Diversity and Traditional Knowledge of Textile Dyeing Plants in Northeastern Thailand

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The objective of this study was to document the traditional knowledge of plants used for textile dyeing by the Tai-Lao ethnic group in Roi Et province in northeastern Thailand. Traditional knowledge of plants used for textile dyeing is disappearing because of modernization including new lifestyles, urbanization, and the introduction of synthetic colors. Textile dyeing with local plants, however, is experiencing a revival connected to ecotourism and global interest in natural products. To exploit that potential, it is important to preserve the local knowledge related to textile dyeing. We interviewed 60 Tai-Lao informants in 15 villages and 9 districts about their dyeing traditions and the species used through individual semi-structured and focus groups interviews. A total of 56 species in 50 genera and 31 families were used for dyeing cotton and silks; most species belonged to Fabaceae (11 spp., 19%) and Anacardiaceae (5 spp., 9%). Trees (36 spp., 65%) were the best represented life form among the dye plants, followed by shrubs and herbs (8 spp., 16% each), and climbers (4 spp., 7%). Bark was the plant part most commonly used for dyeing (25 spp., 42%) followed by leaves (12 spp., 20%), and fruits (9 spp., 15%). Home gardens were the most common habitat of dye plant (30 spp., 53%) followed by community forests (16 spp., 28%). *Indigofera tinctoria* L. and *Pterocarpus indicus* Willd. were the most important dye plant species of the Tai-Lao ethnic group as demonstrated by their high use value index (UV = 0.60). Blue/indigo-blue was the color most informants had common knowledge about with an informant consensus factor (ICF) of 0.92 followed by black with ICF = 0.84. Ten different colors were obtained from the 56 plant species. Brown/pale-brown/golden-brown was the color obtained from most dye plant species (14 spp., 25%) followed by green/pale-green/dark-green (13 spp., 23%). Nine different kinds of mordants were used in the dyeing, including alum, chrome (potassium dichromate; $K_2Cr_2O_7$), copper sulfate ($CuSO_4$), iron oxide (Fe_2O_3), tamarind juice (tartaric acid), salt (NaCl), lime (calcium oxide; CaO), ash (potassium hydroxide; KOH), and mud. Among the 56 species used for textile dyeing, three are on the IUCN Red List of Threatened Species, including: *Dipterocarpus alatus* Roxb. & G.Don, *Dipterocarpus obtusifolius* Teijsm. ex Miq., and *Pterocarpus indicus* Willd. Documenting these and other species used for textile dyeing will provide additional arguments for their conservation. It will also help to secure the reappearing tradition of textile dyeing with local plants, and hence support the cultural integrity of the Tai-Lao communities, and serve as an example for other communities in Thailand and elsewhere for preserving their traditional knowledge.

[1] Received 4 January 2017; accepted 22 August 2017;
published online 12 September 2017

Economic Botany, 71(3), 2017, pp. 241–255

วัตถุประสงค์ในการศึกษาครั้งนี้เพื่อบันทึกและรวบรวมองค์ความรู้การย้อมผ้าจากสีธรรมชาติ
และชนิดของพืชให้สีย้อมของกลุ่มชาติพันธุ์ไท-ลาว ในจังหวัดร้อยเอ็ด
ภาคตะวันออกเฉียงเหนือในประเทศไทย เนื่องจากองค์ความรู้พื้นบ้านเหล่านี้กำลังจะหายไปเพรา
ะการเปลี่ยนแปลงวิถีชีวิตเนื่องมาจากการเปลี่ยนแปลงสู่สังคมเมืองของคนในชนบทและการนำเข้าของสี-
สังเคราะห์ การย้อมสีผ้าด้วยพืชในท้องถิ่น เป็นการฟื้นฟูวัฒนธรรมดั้งเดิม
ซึ่งเชื่อมโยงไปถึงการท่องเที่ยวเชิงนิเวศน์ ซึ่งในขณะนี้ทั่วโลกกำลัง
ให้ความสนใจในผลิตภัณฑ์จากธรรมชาติ การสำรวจศักยภาพของพืชที่ให้สีย้อมในชุ
มชนเป็นสิ่งสำคัญที่จะต้องทำ และเพื่อเป็นการอนุรักษ์องค์ความรู้ในการย้อมสีผ้าในชุมชนได้อีกด้วย
การศึกษาครั้งนี้ทำการสัมภาษณ์กลุ่มชาติพันธุ์ไท-ลาว ใน 15 หมู่บ้าน 9 อำเภอ
ในจังหวัดร้อยเอ็ดเกี่ยวกับการย้อมสีผ้าแบบพื้นบ้านและชนิดของพืชที่นำมาย้อมสี
ผ่านการสัมภาษณ์เดี่ยวโดยใช้แบบสัมภาษณ์แบบกึ่งโครงสร้าง และสัมภาษณ์แบบเฉพาะกลุ่ม
พบพืชให้สีทั้งหมด 56 ชนิด 50 สกุล 31 วงศ์ ที่ใช้ในการย้อมสีผ้า โดยใช้ย้อมทั้งผ้าไหมและผ้าฝ้าย
วงศ์ที่พบมากที่สุดคือวงศ์ Fabaceae (11 ชนิด 19%) รองลงมาเป็นวงศ์ Anacardiaceae (5 ชนิด 9%)
ลักษณะวิสัยของพืชให้สีย้อมเป็นไม้ต้นมากที่สุด (36 ชนิด 65%) รองลงมาเป็นไม้พุ่ม และไม้ล้มลุก
(อย่างละ 8 ชนิด 16% เท่ากัน) และไม้เลื้อยพบน้อยที่สุด (4 ชนิด 7%)
เปลือกไม้เป็นส่วนที่ได้รับความนิยมในการนำมาสกัดสีย้อมมากที่สุดที่ (25 ชนิด 42%) รองลงมาเป็นใบ (12
ชนิด 20%) และผล (9 ชนิด 15%) สวนหลังบ้านเป็นแหล่งที่พบพืชให้สีย้อมมากที่สุด (30 ชนิด 53%)
รองลงมาเป็นป่าชุมชน (16 ชนิด 28%) โดยพบว่าพืชที่ให้สีย้อมที่มีค่า UV สูงที่สุด 0.60 เท่ากัน ได้แก่ คราม
(*Indigofera tinctoria* L.) และ ประดู่ (*Pterocarpus indicus* Willd.) โทนสีน้ำเงิน ฟ้า เป็นเฉดสีที่ผลมีค่า
IAR สูงสุด คือ 0.92 รองลงมาเป็นสีดำ ICF เท่ากับ 0.84 เฉดสีที่ได้จากการศึกษาครั้งนี้มีทั้งหมด 10 เฉดสี
จากพืช 56 ชนิด เฉดสีที่มีจำนวนชนิดพืชมากที่สุดคือ น้ำตาล/ น้ำตาลอ่อน/ น้ำตาลทอง (14 ชนิด 25%)
รองลงมาเป็นสีเขียว /เขียวเข้ม/ เขียวอ่อน (13 ชนิด 23%) พบสารช่วยติดสี (mordants) ทั้งหมด 9 ชนิด
ได้แก่ สารส้ม จุนสี เกลือ, สนิม, น้ำปูนใส สารส้ม, น้ำมะขามเปียก, ขี้เถ้า, และน้ำโคลน
การศึกษาครั้งนี้พบพืชที่อยู่ในบัญชีรายชื่อพืชที่มีความเสี่ยงของ IUCN Red List ทั้งหมด 3 ชนิด คือ
ยางนา (*Dipterocarpus alatus* Roxb. & G.Don), สะแบง (*Dipterocarpus obtusifolius* Teijsm. ex
Miq.) และประดู่ (*Pterocarpus indicus* Willd.) ผลการศึกษาครั้งนี้จะนำไปสู่การอนุรักษ์พืชในชุมชน
ไทลาวและยังช่วยฟื้นฟูวัฒนธรรมการย้อมสีผ้าด้วยวัสดุธรรมชาติให้คงอยู่ต่อไปในชุมชน
และจะเป็นต้นแบบที่ดีในการอนุรักษ์องค์ความรู้พื้นบ้านให้กับชุมชนอื่นๆ ในประเทศไทยได้อีกด้วย.
คำสำคัญ; ผลิตภัณฑ์จากพืช, สี, การเปลี่ยนแปลงทางสังคม, การให้บริการทางนิเวศวิทยา,
กลุ่มชาติพันธุ์ไท-ลาว, พฤกษศาสตร์พื้นบ้าน.

Key Words: Plant product, colors, cultural change, ecosystem services, Tai-Lao ethnicity, ethnobotany.

Introduction

Dye plants have been cultivated and used since ancient times (Zohary et al. 2012) and the earliest persisting indication of textile dyeing comes from an over 5000-year-old piece of cloth colored with natural madder (*Rubia cordifolia* L.) that was discovered at Mohenjodaro in Pakistan (Mahanta and Tiwari 2005). Other early records of dyeing textiles with extracts from plants originate in the Indus valley civilization at Mahenjodaro and Harappa (3500 B.C.E.), and ancient Egypt and China (Siva 2007). The use of natural dye for many coloring purposes, including textile dyeing, by Phoenicians, Hebrews, and Venetians was common in the beginning of thirteenth century (Dogan et al. 2008). Dyeing textiles with plants also existed in pre-Columbian Central- and South America (Jurasekova et al. 2010).

In addition to coloring fabrics, dye plants have been used to enhance the quality of people's lives by spicing and decorating food, decoration of crafts (Guarrera 2006), hair, and the human body (Liu et al. 2014). This occurred in northwestern Argentina for dye plants in general (Lambare et al. 2011), for weavers in Iraq (Mati and de Boer 2010), and in Turkey 123 dye plants species in 50 families were used for coloring textiles for carpets and rugs (Dogan et al. 2003). Also in Europe, dye plants have been used as household dyes in Italy (Guarrera 2006) among others. For textile dyeing plants, there are records from Japan for textiles (Hill et al. 2000; Balfour-Paul 2002). In Malaysia, 51 plant species were identified as sources of natural dyes used mostly for body paints by the Orang Ulu, an informal collective name for several ethnic groups on the island of Borneo (Rosli et al. 2015). In India, nearly 450 plant taxa are known to yield dyes for a variety of purposes including the dyeing of textiles (Siva 2007). In Dong communities in China, researchers found 13 species from 9 families used as dyes to color textiles and food (Liu et al. 2014). Furthermore, the study of dyeing plants in China was found by Han (2015) who identified historical Chinese dye plants in four important dye manuscripts of the Ming and Qing dynasties (1368–1911). Through investigation, systematic and reliable resources for plant names, dyeing properties, and typical desired coloring effects for the dyes of common dye plants has been identified. In northern Vietnam, 54 ethnic communities used 43 different plants as food colorants (Luu-dam et al. 2016). In Sapa in northwestern Vietnam, the Hmong extract the blue indigo compound from the leaves of *Strobilanthes cusia* (Nees) Kuntze—the Assam indigo—in a process where the leaves are fermented and oxidized to produce a blue powder (Bate 2012). In Thailand, many ethnic groups continue to practice textile dyeing in traditional weaving with plant extracts, which is different and unique in each ethnic group (Meesin 2010). Their world famous hand-woven fabrics such as Thai silk and others are part of that tradition, and weaving provides additional income to many families, especially in rural areas (Nilvarangkul et al. 2006). In northeastern Thailand, 2 previous studies recorded 51 species (Hongtongdang 2005) and 80 species of dye plants (Meesin 2010).

Colors obtained from natural dyes depend on the concentration of the chemicals in the plants, the plant part used, the season in which the material was collected, the growth stage of the plant, and the use of mordants (Lambare et al. 2011). The plant material that is used in textile dyeing can be fresh, dried, or fermented (Meesin 2010). Dyes extracted from the various plant parts may be weak, and their permanency varies from plant to plant and traditional techniques of preparation (Meesin 2010). Use of multiple plant parts in certain proportions may increase the durability of the dye. Sometimes special techniques such as heat and cold treatment may increase dye stability.

Normally, the color of newly dyed textiles is lighter and not always very pure. Therefore, the producers add a so-called mordant to make the binding tight and to help fixing the colors to the fiber and lighten the fabric to produce brighter colors.

Traditional natural plant dyes for silk, wool, and cotton fibers have over time been replaced by synthetic dyes (Hartl and Vogel 2003) because they were cheaper, more easily available, of consistent quality, with greater color fastness, and more stable (MacFoy 2004). Unfortunately, synthetic dyes may have negative side effects for humans and the environment, including health and safety risks such as cancer, caused by the toxic mordants (MacFoy 2004). For example, 63% of women in a sample from northeastern Thailand developed skin rashes and had respiratory problems from inhaling fumes from the chemicals used to bleach silk and cotton (Nilvarangkul et al. 2004). Furthermore, in blood tests to identify levels of toxic metallic compounds from 40 weaving women in northeastern Thailand, two samples contained heavy metals, which may have originated from the synthetic dyes since mordants are not used with synthetic dyes (The Study and Development of Home-Based Work in the Northern Region 1997).

As a counter current to the use of synthetic dyes, there has been recurring interest over the past decades in natural textile dyes because of growing awareness of the toxicity (Lawarence et al. 2015) and pollution resulting from the production and use of synthetic colorants (Mahanta and Tiwari 2005; Teron and Borthakur 2012). Consequently, the demand for natural dyes has increased. As in Thailand, indigenous people in many parts of the world now reduce their dependence on synthetic textile dyes and go back to dyeing with plants. This is happening in Turkey (Bollag 1998), southwestern USA (Redfern 2001), and Ghana (Acquah and Oduro 2012). In India, dyeing with local plants for many different uses is also being reintroduced (Das and Mondal 2012). Also in the industrial textile production, plant-based natural dyes have emerged as important alternatives to synthetic dyes for the same reasons as in the artisanal plant textile coloring (Bhuyan and Saikia 2003, 2005; Samanta and Agarwal 2009). This increased use of natural dyes is being promoted in many recent studies (Hill et al., 2000; Balfour-Paul 2002; Siva 2007; Samanta and Agarwal 2009; Wanyama et al. 2011; Liu et al. 2014). Silk and cotton dyed with natural products is also in high demand among tourists even if they are much more expensive than textiles dyed with synthetic colorants (Meesin 2010).

Unfortunately, plant-based dye resources and their associated traditional knowledge are being threatened by globalization, including changing lifestyles of rural populations, the growing generation gap wherein knowledge transmission between older and younger folks is threatened, urbanization which involves remoteness to the natural habitats, and others (Gilbert and Cooke 2001; Mati and de Boer 2010). Although some indigenous communities in remote areas continue to use dye plants for coloring fabrics and for generating economic income, they often experience a rapid depletion of raw materials and resources. In northeastern Thailand, as in many other parts of the world such as in the Kurdish Autonomous Region (Mati and de Boer 2010), traditional knowledge of dye plants is no longer common among weavers. Abandonment of weaving, the nomadic life, and recent changes in the economy in northeastern Thailand have contributed to significant changes in the culture of natural dyes (Meesin 2010). This erosion of traditional knowledge concerning plant dyes is found in remote areas all around Thailand where weaving and dyeing fabrics from plants used to be common (Hongtongdang 2005).

Due to abandonment of weaving in general, traditional knowledge of natural dye plants is no longer as common as it used to be. Unfortunately, this treasure chest of knowledge of textile dye plant species and natural dye preparations remains understudied. Two previous studies presented in the Thai language provide some information about the northeastern Thai traditions of textile dyeing with local plants. The first (Hongtongdang 2005) described the use of natural textile dyes in the province of Nakhon Ratchasima northeast of Bangkok and listed 51 species that produced 6 different colors. It provided scientific plant names and descriptions of the plants and their uses. The second reference (Meesin 2010), although in a popular format, was based on 150 interviews made all over northeastern Thailand. It lists 80 different dye plants used for producing 10 colors, and for each species information is given about scientific and common names and how they used, and also describes 12 kinds of mordant. Our study covers the same themes as these popular treatises, but we provide scientific documentation of the plants used and the procedures employed, and we focus on one particular ethnic group.

We are witnessing a cultural system in flux and under the influence of opposing trends: loss of knowledge due to urbanization and change of life styles on the one hand, and growth of cultural tourism that produces renewed interest in ethnic traditions, including weaving and textile dyeing with natural colors on the other. With the growing interests in the use of textile dye plants, the need to explore the relevant plant species, and the knowledge and sources of natural dyes, has become imperative. If the dye species disappear, it is only a matter of time before the local knowledge related to them vanishes as well. Therefore, it is essential that proper documentation and conservation measures are undertaken to preserve these natural dye-yielding plants (Das and Mondal 2012).

Given the potential knowledge decline and genetic erosion in northeastern Thailand, the objective of this study was to document the traditional knowledge of local plants species used for textile dyeing by the Tai-Lao ethnic group in the Roi Et province.

Methods

Study Area

Northeastern Thailand, or Isan as it is usually known, stretches from the Mekong River (Mae Nam Khong in Thai) to the edges of the Khorat Plateau. This region of Thailand covers 170,000 km^2 (Office of Agricultural Economics 2004) and has more land dedicated to agriculture than the rest of the country (9.25 million hectares) (Field Crops Research Institute 2001). Approximately 30% (17 million) of the Thai population live in the region (Keyes 1989), and 94% of reside in rural areas (Office of Agricultural Economics 2004). The Isan people (northeastern Thai) constitute an ethno-regional group (Hattaway 2004). Like Thais and Laotians, they belong to the linguistic family of Tai peoples. Almost all inhabitants of Thailand's northeast are Thai nationals. Most of them belong to the Tai-Lao ethnic group (Prachaiyo 2000). Yet a majority of them (approximately 80%) (Grabowsky 1995) are ethnically Laotians and speak a variant of the Lao language when at home (the Lao dialects spoken in northeastern Thailand are usually denominated as Isan language). Farming is the major occupation of 80% of the population of the region and, on average, 75% of the household income comes directly from farming. Major crops are paddy rice (*Oriza sativa* L.), cassava (*Manihot esculenta* (L.) Crantz), and sugar cane (*Saccharum officinarum* L.). Agricultural production remains low due to the relatively dry climate and the salinity of the soils (Vityakon et al. 1988). The natural vegetation of this region is dry monsoon forest, primarily composed by dry dipterocarp forest (Parnwell 1988; Prachaiyo 2000), with *Dipterocarpus tuberculatus* Roxb., *D. obtusifolius* Teijsm. ex Miq., *Shorea obtusa* Wall., *S. siamensis* Miq., *Xylia xylocarpa* (Roxb.) Taub., *Irvingia malayana* Oliv. ex A.W. Bennett, *Cratoxylum formosum* (Jack) Dyer., and *Careya arborea* Roxb. as dominant species (Tipraqsa 2006).

Roi Et is one of the 17 provinces in northeastern Thailand. Its geographical extension is 8299 km^2, and it is located at approximately 16°03′ N latitude and 103° 39′ E longitude (Fig. 1). We selected 15 villages inhabited by the Tai-Lao ethnic group in which hand-weaving of textiles and natural dyeing was still common. The data were collected in nine districts in Roi Et province (Fig. 1).

In Roi Et province, modern and traditional textile dyeing are common and important in people's lives. The province is the home of seven ethnic groups including Tai-Lao, Phu-Tai, Tai-Kamon, Tai-Suey, Tai-Yaw, Tai-Co Rat, and Gu La. Of these, Tai-Lao is the largest, not only in Roi Et but also in northeastern Thailand in general. Traditionally, knowledge of textile dye plants and their processing in Tai-Lao communities was transferred from generation to generation. The traditional local textile products in Roi Et province are hand-woven silk and cotton with colorful and exquisite patterns. Each silk-weaving village has a housewife group selling village products. However, recent changes accompanying globalization have caused significant changes in the traditional lifestyle, including the natural textile dyeing culture. Abandonment of weaving as a consequence of labor migration to the capital has been common in northeastern Thailand, and traditional knowledge of natural dye plants is no longer as common among weavers as it used to be. Many young Tai-Lao people look for jobs outside of their communities. Nevertheless, interest in the use of plant dyes in Roi Et has been revived due to new market demands and the growth of rural tourism, and it is possible that traditional knowledge will provide an alternative for the diversification and quality of existing crafts in the same way as it has happened in the Dong communities in China (Liu et al. 2014).

Data Collection

We gathered data on plant dyes, including local and scientific names, plant parts used, colors and shades obtained through dyeing, method of preparation, and the traditional knowledge of dyeing. Ethnobotanical indices were used to analyze the data to identify the most important textile dye plant

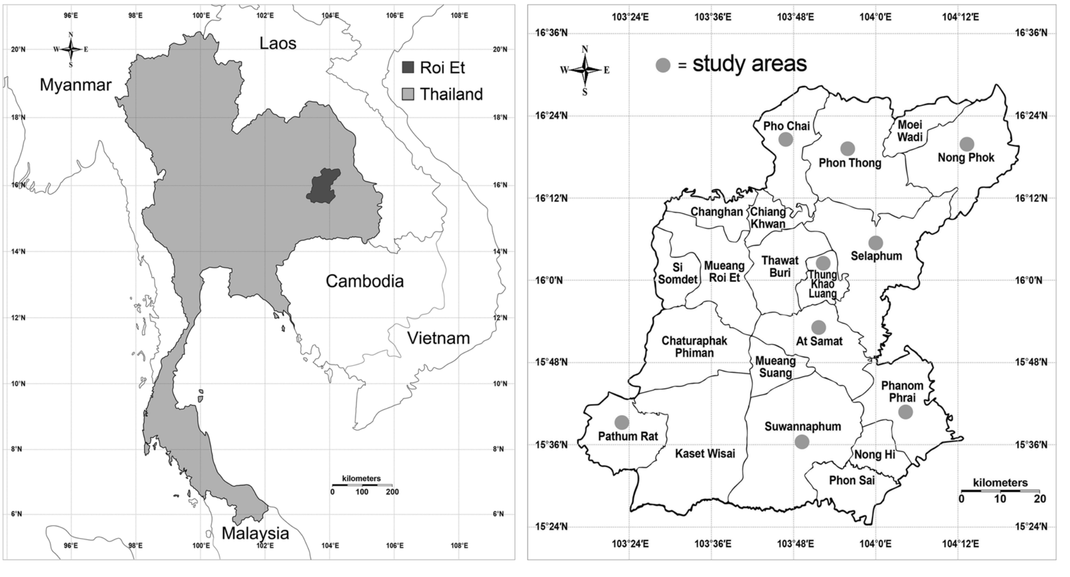

Fig. 1. Location of Roi Et province in Thailand (left) where ethnobotanical data concerning textile dye plants were collected in nine districts (right).

species and homogeneity of dyeing knowledge among the Tai-Lao.

We used the snowball sampling technique to recruit informants (Bernard 2000). Local experts and/or persons active in textile dyeing were selected, and those who agreed to participate in the study were interviewed. Traditional knowledge of the textile dyeing process and plant species was gathered through individual semi-structured interviews, as well as group interviews with focus groups with selected informants from August 2014, to May 2015. In total, 60 informants (59 females and one male) organized into cooperatives and groups were selected and interviewed. In each of the 15 villages, we interviewed 3–5 key informants individually, and subsequently we performed a group interview with the same informants. The age of informants ranged from 34 to 78 years. Interviews consisted of a short conversation starting with a presentation of the background for the research, and prior informed consent was obtained before proceeding with data collection. Personal data on the informant was gathered in the beginning of each session noting the informants' age, educational level, gender, and occupation (Martin 2004). Questions were limited to current uses (active knowledge) and we did not ask about previous traditions (passive knowledge). We asked about local names of plants, the plant parts used for dye extractions, the textile dyeing process, colors, habitats where they collected dye plant, and how to collect them. Species were initially identified on the basis of their common names following *Tem Smitinand's Thai Plant Names* (Pooma and Suddee 2014). Subsequently, voucher specimens were collected and brought to the herbarium of the Queen Sirikit Botanical Garden (QSBG) for taxonomic identification based on the Flora of Thailand treatments and comparison with existing collections by Dr. Wattana Tanming. The voucher specimens were collected with the help of the informants in forest areas adjacent to the villages and in home gardens. The vouchers are kept in the herbarium of Department of Science and Technology, Roi Et Rajabhat University, Roi Et province, Thailand.

Data Analysis

The *use value index* (UV, Phillips et al. 1994) was calculated to determine the most important textile dye plant species used by the Tai-Lao:

$$UV = \frac{\sum Ui}{N}$$

Ui is the number of uses mentioned by each informant for a given species and *N* is the total number of informants. UV for species are low (approaching 0) when there are few reports related to their use and high (approaching 1.0) when there are many use-reports, implying that the plants are important.

We used the *informant consensus factor (ICF,* Trotter and Logan 1986*)* to analyze the homogeneity in knowledge of textile dyeing plants among the Tai-Lao:

$$\mathrm{ICF} = \frac{Nur - Nt}{(Nur - 1)}$$

Nur refers to the number of use-reports for a particular color shade and *Nt* refers to the number of taxa used for a particular use category by all informants. ICF values range from 0 to 1 and are low (approaching 0) if plants are chosen randomly or if there is no exchange of information about their use among informants. ICF approaches one (1.0) when there is a well-defined selection criterion in the community. It indicates a high degree of consensus and/or if information is exchanged between informants (Gazzaneo et al. 2005).

Results

Plant Preparation for Dyeing Fabrics

The Tai-Lao villagers prepared plant materials for textile dyeing in different ways depending on what species they used. The plant material was used in a dry form, for example, *Caesalpinia sappan* L., fresh, *Mangifera indica* L., or fermented, such as, *Indigofera tinctoria* L. For dried and fresh plants the processing was similar. The pounded (macerated) bark, stem, roots, or (chopped) leaves were placed in a pot with water, and boiled for 30–60 min or until the desired intensity of coloration was achieved. The amount of plant material and water used depended on the amount of fabric to be dyed and the state of the plant material (fresh or dry). Both cold and hot extractions of dye plant were used. Some examples that represent the range of the traditional textile dyeing processes of the Tai-Lao are shown in Table 1.

Traditional Dyeing Process

Before dyeing cotton or silk the fabrics were thoroughly soaked in clean water and the water squeezed out or the material was left to drip off excess water. The fabrics should not be dried, as it had to be processed while wet so that the dye would penetrate and fix well onto the fibers. Other methods of preparation included, for silk, boiling the fabric with soap for 30–60 min to remove the protein or any remaining starch. This increased the ability of the fabric to absorb the dyes. Otherwise the fabric to be dyed was soaked in warm water for 15–30 min and squeezed. The wet fabric was then immersed in the dye bath with a stick and left there for 30–60 min and stirred every 10 min to achieve the desired level of coloration. The timing of the dyeing process was different depending on what species and plant part were used, and it also depended on the desired level of coloration. Normally, the fabrics were boiled in a stainless steel dye pot for 1–2 h. For dyeing 1 kg of silk fibers, 1–50 l of water and 1–3 kg of dried and ground plant parts were put into a large pot and boiled over a low heat for 1 h with the fibers inside. To prevent evaporation, the pot was kept closed. From time to time, the mixture was stirred to make dyeing uniform. The fabric was then immersed again as before, three or four times until the desired color was achieved. However, the fabric could be left in the dye bath until the desired shade was achieved, and the dye bath could be kept and reused. So, the level of coloration increased with repeated dyeing. The dyed fabric was then taken out from the mixture and washed with cold water and then rinsed until the water was clear before being hung on strings for air-drying in the shade. For indigo-blue from *Indigofera tinctoria*, the Tai-Lao had their own traditional knowledge for dyeing. A blue coloration was achieved by letting the leaves and stems ferment for several days or even up to 1–3 months.

There were special restrictions or taboos for dyeing. Women were not allowed to dye during their menstrual period or when they were pregnant, because they believed that the desired color could not be achieved under those conditions. Dyeing was also prohibited on Buddhist's Day, again because they believed that the desired color could not be achieved under those conditions.

Mordant substances were commonly used to make dyeing substances purer and to produce different colors. Mordants, as elsewhere, were added to the pot with dried and ground plant parts. We registered nine mordants including: alum, chrome (potassium dichromate; $K_2Cr_2O_7$), copper sulfate ($CuSO_4$), iron oxide (Fe_2O_3), tamarind juice (tartaric acid), salt (NaCl), lime (calcium oxide; CaO), ash (potassium hydroxide; KOH), and mud from the river or pond near the village. Furthermore, the Tai-Lao made a pink-shaded color from the lac insect (*Laccifer lacca* Kerr) for which the Thai and Tai-Lao people use the

Table 1. Some examples showing the range of proportions of plant material and the process of dyeing among Tai-Lao in Northeastern Thailand.

Species	Plant material in kg	Water in liter	Mordant and amount in liter and grams	Boiling time in hours	Fabric in kg
Indigofera tinctoria L.	Leaves 1 (Fermented 1–3 months)	1–5	Tamarind juice 100 Ash water (3 l. fermented)	-	Cotton, Silk 1
Terminalia catappa L.	Leaves 1 (fresh)	3	Salt 30	1	Silk 1
Syzygium cumini (L.) Skeels.	Barks 2 (Dried)	15	Tamarind juice 200	2–3	Silk 1
Murraya paniculata (L.) Jack	Leaves 1 (Fresh)	10	Salt 100	3	Silk 1
Oroxylum indicum (L.) Kurz	Bark 3 (Fresh)	15	-	8–10	Silk 1
Musa × *paradisiaca* L.	Stem (fired) 1 (fermented overnight)	50	Soap 100	1	Silk 1

vernacular name Crang. This insect is associated with certain plant species such as *Samanea saman* (Jacg.) Merr. and *Mangifera indica* L. The lac may be collected by the dyers themselves or they may buy them from farmers who cultivate the insect.

The Tai-Lao Dye Plants

A total of 56 species in 50 genera and 31 families were identified as textile dyeing plants among the Tai-Lao. All of these were used for dyeing cotton and silks (Table 2). Fabaceae had most dye species (11), followed by Anacardiaceae (5) (Fig. 2).

The most common life form of the dye plant species was trees with 36 species (64%) followed by shrubs and herbs with 9 species (14% each), and climbers with 4 species (7%).

The most common plant part used for extracting textile dye from the 56 species of plants was the bark, which was used in 25 species, followed by the leaf (12 spp.), and the fruit (9 spp.). Flowers, stems, whole plants, roots, and seeds were also used for dyeing, but from less than 5 species each.

Most textile dye plant species (30 spp.) were collected in home gardens followed by community forests (15 spp.), whereas orchards, sacred forest, and paddy fields each provided four dye plant species. Finally, the lowest number of dye plant species was found along the road side (1 sp.).

Among the 56 species used for textile dyeing, 3 are on the IUCN Red List, including *Dipterocarpus alatus*, *Dipterocarpus obtusifolius*, and *Pterocarpus indicus* Willd.

Numbers of Different Plant Species Producing Each Color

We found ten different colors extracted from dye plants. Brown/pale-brown/golden-brown, green/pale-green/dark-green, and yellow/golden-yellow/yellow-green were the three colors derived from most species, each of them originating from between 10 and 14 different plant species. A middle group, in terms of number of species, were pink/pale-pink/brown-pink and gray/dark-gray colors, which were derived from five and seven plant species, respectively. Colors derived from only two to three different plant species were violet/purple, red/red-brown/pale-red, orange/pale-orange/cream/pale-cream, black, and blue/indigo-blue.

Use Value Index (UV) and Informant Consensus Factor (ICF)

The most important and widely used dye plants species among Tai-Lao groups in Roi Et province were *Indigofera tinctoria* and *Pterocarpus indicus* with the highest UV (0.60) followed by *Eucalyptus globulus* Labill., *Mangifera caloneura* Kurz., and *Mangifera pentandra* Hook. F. (UV = 0.56 each) (Table 2).

Blue/indigo-blue had the highest degree of consensus with ICF of 0.92 based on the use of *Bombax ceiba* L. and *I. tinctoria* and followed by black with ICF = 0.84 based on the use of *Cocos nucifera* L. and *Diospyros mollis* Griff. Some other colors also had high degrees of consensus with ICF values greater than 0.7 including orange/pale-orange with 0.75 based on the use of *Nyctanthes arbor-tristis* L. and *P. indicus* (Table 3).

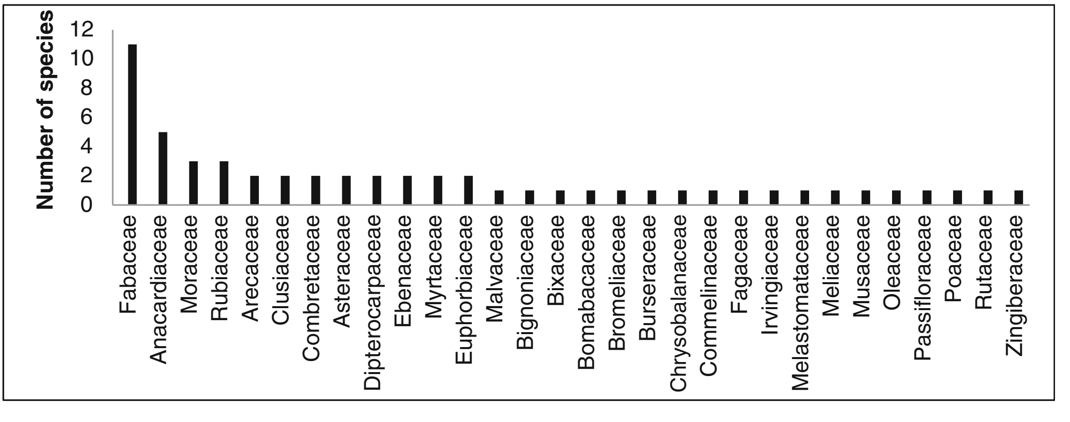

Fig. 2. The number of plant species used as textile dyes in various plant families in Roi Et province, Thailand.

TABLE 2. FIFTY-SIX DYE PLANTS USED BY THE TAI-LAO IN ROI ET PROVINCE, THAILAND.

Species	Family	Vernacular name	Obtained color	Plant part used	Fabric type: Silk	Fabric type: Cotton	Habitat	Life form	UV	Voucher no.
Anacardium occidentale L.	Anacardiaceae	Ma Muang Himmaphan	Pink	Bark	√	√	Community forest	Tree	0.04	AJ-36
Ananas comosus (L.) Merr.	Bromeliaceae	Mak Nut	Yellow	Leaf	√	√	Home garden	Herb	0.04	AJ-37
Areca catechu L.	Arecaceae	Mak	Red	Fruit	√	√	Home garden	Tree	0.04	AJ-38
Artocarpus heterophyllus Lam.	Moraceae	Mak Mee	Yellow	Bark	√	√	Home garden	Tree	0.34	AJ-01
Azadirachta indica A. Juss.	Meliaceae	Sa Dao	Brown, golden-yellow	Bark	√	√	Home garden	Tree	0.39	AJ-02
Bauhinia sp.	Fabaceae	Krua Tong Ang	Brown	Stem	√	√	Sacred forest	Climber	0.04	AJ-30
Bixa orellana L.	Bixaceae	Kam Sad	Red	Bark, Seed	√	–	Community forest	Tree	0.21	AJ-04
Bombax ceiba L.	Bombacaceae	Ngew Nam	Blue	Bark	√	√	Community forest	Tree	0.13	AJ-03
Caesalpinia sappan L.	Fabaceae	Phang	Red, pink	Stem	√	√	Home garden	Tree	0.13	AJ-39
Canarium subulatum Guillaumin	Burseraceae	Mak Kok	Gray-purple	Fruit	√	–	Community forest	Tree	0.08	AJ-40
Cassia fistula L.	Fabaceae	Koon	Brown, yellow	Bark, fruit	√	√	Home garden	Tree	0.3	AJ-05
Castanopsis piriformis Hickel & A. Camus	Fagaceae	Kaw	Brown	Bark	√	–	Community forest	Tree	0.08	AJ-34
Catunaregam tomentosa (Blume ex DC.) Tirveng.	Rubiaceae	Nam Tang	Gray	Bark	–	√	Community forest	Tree	0.04	AJ-41
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	Sap Suea	Gray-green	All part	√	–	Along the road	Herb	0.04	AJ-44
Clitoria ternatea L.	Fabaceae	Anchan	Purple, violet	Flower	√	√	Home garden	Climber	0.21	AJ-33
Cocos nucifera L.	Arecaceae	Mak Praw	Violet, black	Bark	√	–	Home garden	Tree	0.3	AJ-06
Coffea sp.	Rubiaceae	Ka Fae	Brown	Fruit	√	–	Home garden	Shrub	0.08	AJ-42
Curcuma longa L.	Zingiberaceae	Ka Min	Yellow	Root	√	√	Home garden	Herb	0.08	AJ-43
Cymbopogon citratus Stapf	Poaceae	Ta Krai	Green-golden	Leaf	√	–	Home garden	Herb	0.08	AJ-45
Dialium cochinchinense Pierre	Fabaceae	Keng	Red-brown, pale-brown	Bark	√	–	Community forest	Tree	0.47	AJ-09
Diospyros mollis Griff.	Ebenaceae	Ma Kluea	Black	Fruit	√	√	Sacred forest	Tree	0.26	AJ-07
Diospyros rhodocalyx Kurz	Ebenaceae	Tako Na	Brown	Fruit	√	–	Paddy field, orchard	Tree	0.13	AJ-25
Dipterocarpus alatus Roxb. ex G.Don	Dipterocarpaceae	Yang Na	Brown	Bark	√	–	Paddy field, orchard	Tree	0.13	AJ-24
Dipterocarpus obtusifolius Teijsm. ex Miq.	Dipterocarpaceae	Sabang, Yangrad	Cream, pale-cream	Bark	√	–	Paddy field, orchard	Tree	0.08	AJ-29
Eucalyptus globulus Labill.	Myrtaceae	Yu Ka	Pale-brown	Leaf, bark	√	–	Paddy field, orchard	Tree	0.56	AJ-11
Garcinia dulcis (Roxb.) Kurz	Clusiaceae	Pra Hoad, Ma Phut	Yellow	Bark	√	√	Sacred forest	Tree	0.3	AJ-12
Garcinia mangostana L.	Clusiaceae	Mung Khut	Purple	Fruit, bark	√	–	Home garden	Tree	0.13	AJ-32
Hibiscus rosa-sinensis L.	Malvaceae	Cha Ba	Pale-pink	Flower	√	–	Home garden	Shrub	0.04	AJ-46
Indigofera tinctoria L.	Fabaceae	Kram	Blue/indigo-blue	All part	√	√	Home garden	Shrub	0.60	AJ-15
Irvingia malayana Oliv. ex A. Benn.	Irvingiaceae	Mak Buk	Dark-gray	Bark	√	√	Community forest	Tree	0.34	AJ-16
Jatropha gossypiifolia L.	Euphorbiaceae	Sabu Luead	Pale-green	Leaf	–	√	Community forest	Herb	0.3	AJ-47
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Kraset	Pink	Bark	√	√	Home garden	Shrub	0.17	AJ-17
Maclura cochinchinensis (Lour.) Corner	Moraceae	Kaelae, Kae	Yellow	Stem	√	√	Sacred forest	Climber	0.3	AJ-18
Mangifera indica L.	Anacardiaceae	Ma Muang	Dark-green	Bark	√	√	Home garden	Tree	0.08	AJ-48
Mangifera caloneura Kurz	Anacardiaceae	Ma Muang Pa	Pale-green	Bark	√	√	Home garden	Tree	0.56	AJ-21

(Continued)

TABLE 2. (CONTINUED).

Species	Family	Vernacular name	Obtained color	Plant part used	Fabric type: Silk	Fabric type: Cotton	Habitat	Life form	UV	Voucher no.
Mangifera pentandra Hook.f.	Anacardiaceae	Ma Muang Noi	Pale-green	Bark	√	√	Home garden	Tree	0.56	AJ-21
Memecylon edule Roxb.	Melastomataceae	Plong	Green	Leaf	√	–	Community forest	Shrub	0.08	AJ-26
Morinda citrifolia L.	Rubiaceae	Yaw Pa	Yellow	Root	√	–	Home garden	Tree	0.08	AJ-08
Morus alba L.	Moraceae	Mon	Yellow	Fruit	√	–	Home garden	Shrub	0.17	AJ-50
Murraya paniculata (L.) Jack	Rutaceae	Kaew	Green, pale-green	Leaf	√	√	Home garden	Shrub	0.47	AJ-13
Musa x *paradisiaca* L.	Musaceae	Kuay	Pale-green	Stem	√	–	Home garden	Herb	0.34	AJ-14
Nyctanthes arbor-tristis L.	Oleaceae	Kan Ni Ka	Orange	Flower	√	–	Home garden	Shrub	0.08	AJ-51
Oroxylum indicum (L.) Benth. ex Kurz	Bignoniaceae	Linn Fa	Green, yellow-green	Bark, leaf	√	√	Home garden	Tree	0.3	AJ-10
Passiflora laurifolia L.	Passifloraceae	Sao Wa Rod	Pink	Fruit	√	√	Home garden	Climber	0.13	AJ-31
Parinari anamensis Hance	Chrysobalanaceae	Ma Pok	Gray-brown	Bark	√	–	Community forest	Tree	0.08	AJ-52
Peltophorum dasyrhachis (Miq.) Kurz	Fabaceae	A Rang	Brown	Bark	√	√	Community forest	Tree	0.08	AJ-19
Phyllanthus acidus (L.) Skeels	Euphorbiaceae	Ma Yom	Brown-pink	Bark	–	√	Home garden	Tree	0.04	AJ-53
Pterocarpus indicus Willd.	Fabaceae	Pra Doo	Pale-orange, brown	Bark	√	√	Community forest	Tree	0.60	AJ-20
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	Khi Lek	Dark-green	Leaf	√	√	Home garden	Tree	0.21	AJ-27
Sesbania grandiflora (L.) Poir.	Fabaceae	Care	Green	Leaf	√	√	Home garden	Tree	0.04	AJ-54
Spondias pinnata (L.f.) Kurz	Anacardiaceae	Ma Kok	Pale-brown	Bark	√	–	Community forest	Tree	0.13	AJ-35
Syzygium cumini (L.) Skeels	Myrtaceae	Waa	Brown-gray	Bark	–	√	Community forest	Tree	0.08	AJ-55
Tagetes erecta L.	Asteraceae	Dao Rueang	Yellow	Flower	√	√	Home garden	Herb	0.04	AJ-56
Terminalia catappa L.	Combretaceae	Hu Kwang	Green	Leaf	√	–	Community forest	Tree	0.26	AJ-22
Terminalia chebula Retz.	Combretaceae	Sa Mor	Green	Leaf	√	–	Paddy field, orchard	Tree	0.34	AJ-23
Tradescantia spathacea Sw.	Commelinaceae	Kab Hoi Khraeng	Pink	Leaf	√	–	Home garden	Herb	0.04	AJ-28

TABLE 3. INFORMANT CONSENSUS FACTOR (ICF) FOR DYES RECORDED AMONG THE TAI-LAO IN ROI ET PROVINCE, THAILAND.

Colors/shades	Number of uses reported (Nur)	Number of species (Nt)	ICF
Blue/indigo-blue	14	2	0.92
Black	13	2	0.84
Orange/pale-orange/cream/pale-cream	5	2	0.75
Gray/dark-gray	13	6	0.58
Yellow/golden-yellow/yellow-green	23	11	0.54
Violet/purple	3	4	0.50
Pink/pale-pink/brown-pink	18	6	0.47
Green/pale-green/dark-green	22	13	0.42
Brown/pale-brown/golden-brown	23	14	0.40
Red/red-brown/pale-red	5	4	0.25

Discussion

THE TAI-LAO TEXTILE DYERS

The 60 informants in this study were all females except for one male. They were chosen for their knowledge of textile dyeing with local plants, indicating that this traditional knowledge is largely held by women. The age of the informants (34–76 years) was not related in any obvious way to the knowledge they possesses; some of the older informants knew fewer dye plants than the younger ones, and vice versa. This suggests that the process of declining biocultural knowledge is complex and not a simple matter of young people not being interested in learning from the older generation.

THE THAI-LAO DYE PLANTS

The Fabaceae included the largest number of species used for textile dyeing in our study site. This agrees with reports from India (Mahanta and Tiwari 2005), while in Malaysia Euphorbiaceae and Arecaceae had the largest number of taxa of dyeing plants (Rosli et al. 2015). The similarity between northeastern Thailand and India in terms of important plant families of textile dyeing plants maybe because both regions are heavily populated and largely covered by open, anthropogenic landscapes. The difference to Malaysia may be because the Malaysian study was done among forest dwellers in dense rainforests habitats where both Euphorbiaceae and palms are dominant elements of the vegetation.

Trees were the most common life form among the textile dye plants in northeastern Thailand, which has been a common finding in other dye plant studies. Bark was the most common plant part used to extract textile dyes in this study, which agrees with the situation in Sierra Leona that has similar climatic conditions (MacFoy 2004). In contrast, in northwestern Argentina in an area of subtropical montane climates, leaves were the most common plant part used for the extraction of dyes although these included dyes used for other than textile coloring (Lambare et al. 2011).

The dye plant species with a highest use value index (UV) were *I. tinctoria* and *P. indicus*, meaning that these two species were the most important and well-known textile dye plant species in the Tai-Lao community in Roi Et province. This goes hand in hand with the high ICF index values for blue/indigo-blue obtained from *I. tinctoria.* The higher ICF value indicates that taxa were used by many informants, thus inferring a high degree of consensus and a well-defined dye plant tradition (Gazzaneo et al. 2005). Plants with low use values are not necessarily unimportant, but having low use values may indicate that traditional knowledge about them is at risk of not being transmitted and that it may be gradually disappearing (Chaudhary et al. 2006). Additionally, the low use value of some plant species could be related to their recent introduction or to their scarcity (Benz et al. 1994). Maclura cochinchinensis *(Lour.) Corner was rare around the study villages and restricted to sacred forest, which may have restricted its use, but* our informants most commonly mentioned low quality as a reason not using a plant.

The use of textile dyes derived from plants has persisted in the Roi Et province in northeastern Thailand and it has remained an important element in the expression of the Tai-Lao communities' cultural identity through customary clothing. Most of the 56 textile dye species registered were also used for medicinal purposes.

The majority of the textile dye plants (53%) of the Tai-Lao came from their home gardens, which provided such dye plants as *I. tinctoria*, *Azadirachta indica* A. Juss., *Artocarpus heterophyllus*, and *Clitoria ternatea* L. (Table 2). These home garden plants were easy to access. Community forests, which provide plants not available in home gardens, were the second most important habitat of dye plants in the Tai-Lao communities. Although textile dye plants are still available in their community, deforestation and extensive raw material depletion of the forest occurs in many places. Managing these resources sustainably could help local communities to conserve traditional natural dyeing. In this way, the sustainable use of this natural resource could assist in the promotion of biodiversity and conservation (Peyre et al. 2006).

The occurrence of three of the natural dyes species on the IUCN Red List (*Dipterocarpus alatus*—endangered; *Dipterocarpus obtusifolius*—least concern; *Pterocarpus indicus*—vulnerable) suggest that documenting these and other species used for textile dyeing will provide additional arguments for their conservation. In addition to these Red List species, the rare *Maclura cochinchinensis* may be locally threatened, although its presence in the sacred forests around the village gives it some protection.

Colors Obtained from Tai-Lao Dye Plants

The Tai-Lao used their own customary approach to extract and process the natural textile dye, which is similar to the situation in India (Sutradhar et al. 2015). Ten different colors were obtained from eight different plant parts in this study. That dye plants yield different colors was reported in many studies. Eight different colors were derived from plants in Malaysia, though these were mostly used for body paintings (Rosli et al. 2015). In northwestern Argentina, six different natural plant colors were reported (Lambare et al. 2011). Five different colors derived from dye plants was reported from the Dong community in China (Liu et al. 2014), and the same number was found in Italy (Guarrera 2006). Often the same species is used as a source of textile dyes in many different countries. This is true for *Azadirachta indica* (bark) which produced a brown-golden-yellow color in Roi Et province, but was used to extract a red-brown color in Ghana (Acquah and Oduro 2012), whereas in Uganda it produced medium to fairly dark shades (Wanyama et al. 2011). *Caesalpinia sappan* reported in this study as a source of red or pink colors and *Tagetes erecta* L. as a source of yellow dye are also used in India to produce the same colors (Siva 2007). The well-known blue dye from leaves of *I. tinctoria* reported here is also used in other parts of Southeast Asia such as in Laos for traditional textile dyeing (Tagwerker 2009). The Tai-Lao in northeastern of Thailand are related to the Laos people not least through their language, and so are similar culturally and socially. Furthermore, indigo-blue from *I. tinctoria* is also used by the Hmong in Vietnam (Bate 2012). In many other parts of the world such as in Italy (Gilbert and Cooke 2001), Iraq (Mati and de Boer 2010), and India (Teron and Borthakur 2012), this species is also used for dyeing textiles using the same method. Red dye from wood of *Caesalpinia sappan* was also found in China (Han 2015). However, blue dyes such as indigo-blue can also obtained from *Strobilanthes cusia* (Nees) Bremek, which occurs in the northern but not northeastern parts of Thailand. The same is true for the orange color derived from the bark and seeds of *Bixa orellana* L. (Mahanta and Tiwari 2005).

The ten main colors registered here were: yellow, red, green, brown, gray, pink, orange, purple, black, and blue. These same colors were also found in a study in Turkey (Dogan et al. 2003). Some colors can be obtained from only one species such as orange, which can only derived from flowers of *Nyctanthes arbor-tristis* L. In other cases, the same color can be produced from many species, such as blue from the bark of *Bombax ceiba* L. and the leaf of *I. tinctoria*, or yellow from leaves of *Ananas comosus* (L.) Merr., bark of *Artocarpus heterophyllus* Lam., roots of *Curcuma longa* L., and/or flowers from *Tagetes erecta*. A likely explanation of the relatively high number of colors extracted could be the current market demand resulting from ecotourism and cultural tourism especially in northeastern Thailand. This potential source of income has encouraged weavers to search for new colors to dye their silk and cotton products.

Tai-Lao Use of Mordants

Using mordants was part of the traditional knowledge of natural textile dyeing in Tai-Lao communities. Similar results have been found in Turkey, India, and other Asian locations (Dogan et al. 2003; Mahanta and Tiwari 2005; Chairat et al. 2007). Post-mordanting was reported to produce better results by Kawahito and Yasukawa (2009). Here, we show that the dyeing process and the post-mordanting method used many types of mordants, most commonly iron oxide (Fe_2O_3), tamarind juice (tartaric acid), salt (NaCl), and ash (potassium hydroxide; KOH). Using these particular mordants not only provided better depth of shade but also better wash-fastness and light-fastness than with other mordants or without a mordant. By using different mordants, a variety of shade and sometimes even different colors were obtained from one color. Good fastness properties were also obtained using a post-mordants silk with calcium hydroxide. In northwestern Argentina, alum and salt was also used as mordant for dyeing process (Lambare et al. 2011).

Recommendations

Globalization and rapid socioeconomic change has affected indigenous communities in Thailand. Nevertheless, the use of textile dyes derived from plants persists in Roi Et province; it has an important role in expressing Tai-Lao cultural identity, for instance, through customary clothing. However, further research is needed to improve the extraction technique, the stability of the dye, and to develop pilot units to produce the pigments on a larger scale to sustainably supply national and international markets. Additional studies are also needed to evaluate the phytochemical profiles, bioactivity, stability, and safety of plant pigments (Liu et al. 2014), and to better orient these resources and their associated culture towards their preservation and sustainable use to support livelihoods, as has been done in China (Liu et al. 2014). This study suggests that these economically important dye-yielding plants, especially those that are included on IUCN's Red List (*Dipterocarpus alatus*—endangerd; *Dipterocarpus obtusifolius*—lower/risk least concern; *Pterocarpus indicus*—vulnerable) need to be conserved for their biodiversity value as well as traditional ethnic knowledge. This could enhance the rural economy and also preserve traditional knowledge and culture. Community-based marketing efforts are needed to develop a viable outside market for production in order to provide market incentives for their preservation and sustainable use. The government of Thailand, particularly in northeastern Thailand, should encourage proper management and forest conservation initiatives to preserve Tai-Lao indigenous knowledge and to sustain their economy and cultural heritage. Natural plant dyes are particularly appealing to the current trend of sustainability in food and clothing choices (Liu et al. 2014).

Acknowledgments

We thank all Tai-Lao villagers in Roi Et province who provided knowledge about natural dyes and the community-based research from Thai Government (2016) for funding. We also thank our students and technical staff who participated in this project.

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