Biochemical Studies in Several Dye Yielding Plants

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Abstract

Ten natural dye yielding and two mordant plants were biochemically analyzed. Though natural dyes are widely used, information about the active principles responsible for dyeing is hardly available. In the present experiment, total chlorophyll, carotinoids, tannins, phenolics, flavonoids and curcumin were determined among the dye yielding plants, while K, S, P, Ca, Mg, Mn, Zn, Fe and Cu were determined in the case of mordant plants. In Bixa orellana, used for yellow dyeing, the carotinoid content was 163.11 mg g⁻¹ and in Clerodendrum chinense and Datura stramonium, which were used for green colouring, total chlorophyll content of 10.29 mg and 11.83 mg g⁻¹ was recorded. Curcumin content responsible for orange colouring in Curcuma domestica was 27.7 mg g⁻¹ while flavonoid content in Solanum nigrum and Terminalia chebula, which were used for brown, brown to black dyes was 24.89 and 21.73 mg g⁻¹. Among the plants used for dyeing different colours, Punica granatum and Parkia timoriana were found to contain higher amounts of total phenols and bound phenols by recording 681.2 mg g⁻¹ and 287.6 mg g⁻¹ total phenols and 151.6 mg g⁻¹ and 130.2 mg g⁻¹ bound phenols, while higher amounts of orthodihydric phenols and tannins were recorded in Punica granatum and Strobilanthes flaccidifolius by recording 20.11 mg g⁻¹ and 9.54 mg g⁻¹ orthodihydric phenols and 675.57 mg g⁻¹ and 648.12 mg g⁻¹ tannins, respectively. In case of the plants used as mordant, higher contents of Ca, Mg, K, Zn, Fe and Mn were detected in Achyranthes aspera, while higher amounts of P, Fe and Cu were recorded in Garcinia xanthochymus.

Keywords: carotenoids, chlorophyll, curcumin, minerals, natural dyes, phenols, tannins

Introduction

Archaeologists have found evidence of textile dyeing dating back to the Neolithic period. In China, dyeing with plants, barks and insects has been traced back more than 5,000 years. The essential process of dyeing changed little over time. Typically, the dye material is put in a pot of water and then the textiles to be dyed are added to the pot, which is heated and stirred until the color is transferred (Barber, 1991). Vegetable dyes or natural colorants have been used historically throughout the world. Every civilization has its myth and association with colour.

In the early 21st century, the market for natural dyes in the fashion industry is experiencing resurgence. Western consumers have become more concerned about the health and possible environmental impact of synthetic dyes. The European Union, for example, has encouraged Indonesian batik cloth producers to switch to natural dyes to improve their export market in Europe (Bryan and Stella, 2002).

The people of Manipur have been using indigenous dyestuffs from plants and animal sources in handicrafts, handlooms, fine arts etc. since time immemorial. In modern Manipur, natural dyes play an important role in traditional Manipuri fabrics and other household items. They obtain natural dyes from plants and animals by simple, traditional extraction methods (Mutua, 1997; Sharma, 2000).

Natural dyes can be used on most types of material or fibre but the level of success in terms of fastness and clarity of colour varies considerably. Mordant substances are needed to set the colour when using some natural dyes. There are many naturally occurring mordant plants which give different shades and also facilitate the bonding of the dyestuff to the fibre.

The chemical analysis that would definitively identify the dyes used in ancient textiles has rarely been conducted, and even when a dye such as indigo blue is detected, it is impossible to determine which one of the indigo-bearing plants was used (Goodwin, 1982; Hofenk de Graaf, 2004). Nevertheless, in the present experiment, based on the colours of surviving textile fragments and the evidence of actual dyestuffs found in archaeological sites as well as from dyers’ house, ten natural dyes yielding plants which have unique uses in the Meitei society of Manipur were analyzed for the biochemical substances responsible for dyeing (Fig. 1) and two other plants which were used as an alkaline and acidic mordant were analyzed for their mineral content (Fig. 2).
Materials and methods

Plant samples collected from the local dyers of the state were air dried at room temperature and ground with a Remi grinder and sieved (1 mm). The powder samples were stored inside desiccators until analysis. The estimation of chlorophyll was done on the fresh leaves of the experimental material.

Estimation of minerals

Wet digestion method of Capar et al. (1978) was followed for the analysis of different minerals. K was estimated in a systronics-105 flame photometer. Sulphur and phosphorus were determined in a UV-VIS double beam Spectrophotometer following the procedures described by Murthy (2006) and Gupta (2006). Ca, Mg, Mn, Zn, Fe, Cu and Co were analyzed in a Perkin Elmer Atomic Absorption Spectrophotometer, Analyst AA-200.

Statistical analysis

The data obtained was statistically analyzed by using proper statistical methods and reported as means ± S.Em.

Results

The ten plants taken for the experiment and their parts used are indicated in Table 1 and 2. The quantitative analysis of the ten selected plants with their respective secondary metabolites or pigments responsible for dyeing is given in Table 3. *Bixa orellana* recorded 163.11 mg g⁻¹ of carotenoid pigment responsible for dyeing while curcumin content in *Curcuma domestica*, which is the pigment responsible for yellow to orange colour dye was found to be 27.7 mg g⁻¹. Total chlorophyll content of *Clerodendrum chinense* and *Datura stramonium* which is used to dye green colour was 10.29 mg g⁻¹ and 11.83 mg g⁻¹, while that of chlorophyll a...
The natural organic dyes and pigments cover a wide range of chemical classes viz., quinone, benzoquinone, naphthaquinone, anthraquinone, flavone, flavonone, indigoid, chalcone, aurone, carotenoid, diaroyl methane, alkaldoid, chlorophyll etc. (Daniel et al., 2006). In Tab. 3, the seeds of *B. orellana* were found to contain higher concentration of carotinoids. *B. orellana* seeds were used to dye local made bathing towels known as ‘phadi’ (Fig. 3A to D). The data agrees with the reports of Gokhale et al. (2004) that a carotenoid, bixin occurring in *B. orellana* is responsible for yellow to red dyeing property of the plant. The yellow colour dye of *C. domestica* and green colour dye of *C. chinense* and *D. stramonium* were used to dye cotton clothes for making small religious flags used for offering to deities (Fig. 3E and F).

Curcumin and other related curcuminoids were also reported for yellow colour of the dye in *C. domestica* (Gurlajani et al., 1992). Ruby et al. (1995) reported 90% of the yellow dye in *C. domestica* is due to curcumin, the remaining comes from demethoxycurcumin and bisdemethoxycurcumin. Higher content of curcumin (27.7 mg g\(^{-1}\)) in *C. domestica* correlates with its yellow dyeing property.

Higher phenol concentration in plants like *P. timoriana*, *L. pachyphylla*, *P. granatum* and *S. flaccidifolius* indicated their properties of dyeing as the presence of phenolic compounds was found to be inhibiting decolorization at a concentration of 1mM (Tony and Risky, 2012). Phenolics were reported to be responsible for dyes in various plants (Aviram and Domfeld, 2001; Salah et al., 2002). *S. flaccidifolius* dye is used for applying black and indigo colour to loin loom ‘phanek’ (Fig. 3G and 3H), a Meitei women’s formal folk dress. The fruit peel of *P. timoriana* is used for dyeing the local fishing net (Fig. 3I). Similarly, fruits of *S. flaccidifolia* and *T. chebula* are used in dyeing ‘chaddars’ worn by the Meitei women (Fig. 3J). Higher contents of tannins in *P. timoriana* (353.54 mg g\(^{-1}\)), *P. granatum* and (B) *D. stramonium* were used to dye cotton clothes for making small religious flags used for offering to deities (Fig. 3E and F).

Discussion

Tab. 2. List of two selected plants used as alkaline and acidic mordants for mineral analysis

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Botanical Name</th>
<th>Local Name</th>
<th>Family</th>
<th>Part Used</th>
<th>Colour of the dye</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Achyranthes aspera L.</td>
<td>Khujum pere</td>
<td>Amaranthaceae</td>
<td>Whole plants</td>
<td></td>
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<tr>
<td>2</td>
<td><em>Garcinia xanthochymus</em> Hook.</td>
<td>Heibung</td>
<td><em>Guttiferae</em></td>
<td>Fruit</td>
<td></td>
</tr>
</tbody>
</table>
lates their dyeing property as flavonoids are also reported to be used in dyeing brown and black hues (Jondiko and Pattenden, 1989).

Among the two mordant plants, higher contents (mg g\(^{-1}\)) of Ca (6.24), Mg (6.04), K (21.36), Zn (0.28), Fe (1.0) and Mn (0.22) were detected in *A. aspera*, while appreciable amounts of K (15.17 mg g\(^{-1}\)), P (3.27 mg g\(^{-1}\)), Fe (0.99

natum*) (675.57 mg g\(^{-1}\))*.* flaccifolius* (648.12 mg g\(^{-1}\)) and *T. chebula* (292.24 mg g\(^{-1}\)) indicated its use as dyes as tannins are reported to be responsible for various dyes (Shahid et al., 2009). The fruits of *Solanum nigrum* were used to dye a cloth worn by the royals in early days known as ‘Khamen chata’ (Fig. 3K). Appreciable quantity of flavonoids in *S. nigrum* (24.89 mg g\(^{-1}\)) and *T. chebula* (21.72 mg g\(^{-1}\)) correlates their dyeing property as flavonoids are also reported to be used in dyeing brown and black hues (Jondiko and Pattenden, 1989).

Fig. 3. Different shades and designs of clothes dyed from the ten dye yielding plants
mg g\(^{-1}\) and Cu (0.24 mg g\(^{-1}\)) were recorded in *G. xanthochymus* (Tab. 3). Higher concentration of potassium, iron and copper shows the property of using as mordants as the metal salts of iron, copper, aluminium etc. were reported to be used as metallic mordants (Gulrajani, 1999). Alum, chrome, stannous chloride, copper sulphate, ferrous sulphate etc. were also reported to be the commonly used mordants (Siva, 2007; Mahangade et al., 2009; Samanta and Agarwal, 2009). Metal ions of mordants act as electron acceptors for electron donors to form co-ordination bonds with the dye molecule, making them insoluble in water (Mongkholrattansit et al., 2011). Use of *A. aspera* and *G. xanthochymus* as mordants agrees with the above reports.

### Conclusions

Natural dyes are nowadays in demand not only in textile industry but in cosmetics, leather, food and pharmaceuticals. Natural dyes can offer not only a rich and varied source of dyestuff, but also the possibility of an income through sustainable harvest and sale of the dye plants. In areas, where synthetic dyes and mordants are imported (therefore relatively expensive), natural dye yielding and mordant plants like *B. orellana, C. domestica, P. granatum, P. timoriana, S. nigrum* and *A. aspera* can offer an attractive alternative.

### Acknowledgements

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### References


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**Tab. 3. Pigments responsible for dyeing in ten selected natural dye yielding plants of Manipur (mg/g) mean ± S. Em**

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Botanical Name</th>
<th>Total Phenols</th>
<th>Bound Phenol</th>
<th>Ortho</th>
<th>Tannin</th>
<th>Flavonoid</th>
<th>Total Chlorophyll</th>
<th>Chlorophyll a</th>
<th>Chlorophyll b</th>
<th>Chlorophyll g</th>
<th>Carotenoid</th>
<th>Curcumin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>Bixa orellana</em> L.</td>
<td>-</td>
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<td>-</td>
<td>163.11±0.73</td>
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<td>2.</td>
<td><em>Clerodendrum chinense</em> (Osbeck) Labb.</td>
<td>-</td>
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<td>-</td>
<td>10.29±0.001</td>
<td>7.43±0.04</td>
<td>2.87±0.06</td>
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<td>3.</td>
<td><em>Curcuma domestica</em> Valeton.</td>
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<td>-</td>
<td>-</td>
<td>27.7±2.19</td>
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<td>4.</td>
<td><em>Datura stramonium</em> L.</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>11.83±0.06</td>
<td>8.72±0.01</td>
<td>3.11±0.001</td>
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<td>5.</td>
<td><em>Parkia timoriana</em> (A.DC.) Merr.</td>
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<td>6.</td>
<td><em>Lithocarpus pachyphylla</em> (Kurz) Rehd.</td>
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<td>7.</td>
<td><em>Punica granatum</em> L.</td>
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<tr>
<td>8.</td>
<td><em>Solanum nigrum</em> L.</td>
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<tr>
<td>9.</td>
<td><em>Strobilanthes flaccidifolius</em> Nees</td>
<td>-</td>
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<td>-</td>
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<td>10.</td>
<td><em>Terminalia chebula</em> Retz.</td>
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**Tab. 4. Micro- and micro-element contents (mg/g) of the two plants used as mordant (Mean± S. Em)**

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>P</th>
<th>S</th>
<th>Zn</th>
<th>Fe</th>
<th>Mn</th>
<th>Cu</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achyranthes aspera</em></td>
<td>6.2±0.16</td>
<td>6.04±0.06</td>
<td>21.36±1.15</td>
<td>1.23±0.02</td>
<td>1.08±0.31</td>
<td>0.28±0.001</td>
<td>1.00±0.01</td>
<td>0.22±0.006</td>
<td>0.15±0.001</td>
<td>0.03±0.001</td>
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<tr>
<td><em>Garcinia anomala</em></td>
<td>2.21±0.17</td>
<td>1.16±0.11</td>
<td>15.17±0.09</td>
<td>3.27±2.19</td>
<td>1.06±0.07</td>
<td>0.12±0.001</td>
<td>0.94±0.01</td>
<td>0.07±0.001</td>
<td>0.24±0.02</td>
<td>0.04±0.001</td>
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</tbody>
</table>


