloring component of pomegranate rind (PPE) [41]. Pomegranate juice contains various types of anthocyanins mainly cyanidin-3-glucoside, delphinidin-3-glucoside, pelargonidin-3,5-diglucoside, cyanidin-3,5-diglucoside, delphinidin-3,5-diglucoside and pelargonidin-3-glucoside. The outer covering of pomegranate has been known to be very rich in ellagitannins and gallotannins [42,43].

Babool (*A. nilotica*) is a rich source of polyphenols, mainly composed of condensed tannin and phlobatannin in addition to gallic acid, ellagic acid, (+) − catechin, and (−) − epigallocatechin-7-gallate [44,45]. Bark of babool constitutes one of the most important tanning materials of Northern India; tannin content varies from 9 to 16.5% on dry weight basis [46]. Tannin content present in *A. nilotica* can be explored as an effective biomordant for the production and development of environment friendly textile materials [47,48].

#### 2.1.3. Instruments

A Perkin Elmer Lambda-40 double-beam UV–visible spectrophotometer was employed for recording absorbances values of dye bath solutions. A pH/mV Meter (BD 1011) from Decibel digital technologies was used for measuring pH of dye solutions.

### 2.2. Methods

#### 2.2.1. Mordanting

Woolen yarn samples were mordanted by pre-mordanting technique using 10% (o.w.f.) potassium aluminium sulfate ($K_2Al_2(SO_4)_4.24H_2O$), 5% (o.w.f) ferrous sulfate ($FeSO_4.5\%H_2O$), 1% (o.w.f.) stannous chloride ($SnCl_2{\cdot}2H_2O$) and 1–5% (o.w.f.) biomordants namely gallnut, PPE and babool. Before the application of mordants, woolen yarns samples were soaked in non-ionic detergent solution (5 ml/L) to increase surface wetability.