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Diversity of plant species for food coloring in Vietnam

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Abstract. *Luong NT, Hop NV, Quy NV, Hoan VM. 2023. Diversity of plant species for food coloring in Vietnam. Nusantara Bioscience 15: 95-104.* Using natural colors of plants for food processing is an inevitable trend for the safety of consumers' health. It also provides essential vitamins, minerals, and nutrients to the body. This study aimed to systematize indigenous knowledge about food coloring plants of 11 ethnic groups in North, Central, and South Vietnam. Methods of ethnobotanical investigation, field investigation under the instruction of local people, and inheritance of documents combined with data analysis were employed. Therefore, 110 species of vascular plants belonging to 54 families of food coloring were discovered in Vietnam. As a result, 28 species were used with high frequency, and 15 species were identified as conservation values domestically and globally. Besides, the richness of folk knowledge of local people was also recorded. Five plant life forms were identified, i.e., shrubs, wood, vines, herbaceous, and bamboo. Eleven plant parts were used; leaves accounted for the largest proportion (36.36%), followed by fruit, wood, flowers, bark, seeds, tubers, rhizomes, young tops, sap, and roots. Ten different colors were created from plants for food dyeing; red accounted for the highest percentage (28.18%), followed by yellow, green, black, and gray was the lowest (0.91%). Most plants can produce monochromatic colors (94/110 species). Of the species recorded, 39.09% were wild plant species, 40.00% were cultivated, and 20.91% of species could be found in the wild or cultivated. The number of species that gave color to cook rice was dominant (68.18%), followed by cakes, drinks, and soups, soaked in alcohol and sticky. This study shows the diversity of species composition, the abundance of traditional knowledge, and the potential of plants for food coloring in Vietnam. In the future, in-depth studies on the species' nutritional composition, chemistry, vitamins, and extracts should be proposed, contributing to the food and beverage industry and especially maintaining and developing a culinary culture imbued with national identity.

Keywords: Diversity, dye plant, folk knowledge, food coloring, Vietnam

INTRODUCTION

Plant-based colorants are becoming globally significant as a potential source of natural food coloring because of their versatility and for avoiding many synthetic colors' health hazards (Shamina et al. 2007). So, artificial colorants have gradually been replaced by natural pigments, which are becoming increasingly important in Vietnam and other parts of the world due to the potential noxiousness of artificial food dyes to human health (Ung et al. 2018). Natural dyes are less toxic, less polluting, less hazardous to health, non-carcinogenic, and non-toxic. They harmonize in color, are light, soft, and delicate, and create a tranquil effect and product aesthetics (Das and Kalita 2016; Hop et al. 2022). Best of all, they are environmentally friendly and can be recycled afterward (Das and Kalita 2016; Hop et al. 2022). Therefore, using natural colors created from plants that are not harmful to human health is inevitable.

Colorant's applications include papers, printing, plastics, leather, textile, cosmetics, indicators in analytical chemistry, and food (Brudzynska et al. 2021). Especially food coloring plants have high applicability in people's daily life and the food and beverage processing industry. Food coloring plants are one, group, or more species capable of providing natural food coloring from any part of the plant. They are added to food to create or improve its color, increase the product's attractiveness, and provide essential nutrients to consumers. They are extracted from natural sources and artificially synthesized. Natural colorants are extracted or processed from organic materials available in nature. It is safe for human health and easy to create natural colors using manual methods. Many species also add vitamin and mineral content to the body (Hop et al. 2022). In this context, artificial colors used in food, if used regularly or in high concentrations, can cause allergic reactions such as itching, rash, or swelling of a body part (Shamina et al. 2007). They are even dangerous to the consumer's health. Therefore, using these derived from plant species to create food coloring is an inevitable trend now and in the future.

Food is an integral part of every culture. It has always traveled alongside the history and development of every ethnic group in Vietnam (Luu-Dam et al. 2016). Vietnam's culinary culture is a place of cultural interference of 54 ethnic groups residing in 63 provinces and cities from plains and midlands to mountainous areas, rural to urban areas, and from the North to the South. That creates a culinary culture imbued with national identity. Vietnam's culinary culture is formed from productive labor activities and daily life. The King Hung legend mentions Chung cake wrapped in La dong leaves (*Phrynium* spp.) as green represents earth and Day cake made of sticky rice as white

represents heaven. Prince Lang Lieu created these two types of cake, and thanks to his unique idea, Lang Lieu became the next Viet King (Luu-Dam et al. 2016).

Vietnamese dishes are often harmonious in color and flavor, making the overall dish reasonable and increasing the irresistible attraction. These colors and flavors are extracted from plants according to folk experience and are passed down from generation to generation in various ways. Several studies on coloring plants have been conducted in Northern Vietnam (Luu-Dam et al. 2016; Hop et al. 2022). However, there is still a lot of indigenous knowledge about the use of plants for coloring by ethnic groups in other regions that have not been discovered. On the other hand, traditional knowledge about the species of plants used to dye food is disappearing due to the use of artificial dyes, the number of people who have experience with the use of coloring plants is decreasing, and the younger generation is less interested. There is no transfer of knowledge on using plant species for food coloring.

Moreover, rapid socio-economic change in Vietnam threatens the persistence of plant-derived dyes and associated cultural practices and traditional knowledge (Luu-Dam et al. 2016). Therefore, preserving traditional knowledge about food coloring plants is very important. This study provides periodic updates on various aspects of food coloring plants utilized in Vietnam, such as species composition, life form, part-used, color composition, origin, and intended use. In addition to recording the indigenous knowledge of ethnic groups about using plants to create food coloring, this study is expected to provide an important database to improve people's awareness. It also understands local people about the role and value of food coloring plants and culinary culture in general, contributing to preserving and developing the unique indigenous knowledge of local people.

MATERIALS AND METHODS

Study site

Vietnam is located in the Southeast of Asia, stretching across many different latitudes (8°34'-23°23' North latitude and 102°109' - 109°24' East longitude) (Figure 1), covering an area of about 331,212 km², the sea 3200 km, the border with China, Laos, and Cambodia with more than 4200 km. Characterized by quite a diverse terrain, including plains, plateaus, and mountains, mountainous areas account for 3/4 of the territory. Besides, the diversity of tropical climates, i.e., the north is characterized by four seasons: spring, summer, autumn, and winter; the south has two seasons: rainy and sunny. These features have created a diversity of ecosystems such as mangroves, dipterocarp forests, semi-evergreen, evergreen, and other land uses. Furthermore, there is a diversity of species composition, with about 20,000 plant species recorded (Ban 2005), of which many taxa are endemic and have economic and use values. Not only known as one of the biodiversity centers of the world. Vietnam is also known for its diversity of ethnic groups, creating a unique and diverse culinary culture. The intersection between indigenous culinary knowledge and the diversity of plant resources throughout the calendar period has formed knowledge about using plant species for food coloring. This knowledge is especially interesting in the traditional festivals of the local people. This study was conducted from November 2021 to November 2022 in eight provinces of Vietnam, which are three northern provinces (Son La, Cao Bang, Tuyen Quang Province), two central provinces (Quang Nam and Quang Tri Province), and three provinces in the South (Dong Nai, Lam Dong, and Dak Nong Province) (Figure 1).

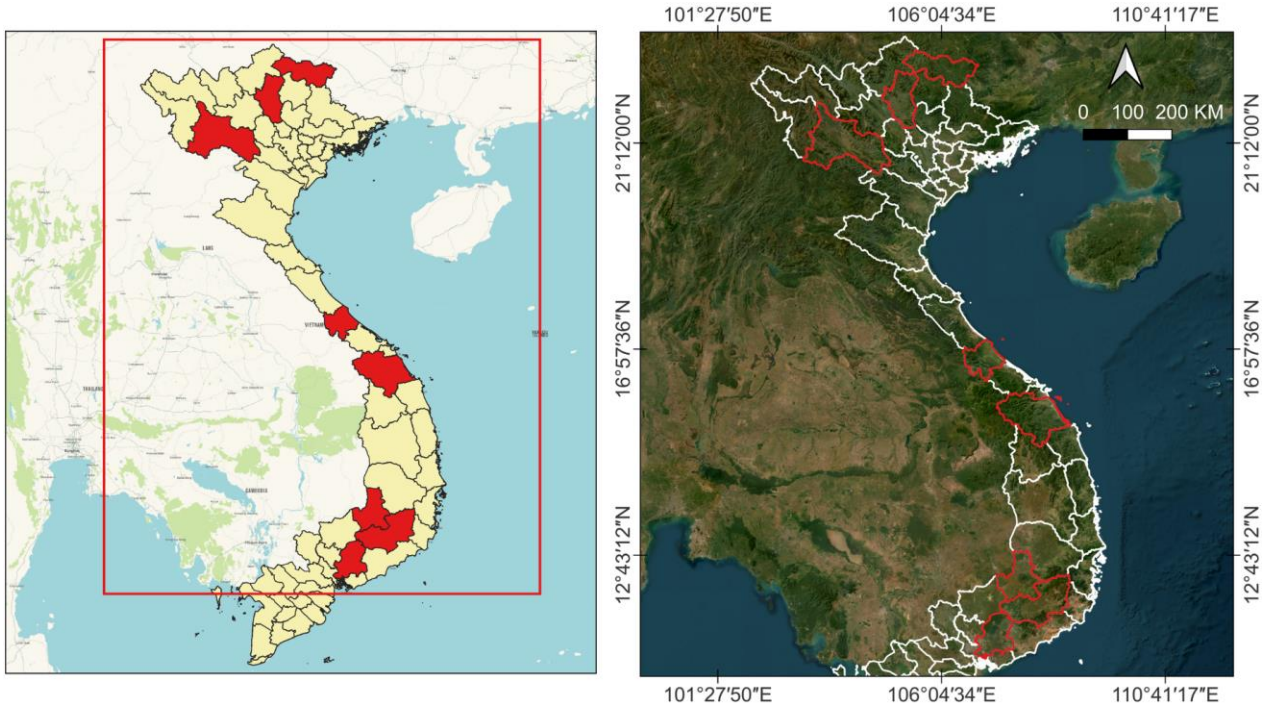

Figure 1. Map of the study area in Vietnam (red)

Data collection

Related documents, articles, websites, and reports on colorant plants for food coloring domestically and globally are collected. Information was collected through structured and semi-structured questionnaire interviews. The interviewees were experienced in collecting and coloring from local plant species in Northern Vietnam, i.e., White Thai peoples in Son La City, Son La Province; H'Mong people in Van Ho District, Son La Province; Tay, Nung people in Quang Uyen District, Cao Bang Province; Dao people in Son Duong District, Tuyen Quang Province; The Central region consists of the Co Tu people in Nam Giang District, Quang Nam Province and the Van Kieu people in Huong Hoa District, Quang Tri Province; and South of Vietnam was the Cho Ro, Kinh people in Vinh Cuu District, Dong Nai Province; Co Ho, Kinh people in Don Duong, Lac Duong District, Lam Dong Province; M'Nong, Tay and Kinh people in Dak Song District, Dak Nong Province (Figure 1). Consult with plant colorists and experts.

The name of the plant species used by people to create food coloring was determined by collecting plant specimens in the field. Experienced local people were selected to guide the plants they use. We collected samples, pictures, and recorded information on that basis, then compared them with specialized documents, standard samples were kept at research institutes and botanical museums to determine the species name. In addition, data about the parts used, life form, color, origin, and purpose of use were also collected. Samples were collected and processed according to the Handbook of biodiversity research (Thin 1997).

Data analysis

Comparative morphological and expert methods were applied to treat and identify plant specimens. After being collected and processed, the specimens were compared and contrasted with the standard specimens kept at the Vietnam National University of Forestry-Dong Nai Campus, Vietnam National University of Forestry, Hue University of Agriculture and Forest, and Southern Institute of Ecology. We used specialized documents for species identification for specimens that do not have a reference sample to search. The references included An Illustrated Flora of Vietnam, volumes 1-3 (Ho 1999); Timber Resources in Vietnam (Hop 2002); 1900 Useful Plant Species of Vietnam (Ly 1993); Vietnamese medicinal plants and Herbs (Loi 2001); Dictionary Medicinal of Vietnam (Chi 2012). The scientific name of the plants was determined and updated by Plants of the World Online (2022) and World Flora Online (2022). The Angiosperm plant species are arranged according to the taxonomy of the APG IV (APG IV 2016). Family and scientific names of species in the list were ordered alphabetically. The life form was evaluated according to documents An Illustrated Flora of Vietnam, volumes 1-3 (Ho 1999). Color classification, intended use, and origin were according to the findings of data synthesis. The threatened species composition was determined based on the VNRB (2007) and IUCN Red List (2022).

RESULTS AND DISCUSSION

Results

Species component

A total of 110 taxa, 94 genera belonging to 54 families, were discovered for food coloring in Vietnam. All species of plants belong to Angiosperms, and most of them belong to Eudicots (over 80% at the taxonomic level) (Table 1, Table 4).

Among the identified plants, 28 species were used frequently by local people (25.45%), 35 species (31.82%) were used occasionally, and 47 species (42.73%) were rarely used. The species-rich families (40.91% of total species) were represented by Fabaceae (9 species, 8,65%), Rubiaceae (8 species, 7.27%), Amaranthaceae, Zingiberaceae, Poaceae, Rubiaceae, and Cucurbitaceae (5 species, 4.55%); Scrophulariaceae, Rosaceae (4 species, 3.64%). In addition, Marantaceae, Asparagaceae, Phyllanthaceae, Moraceae, Malvaceae, Acanthaceae (3 species, 2.73%); Asteraceae, Theaceae, Polygonaceae, Pedaliaceae, Lythraceae, Euphorbiaceae, Primulaceae (2 species, 1.82%); and 33 single species families determined.

Buddleja was the most species (4 species, 3.64%), followed by *Dracaena* (3 species, 2.73%). There were 11 genera with two species, i.e., *Alpinia, Curcuma, Phrynium, Camellia, Phyllanthus, Sesamum, Morus, Paederia, Momordica, Amaranthus*, and *Dicliptera*; and 81 species genera were counted.

There were 15 species identified as conservation values at different domestic and global levels. Fourteen species at Least Concern (LC) and four at Data Deficient (DD) were shown in the IUNC Red List (2022). In addition, two species were categorized as Vulnerable (VU) in the Ministry of Science and Technology (2007) (Table 2).

Diversity of life-form

There were five life forms found for food coloring. The shrubs were the most (32.73%), followed by wood (30.91%), vines (17.27%), herbaceous (14.55%), and the lowest was bamboo (4.55%). Shrubs accounted for the highest percentage, but 13/36 species were domesticated and grown in home gardens and upland fields; 4/36 were cultivated and in the wild; 21/36 were recorded in the forest (Figure 2). While the wood plants were primarily native to natural forests, only a few species were cultivated by local people.

Table 1. Plant distribution for food coloring in the eudicots and monocots

Phylum	Family		Genera		Species	
	N	(%)	N	(%)	N	(%)
Angiosperms	54	100	94	100	110	100
Eudicots	44	81.48	77	81.91	88	80.00
Monocots	10	18.52	17	18.09	22	20.00

Notes: N: Number; (%): Percentage

Table 2. Species composition with conservation value

Family name	Botanical name	Local name	IUCN (2022)	VNRB (2007)
Altingiaceae	*Liquidambar formosana* Hance	Sau sau	LC	
Anacardiaceae	*Rhus chinensis* Mill.	Muối	LC	
Buseraceae	*Canarium pimela* K.D.Koenig	Trám đen		VU
Combretaceae	*Barringtonia asiatica* (L.) Kurz	Bàng vuông	LC	VU
Fabaceae	*Biancaea sappan* (L.) Tod.	Tô mộc	LC	
Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	Lõi thọ	LC	
Lythraceae	*Lawsonia inermis* L.	Móng tay	LC	
Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar	Giổi xanh	LC	
Myrtaceae	*Rhodomyrtus tomentosa* (Aiton) Hassk.	Hồng sim	LC	
Phyllanthaceae	*Breynia androgyna* (L.) Chakrab. & N.P.Balakr.	Bồ ngót	LC	
Phyllanthaceae	*Phyllanthus emblica* L.	Me rừng	LC	
Phyllanthaceae	*Phyllanthus reticulatus* Poir.	Phèn đen	LC	
Rosaceae	*Prunus salicina* Lindl.	Mận	LC	
Scrophulariaceae	*Buddleja officinalis* Maxim.	Mật mông	LC	
Theaceae	*Camellia oleifera* C.Abel	Sở	LC	

Note: VNRB (2007): Vietnam Red Data Book (2007); EN: Endangered; VU: Vulnerable; LC: Least Concern

Diversity of parts used

Thirteen parts used were discovered with the capability to color food. Leaves were the most (40 species, 36.36%), followed by fruit (28 species, 25.45%), wood (18 species, 16.36%), flower (14 species, 12.73%), and root the least (1 species, 0.91%) (Table 3). Although leaves accounted for the highest percentage, they did not influence the growth and evolution of trees, significantly not impacting the structure and stability of forest resources.

The number of species for one part used for food coloring predominates (94 species, 90.38%), followed by two parts used (15 species, 14.42%), and *Tamarindus indica* for three parts used (0.96%) (Figure 3).

Diversity of colors

We found ten colors from plant species. The most were red (31 species, 28.18%), yellow (24 species, 21.82%), green (22 species, 20.00%), black (18 species, 16.36%), and the most petite grey (1 species, 0.91%) (Table 5).

Three species (2.73%) were *M. philippensis*, *T. indica*, and *R. alceifolius* gave the greatest number of colors (3 colors), seven species (6.36%) showed two colors, most species gave one color (100 species, 90.91%).

Diversity of plant origin for food coloring

Of the overall number of species recorded as food coloring, 44 species (40.00%) were domesticated and cultivated in home gardens and upland fields; 43 species (39.09%) were naturalized, and 23 species (20.91%) were in the wild and cultivated (Figure 4).

Table 3. Diversity of part-used

Part-used	No. of species	Percentage (%)
Root	1	0.91
Sap	2	1.82
Young shoots	2	1.82
Rhizomes	3	2.73
Tuber	5	4.55
Seed	7	6.36
Bark	8	7.27
Flower	14	12.73
Wood	18	16.36
Fruit	28	25.45
Leaves	40	36.36

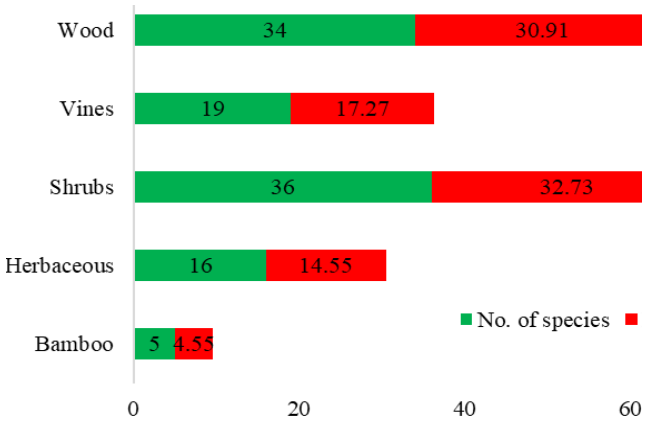

Figure 2. Diversity of life-form

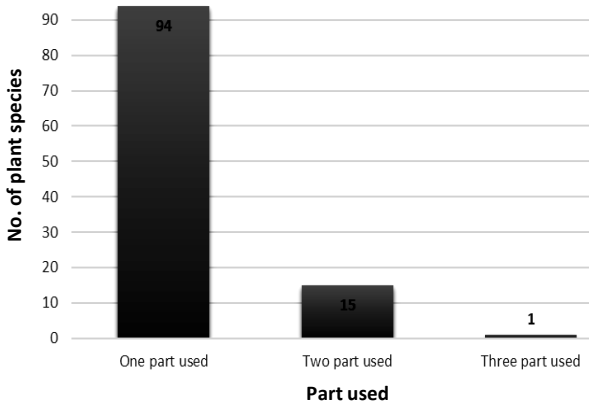

Figure 3. Number of plant species for food coloring by part used

Table 4. The composition of colorant plants for food coloring in Vietnam

Family	Botanical name	Local name	Parts-used	Color	Life form	Origin	Frequency	Food
Eudicots								
Acanthaceae	*Dicliptera chinensis* (L.) Juss.	*Lá diễn*	Leaves	Red	Shrubs	(1)	3*	Rice
Acanthaceae	*Dicliptera tinctoria* (Nees) Kostel.	*Cẩm*	Leaves	Purple	Shrubs	(2)	3*	Rice, drink
Acanthaceae	*Strobilanthes cusia* (Nees) Kuntze	*Chàm mèo*	Leaves	Blue	Shrubs	(1)	2*	Rice
Altingiaceae	*Liquidambar formosana* Hance	*Sau sau*	Leaves	Black	Wood	(1)	2*	Rice
Amaranthaceae	*Amaranthus caudatus* L.	*Dền tía*	Wood, leaves	Red	Shrubs	(2)	3*	Rice, cake, soup
Amaranthaceae	*Amaranthus cruentus* L.	*Dền đỏ*	Wood, leaves	Red	Shrubs	(2)	3*	Cake, rice, soup
Amaranthaceae	*Beta vulgaris* L.	*Dền*	Tuber	Pink	Shrubs	(2)	*	Cake
Amaranthaceae	*Iresine diffusa* f. *herbstii* (Hook.) Pedersen	*Nhung hoa*	Leaves	Red	Shrubs	(2)	3*	Rice
Amaranthaceae	*Spinacia oleracea* L.	*Rau chân vịt*	Leaves	Green	Shrubs	(2)	2*	Cake
Anacardiaceae	*Rhus chinensis* Mill.	*Muối*	Bark	Black	Shrubs	(1)	2*	Rice
Apiaceae	*Daucus carota* L.	*Cà rốt*	Tuber	Orange	Herbaceous	(2)	3*	Cake, rice, drink
Asteraceae	*Artemisia vulgaris* L.	*Ngải cứu*	Leaves, young shoots	Green	Shrubs	(2)	*	Cake
Asteraceae	*Pseudognaphalium affine* (D.Don) Anderb.	*Rau khúc*	Leaves	Green	Herbaceous	(2), (1)	3*	Cake, drink
Basellaceae	*Basella alba* L.	*Mồng tơi*	Fruit	Purple	Vines	(2)	*	Rice
Bignoniaceae	*Oroxylum indicum* (L.) Kurz	*Núc nác*	Wood	Black	Wood	(1)	3*	Cake
Buseraceae	*Canarium pimela* K.D.Koenig	*Trám đen*	Fruit	Black	Wood	(1)	2*	Rice
Brassicaceae	*Brassica oleracea* L.	*Bắp cải tím*	Leaves	Purple	Herbaceous	(2)	3*	Rice
Caricaceae	*Carica papaya* L.	*Đu đủ*	Fruit	Green	Wood	(2)	*	Rice
Combretaceae	*Barringtonia asiatica* (L.) Kurz	*Bàng vuông*	Leaves	Green	Wood	(2), (1)	2*	Cake
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	*Khoai lang tím*	Rhizomes	Purple	Vines	(2)	2*	Rice, cake, drink
Cucurbitaceae	*Citrullus lanatus (*Thunb.) Matsum. & Nakai	*Dưa hấu*	Fruit	Red	Vines	(2)	3*	Rice, drink
Cucurbitaceae	*Cucumis melo* L.	*Mướp*	Leaves	Green	Vines	(2)	*	Rice
Cucurbitaceae	*Cucurbita moschata* Duchesne	*Bí đỏ*	Fruit	Yellow	Vines	(2)	2*	Rice, cake
Cucurbitaceae	*Momordica cochinchinensis* (Lour.) Spreng.	*Gấc*	Fruit	Red	Vines	(2)	3*	Rice, cake, drink
Cucurbitaceae	*Momordica sp.*	*Gấc vàng*	Seed	Yellow	Vines	(2), (1)	*	Rice
Datiscaceae	*Datisca cannabina* L.	*Đa tích*	Wood, leaves	Yellow	Shrubs	(2)	*	Rice
Ebenaceae	*Diospyros kaki* L.f.	*Hồng*	Fruit, leaves	Brown, yellow	Wood	(2)	*	Rice
Elaeagnaceae	*Elaeagnus latifolia* L.	*Nhót*	Leaves	Black	Vines	(2)	*	Rice
Ericaceae	*Vaccinium corymbosum* L.	*Việt quất*	Fruit	Purple	Shrubs	(2)	*	Rice, cake, drink
Euphorbiaceae	*Aporosa octandra var. octandra*	*Thẩu tấu*	Wood	Red	Wood	(1)	*	Rice
Euphorbiaceae	*Mallotus philippensis* (Lam.) Müll.Arg.	*Cánh kiến*	Fruit, flower	Yellow, orange, red	Wood	(1)	*	Rice
Fabaceae	*Biancaea sappan* (L.) Tod.	*Tô mộc*	Wood	Pink, brown, red	Wood	(2), (1)	3*	Rice
Fabaceae	*Caesalpinia crista* L.	*Móc mèo*	Flower	Yellow	Shrubs	(1)	*	Rice
Fabaceae	*Cassia fistula* L.	*Muồng hoàng yến*	Bark	Red	Wood	(2)	*	Rice
Fabaceae	*Clitoria ternatea* L.	*Đậu biếc*	Leaves, flower	Purple	Vines	(2), (1)	3*	Rice, cake, drink
Fabaceae	*Millettia sp.*	*Thàn mát*	Wood	Red	Wood	(1)	*	Drink
Fabaceae	*Saraca dives* Pierre	*Vàng anh*	Flower	Red	Wood	(2), (1)	*	Rice, cake
Fabaceae	*Spatholobus suberectus* Dunn	*Huyết đằng*	Wood, bark	Red	Vines	(1)	2*	Drink
Fabaceae	*Tamarindus indica* L.	*Me chua*	Leaves, fruit, seed	Yellow, brown	Wood	(1)	*	Drink

Fabaceae	*Vigna unguiculata subsp. unguiculata*	*Đậu đen*	Seed	Black	Vines	(2)	2*	Rice, cake, drink
Hypericaceae	*Cratoxylum neriifolium* Kurz	*Thành ngạnh lá hẹp*	Bark	Brown	Wood	(1)	*	Cake, Rice
Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	*Lõi thọ*	Flower	Yellow	Wood	(1)	*	Rice
Lardizabalaceae	*Sargentodoxa cuneata* (Oliv.) Rehder & E.H.Wilson	*Huyết rồng*	Wood, leaves	Red	Vines	(1)	2*	Drink
Lauraceae	*Neolitsea cassia* (L.) Kosterm.	*Quế*	Bark	Brown	Wood	(2), (1)	*	Cake, Rice
Lythraceae	*Lawsonia inermis* L.	*Móng tay*	Wood, leaves	Red	Shrubs	(2)	*	Rice
Lythraceae	*Punica granatum* L.	*Lựu*	Fruit	Red	Wood	(2)	2*	Cake, rice, drink
Magnoliaceae	*Magnolia mediocris* (Dandy) Figlar	*Giổi xanh*	Leaves	Green	Wood	(2), (1)	*	Rice
Malvaceae	*Hibiscus sabdariffa* L.	*Bụp giấm*	Flower, fruit	Red	Shrubs	(2), (1)	3*	Drink, cake
Malvaceae	*Hibiscus sp.*	*Bụp*	Flower	Red	Shrubs	(1)	*	Drink
Malvaceae	*Theobroma cacao* L.	*Ca cao*	Fruit, seed	Brown	Wood	(2)	2*	Cake, rice, drink
Menispermaceae	*Fibraurea tinctoria* Lour.	*Hoàng đằng*	Wood	Yellow	Vines	(1)	2*	Wine
Moraceae	*Ficus simplicissima* Lour.	*Vú bò*	Leaves	Green	Shrubs	(1)	*	Rice
Moraceae	*Morus alba* L.	*Dâu tằm*	Fruit	Red	Wood	(2)	2*	Drink
Moraceae	*Morus cathayana* Hemsl.	*Dâu bầu*	Fruit	Red	Wood	(2), (1)	*	Drink
Myristicaceae	*Knema sp.*	*Máu chó*	Resin, resin	Red	Wood	(1)	*	Drink
Myrtaceae	*Rhodomyrtus tomentosa* (Aiton) Hassk.	*Hồng sim*	Fruit	Pink	Shrubs	(1)	3*	Wine
Pedaliaceae	*Sesamum indicum* L.	*Vừng trắng*	Wood	Black	Shrubs	(2)	*	Cake
Pedaliaceae	*Sesamum radiatum* Thonn. ex Hornem.	*Vừng đen*	Seed	Black	Shrubs	(2)	2*	Cake
Phyllanthaceae	*Breynia androgyna* (L.) Chakrab. & N.P.Balakr.	*Bồ ngót*	Leaves	Green	Shrubs	(2), (1)	3*	Rice, cake, drink
Phyllanthaceae	*Phyllanthus emblica* L.	*Me rừng*	Fruit	Black	Wood	(1)	*	Cake, Rice
Phyllanthaceae	*Phyllanthus reticulatus* Poir.	*Phèn đen*	Fruit	Black, purple	Shrubs	(1)	*	Rice, cake
Polygonaceae	*Fagopyrum esculentum* Moench	*Mạch ba góc*	Leaves	Yellow	Shrubs	(1)	*	Rice
Polygonaceae	*Reynoutria japonica* Houtt.	*Cốt khí*	Tuber	Yellow	Herbaceous	(2), (1)	2*	Sticky
Primulaceae	*Ardisia tinctoria* Pit.	*Cơm nguội nhuộm*	Fruit	Black	Shrubs	(1)	*	Cake, Rice
Primulaceae	*Embelia parviflora* Wall. ex A.DC.	*Chua ngút*	Wood	Red	Shrubs	(1)	*	Rice
Rosaceae	*Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier	*Dâu tây*	Fruit	Red	Herbaceous	(2)	*	Drink, cake
Rosaceae	*Prunus salicina* Lindl.	*Mận*	Fruit	Red	Wood	(2)	2*	Drink
Rosaceae	*Rosa* sp.	*Hoa hồng*	Flower	Pink, red	Shrubs	(2)	*	Cake
Rosaceae	*Rubus alceifolius* Poir.	*Mâm sôi*	Young shoots	Yellow, green, grey	Shrubs	(1)	3*	Cake, drink
Rubiaceae	*Coffea arabica* L.	*Cà phê*	Fruit, seed	Black	Wood	(2), (1)	2*	Cake, rice, drink
Rubiaceae	*Dioecrescis erythroclada* (Kurz) Tirveng.	*Dành dành*	Sap	Black	Shrubs	(1)	*	Rice, cake
Rubiaceae	*Gardenia jasminoides* J.Ellis	*Dành dành*	Fruit	Yellow	Wood	(2)	3*	Rice, cake, drink
Rubiaceae	*Gynochthodes umbellata* (L.) Razafim. & B.Bremer	*Nhàu mặt quỷ*	Bark	Yellow, red	Vines	(1)	*	Rice, cake
Rubiaceae	*Morinda tomentosa* B.Heyne ex Roth	*Nhàu nhuộm*	Bark	Red, yellow	Wood	(1)	*	Rice
Rubiaceae	*Luculia gratissima* (Wall.) Sweet	*Gạc nai*	Wood	Yellow	Wood	(1)	*	Drink
Rubiaceae	*Paederia foetida* L.	*Mơ dây*	Leaves	Green	Vines	(2)	2*	Rice
Rubiaceae	*Paederia lanuginosa* Wall.	*Mơ tam thể*	Leaves	Black	Vines	(2), (1)	2*	Rice
Rutaceae	*Citrus* × *aurantium* L.	*Cam*	Fruit	Orange	Wood	(2)	*	Cake, drink
Schisandraceae	*Illicium verum* Hook.f.	*Hồi*	Fruit	Black	Wood	(1)	*	Cake, Rice
Scrophulariaceae	*Buddleja davidii* Franch.	*Búp lệ da*	Flower	Yellow	Shrubs	(1)	3*	Rice
Scrophulariaceae	*Buddleja macrostachya* Benth.	*Búp lệ chùm to*	Flower	Yellow	Shrubs	(1)	2*	Rice
Scrophulariaceae	*Buddleja officinalis* Maxim.	*Mật mông hoa*	Flower	Yellow	Shrubs	(1)	3*	Rice
Scrophulariaceae	*Buddleja paniculata* Wall.	*Búp lệ chùm tụ tán*	Flower	Yellow	Shrubs	(1)	2*	Rice

Smilacaceae	*Smilax glabra* Roxb.	*Thổ phục linh*	Wood	Red	Vines	(1)	*	Drink
Theaceae	*Camellia oleifera* C.Abel	*Sở*	Bark	Brown	Wood	(2), (1)	*	Cake
Theaceae	*Camellia sinensis* (L.) Kuntze	*Trà xanh*	Leaves	Green	Wood	(2), (1)	3*	Cake, drink
Urticaceae	*Boehmeria nivea* (L.) Gaudich.	*Lá gai*	Leaves	Black	Shrubs	(2), (1)	3*	Cake
Vitaceae	*Vitis vinifera* L.	*Nho*	Fruit	Purple	Vines	(2)	*	Drink
Monocots								
Arecaceae	*Cocos nucifera* L.	*Dừa*	Fruit	Brown	Wood	(2)	*	Soup, Rice
Asparagaceae	*Dracaena angustifolia* (Medik.) Roxb.	*Bồng bồng lá nhỏ*	Leaves	Green	Shrubs	(1)	3*	Cake, drink
Asparagaceae	*Dracaena cambodiana* Pierre ex Gagnep.	*Huyết giác*	Wood	Red	Shrubs	(1)	*	Cake, drink
Asparagaceae	*Dracaena cochinchinensis* (Lour.) S.C.Chen	*Bồng bồng nam bộ*	Leaves	Green	Shrubs	(2), (1)	3*	Cake, drink
Cactaceae	*Selenicereus costaricensis* (F.A.C.Weber) S.Arias & N.Korotkova ex Hammel	*Thanh long*	Fruit	Red	Wood	(2)	3*	Rice, cake, drink
Dioscoreaceae	*Dioscorea alata* L.	*Khoai mỡ*	Tuber	Purple	Vines	(1)	*	Rice
Iridaceae	*Eleutherine bulbosa* (Mill.) Urb.	*Sâm đại hành*	Roots, tuber	Red	Herbaceous	(1)	2*	Drink
Liliaceae	*Lilium longiflorum* Thunb.	*Huệ tây*	Flower	Yellow	Herbaceous	(2)	*	Rice, drink
Marantaceae	*Phrynium imbricatum* Roxb.	*Lá dong*	Leaves	Green	Herbaceous	(2)	2*	Rice, cake
Marantaceae	*Phrynium pubinerve* Blume	*Lá dong*	Leaves	Green	Herbaceous	(2)	2*	Rice, cake
Marantaceae	*Stachyphrynium placentarium* (Lour.) Clausager & Borchs.	*Lá dong*	Leaves	Blue	Herbaceous	(2)	3*	Rice, cake
Pandanaceae	*Pandanus amaryllifolius* Roxb. ex Lindl.	*Dứa thơm*	Leaves	Green	Herbaceous	(2)	3*	Rice, cake, drink
Poaceae	*Bambusa bambos* (L.) Voss	*Tre*	Leaves, wood	Green, black	Bamboo	(2), (1)	2*	Rice, cake, drink
Poaceae	*Oryza sativa* L.	*Lúa nếp*	Seed	Black	Bamboo	(2)	2*	Rice, cake
Poaceae	*Saccharum officinarum* L.	*Mía*	Wood	Brown	Bamboo	(2)	*	Soup, rice, cake, drink
Poaceae	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	*Chít*	Leaves	Yellow	Bamboo	(2), (1)	2*	Rice, cake
Poaceae	*Thyrsostachys siamensis* Gamble	*Tầm vông*	Leaves	Green	Bamboo	(1)	2*	Rice
Zingiberaceae	*Alpinia gagnepainii* K.Schum.	*Riềng*	Leaves	Green	Herbaceous	(1)	2*	Rice
Zingiberaceae	*Alpinia officinarum* Hance	*Riềng*	Leaves	Green	Herbaceous	(2), (1)	2*	Rice
Zingiberaceae	*Curcuma longa* L.	*Nghệ*	Rhizomes	Yellow	Herbaceous	(2), (1)	3*	Rice, soup, cake, drink
Zingiberaceae	*Curcuma aeruginosa* Roxb.	*Nghệ đen*	Rhizomes	Yellow	Herbaceous	(2), (1)	*	Rice
Zingiberaceae	*Zingiber officinale* Roscoe	*Gừng*	Leaves	Green	Herbaceous	(2)	2*	Rice

Note: (1): Naturalized; (2): Cultivated; 3*: Frequently used species; 2*: Occasionally used species; *: rarely used

Diversity of foods group using colorant plants

Colorant plants for food coloring in Vietnam were used for six food groups: rice, cake, drink, soup, wine, and sticky. The colors created were commonly employed for cooking sticky rice (75 species, 68.18%) in the traditional festivals of ethnic groups such as Kinh, Tay, Nung, H'Mong, Thai, and Co Tu (Table 6). The three primary colors are blue, yellow, and red. In comparison, several others, such as purple, pink, orange, and blue, are less frequent.

For example, on the cake (52 species, 47.27%), local people used formulated cakes during Lunar New Year, Pure Brightness Festival, and Mid-Autumn Festival. Popular products in this category include Chung cake, Troi cake, Day cake, Khuc cake, Duc cake, and Tet cake. Drink (41 species, 37.27%) was used for daily drinking. At the same time, soup (5 species, 4.55%) was cooked for people's local meals.

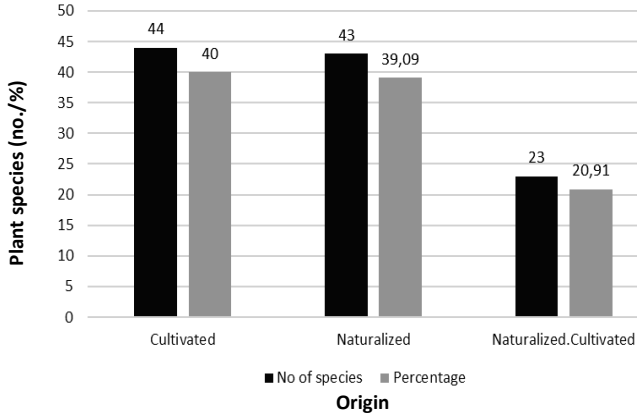

Figure 4. Diversity of plant origin for food coloring

Table 5. Diversity of colors

Colors	No. of species	Percentage (%)
Grey	1	0.91
Blue	2	1.82
Orange	3	2.73
Pink	4	3.64
Brown	9	8.18
Purple	9	8.18
Black	18	16.36
Green	22	20.00
Yellow	24	21.82
Red	31	28.18

Table 6. Diversity of foods using colorant plants

Food	No. of species	Percentage (%)
Sticky	1	0.91
Wine	2	1.82
Soup	5	4.55
Drink	41	37.27
Cake	52	47.27
Rice	75	68.18

Discussion

The present study showed that the species composition of food coloring plants was quite diverse, with 110 species and subspecies of 94 genera belonging to 54 families identified. Several previous studies on this topic were conducted in Vietnam and initially recorded native plant species used by ethnic communities for food coloring. However, these studies only found several case studies concentrated in several specific ecological regions, not systematic and not guaranteed to represent different ecological regions in Vietnam. For example, a study on natural plant colorants widely used in Vietnam's traditional food culture conducted in the Northwest region has recorded 49 species of vascular plants belonging to 30 families (Ung et al. 2018) less than this current study. Another study conducted in the North of Vietnam showed that 43 species of vascular plants belonging to 24 families had been identified with the ability to provide color for food coloring (Luu-Dam et al. 2016). Thus, this study added 61 species of food-coloring plants compared to Ung et al. (2018); and 67 species compared with Luu-Dam et al. (2016). This finding shows that the number of species capable of creating food coloring in the studies is different, possibly due to the difference in scope, research subjects, and sampling methods. Several studies in the Asian region showed that up to 106 plant species of 46 families in the Northwestern Himalayas and 46 species of plants from the Northern Western Ghats were collected for food coloring. Meanwhile, 25 Himalayan plant species have been identified as potential sources of coloring materials in high demand in food processing (Das and Kalita 2016). The ethnobotanical study of the Dong ethnic group in China showed that, in total, seven species were used to color food items, and three species were used to color foods and clothing (Liu et al. 2014).

This study found that, out of 28 species frequently used by people, 15 species were used by local people living in rural and urban areas, namely: *A. caudatus, A. cruentus, D. carota, P. affine, B. oleracea, C. lanatus, M. cochinchinensis, C. ternatea, H. sabdariffa, C. sinensis, B. nivea, S. costaricensis, P. amaryllifolius, D. chinensis, D. tinctoria*. The remaining 13 species were used by ethnic minorities living in mountainous areas where economic conditions were difficult. People living in rural and urban areas mainly use plants grown in home gardens or can be easily purchased from markets and supermarkets. Meanwhile, due to a difficult life living near the mountains and forests, where many native tree species grow naturally, searching for food-coloring plants through the ancestors' experience is also possible. Therefore, people living in rural and urban areas often use plants for food coloring more frequently than in mountainous areas. Because most people living in rural and urban areas are Kinh ethnic groups, they have a better life than people in mountainous areas. Moreover, finding these plants is also easier. People in the mountainous areas are mainly minority ethnics; they only use food coloring plants during traditional holidays and Lunar New Year, Qingming New Year, and Mid-Autumn Festival.

Plants for coloring are still used today by people in this study area, which shows their important role in food coloring. The most recorded use of dye plants is for food coloring, specifically glutinous rice, followed by cakes, beverages, and common soups. Pigments derived from dye plants can produce different colors (Liu et al. 2014). The present study noted that red predominates, followed by yellow, dark blue, black, purple, and brown. These pigments are obtained from different parts of plants, i.e., roots, leaves, flowers, stems, bark, and tubers. In addition to their coloring function, they are also used for medicinal, decorative, preservation, edible, and timber (Liu et al. 2014).

The color type also differs depending on the plant species and part of the plants. Therefore, the featured products of this study were five-colored sticky rice, three-color sticky rice, and gac sticky rice, for example: (1) five-color sticky rice, this product is: an attractive specialty of the northwest mountains because there were up to five colors: red, white, yellow, green, and black (Table 7), each color embodied a vibrancy, a color of its own; this is also the color of the girl's dress in this region. All combine to devise a color palette with high aesthetics. There is also other five-color sticky rice because the composition of the color-producing plants of each ethnic group is different, for example: the Kinh peoples use the red color from the fruit of *M. cochinchinensis*; purple color from the leaves of *D. tinctoria*; green color from the leaves of *A. officinarum*; and yellow from the bulbs of *C. longa*, and white from the seeds of *O. sativa* (Figure 6); (2) three-color sticky rice, this product is composed by three primary colors, i.e., yellow of *G. jasminoides*, red of *M. cochinchinensis*, and green of *P. amaryllifolius* combined to make a harmonious color, and aroma (Table 8). Quan et al. (2016) recorded five varieties of *P. bivalvis*, a synonym of *D. tinctoria*, a source of raw materials for dyeing food and medicine, in which the plant can produce three color varieties, i.e., purple, red, and yellow-orange.

Table 7. Species composition and color for making five-color sticky rice in Vietnam

Species	Color	Parts used
Curcuma longa L.	Yellow	Tuber
Bambusa bambos (L.) Voss	Back	Stem
Rubus alceifolius Poir.	Red	Fruit
Pandanus amaryllifolius Roxb. ex Lindl.	Blue	Leaves
Oryza sativa L.	White	Seed

Table 8. Species composition and color for making three-color sticky rice in Vietnam

Species	Color	Parts used
Gardenia jasminoides J.Ellis	Yellow	Fruit
Momordica cochinchinensis (Lour.) Spreng.	Red	Stem
Pandanus amaryllifolius Roxb. ex Lindl.	Green	Leaves
Oryza sativa L.	White	Seed

Yellow sticky rice is also called Bo phon sticky rice by the people, it is a speciality of the Northwestern people of Vietnam with its natural bright yellow color and delicious taste. The ingredients to make this dish are glutinous rice, and the yellow color is taken from the flowers of *Buddleja officinalis*. Yellow color is obtained from the flower by placing the whole bunch of flowers in boiling water until the desired color is achieved. Then soak glutinous rice in that yellow water and cook. Flowers can be dried, preserved for 1-2 years, and after use, can be reused 2 to 3 times. Subsequent uses, the yellow color of this species of flower is brighter and more natural (Figure 5).

Figure 5. Yellower sticky rice is called Bo phon by the Tay and Dao ethnic groups in Northwestern Vietnam, it is made from the flowers of *Buddleja officinalis*. (Image source: Nong Dinh Don and Mai Tay Bac)

Figure 6. Five-color sticky rice of the King peoples (Image source: Thuy Huong)

This study also found that coloring plants have health care and disease treatment functions besides creating attraction for food consumers; for example, leaves of *D. tinctoria* have diuretic effects and treat kidney stones; urinary incontinence; Flowers of *B. officinalis* Maxim. Cook and drink water to treat eye pain, red eyes or branches, leaves, and root bark as medicine for rheumatism. Several studies in China are similar to this present study. *Persicaria tinctoria* Spach has the effect of clearing heat, detoxifying, cooling blood, curing mumps, reducing swelling, and relieving pain; and itching (Chinese Pharmacopoeia Commission 2010). *S. cusia* can prevent and treat the influenza virus (Liu 1998) and clear heat, reduce toxicity, cool blood, relieve sore throat, and improve immunity by killing pathogenic microorganisms (Chinese Pharmacopoeia Commission 2010). *B. officinalis* is a beverage with medicinal effects recorded in the Chinese Pharmacopoeia (Chinese Pharmacopoeia Commission 2005) that can be used as a substitute for tea in Yunnan province with its cool and refreshing taste (Tang and Zheng 1991). It is used to treat dry eyes, blurred vision, and cataracts. It has also been shown to have anti-inflammatory and blood-sugar-lowering activities, potentially boosting immunity (Li and Sun 1996).

According to the cultural traditions of the ethnic groups in the study areas, indigenous knowledge about the coloring plants of the communities is passed down from generations of grandfathers and fathers to children and grandchildren. However, this method nowadays faces many challenges. The culture of community activities, even between generations in the family, is the traditional way to pass on the father's experience to future generations, which is also difficult to do. Furthermore, because of the change in all aspects of life, today's young generations are being driven away by social development; most young people are looking for work outside of their community, so this knowledge will not be passed on to the younger generation. Moreover, forest resource degradation is also an important reason; some species of color-producing plants could be easily collected in the past, but now it is not easy to access; even moving 5-10 km is searchable.

On the other hand, the use of plants for food coloring of natural origin often occurs within households, is small, fragmented, has low yields, and can only happen during festivals. These are major challenges for conserving and promoting indigenous knowledge of ethnic communities in the study area. Therefore, future studies should be conducted in other communities and ecoregions. These studies could systematize and document this unique knowledge. Some other necessary studies to be carried out to maintain and preserve this knowledge are to direct in-depth studies on the chemical composition of natural colorants, nutritional composition, uses, and method of extracting colorants as a basis for industrial-scale production for the food and beverage industries. These future studies will help to provide guidelines for community-based production and ultimately preserve indigenous knowledge about using plants for food coloring. Therefore, restoring traditional festivals, including culinary culture, is one of the solutions that have been implemented in some regions. Promoting products to tourists by providing traditional products to tourist centers, restaurants, and hotels in tourist areas is the trend to restore and preserve public knowledge on using plants for coloring in Vietnam.

In conclusion, based on indigenous knowledge, this study illustrates the richness of plants for food coloring in Vietnam. Accordingly, 110 taxa of 94 genera belonging to 54 families were recorded. Twenty-eight species were used regularly in classical cultural festivals of the indigenous people. This study also confirmed 15 species with domestic and global conservation values. Fabaceae and *Buddleja* were the species-rich families and genera. There were five life forms, i.e., shrubs, wood, vines, herbaceous, and bamboo. Eleven part-used plants were used for coloring by local people, with leaves used with the most frequency. These plant species produced ten colors: red, yellow, green, black, purple, brown, pink, orange, blue, and grey. Local people observe these species in the wild, then tame and cultivate them in home gardens or fields, remaining wild or cultivated. Therefore, by indigenous information from previous generations, local people have used dye plants to color cakes, rice, drink, soup, wine, or sticky. Faced with the challenges of the decline of color plants and the loss of indigenous knowledge of communities, we recommend the need for the conservation and development of plant colorants and the unique knowledge of communities on the use of food coloring plants through the domestication of native plants and the restoration of festivals' traditional cuisine to preserve them for future generations.

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REFERENCES

APG (Angiosperm Phylogeny Group), Chase MW, Christenhusz MJM, Fay MF, Byng JW, Judd WS, Soltis DE, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF. 2016. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. Bot J Lin Soc 181 (1): 1-20. DOI: 10.1111/boj.12385.

Ban NT. 2005. Checklist of Plant Species of Vietnam. Agriculture Publishing House, Hanoi, Vietnam.

Brudzynska P, Sionkowska A, Grisel M. 2021. Plant-derived colorants for food, cosmetic and textile industries: A review. Materials 14 (13): 3484. DOI: 10.3390/ma14133484.

Chi VV. 2012. Dictionary Medicinal of Vietnam. Medicine Publishing House, Hanoi, Vietnam.

Chinese Pharmacopoeia Commission. 2005. Pharmacopoeia of the People's Republic of China (2005 Edition). People's Medical Publishing House, Beijing.

Chinese Pharmacopoeia Commission. 2010. Pharmacopoeia of the People's Republic of China (2010 Edition). China Medical Science Press, Beijing.

Das H, Kalita D. 2016. Fibers and Dye Yielding Plants of NorthEast India. Purkayastha J Bioprospect Indigenous Bioresour North-East India 6: 77-99. DOI: 10.1007/978-981-10-0620-3_6.

Ho PH. 1999. An Illustrated Flora of Vietnam Second Edition. Youth Publishing, Hanoi,Vietnam.

Hop NV, Quy NV, Ha NT, Huong KM. 2022. Diversity of colorant plants in Vietnam. Intl J Ecol Environ Sci 4 (2): 93-99.

Hop T. 2002. Timber Resources In Vietnam. Agricultural Publishing House, Hanoi, Vietnam.

Li XL, Sun GJ. 1996. The effective ingredients from *Buddleja officinalis* and *Daphne odorato* be bacteriostasis. Northwest Pharm J 11: 165-166. DOI: 10.1016/0924-2031(96)00002-1.

Liu Y, Ahmed S, Liu B, Guo ZY, Huang WJ, Wu XJ, Li SH, Zhou JJ, Lei QY, Long CL. 2014. Ethnobotany of dye plants in Dong communities of China. J Ethnobiol Ethnomed 10: 1-9. DOI: 10.1186/1746-4269-10-23.

Liu Y. 1998. A brief medical introduction to several Dai edible vegetables. Chinese J Ethnomed Ethnopharm 32: 19-20.

Loi DT. 2001. Vietnamese Medicinal Plants and Herbs. Science and Technology Publishing House, Hanoi, Vietnam.

Luu-Dam NA, Ninh BK, Sumimura Y. 2016. Ethnobotany of colorant plants in ethnic communities in Northern Vietnam. Anthropology 4 (158): 2332-0915.DOI: 10.4172/2332-0915.1000158.

Ly TD. 1993. 1900 Useful Plant Species of Vietnam. World Publishing House, Hanoi, Vietnam.

Ministry of Science and Technology. 2007. Vietnam Red Data Book, Part: Plants. Natural Science and Technology Publishing House, Hanoi.

Plants of the World Online. 2022. https://powo.science.kew.org/

Quan NV, Khang DT, Dep LT, Minh TN, Nobukazu N, Xuan TD. 2016. The potential use of a food-dyeing plant *Peristrophe bivalvis* (L.) Merr. in Northern Vietnam. Intl J Phramacol Phytochem Etnomed 4: 14-26. DOI: 10.18052/www.scipress.com/IJPPE.4.14.

Shamina A, Shiva KN, Parthasarathy VA. 2007. Review: Food colors of plant origin. Perspect Agric Vet Sci Nutr Nat Resour 2 (087): 1-25. DOI: 10.1079/PAVSNNR20072087.

Tang SX, Zheng HL. 1991. A promising natural edible plant pigment–yellow pigment from *Buddleia officinalis*. Chinese Wild Plant Resour 4: 4-8.

The IUCN Red List of Threatened Species. 2022. www.iucnredlist.org

Thin NN. 1997. Handbook Of Biodiversity Research. National University Publishing House, Hanoi, Vietnam.

Ung LQ, Liang LH, Chang WM, Hanh NTH. 2018. Natural plant colorants are widely used in Vietnam's traditional food culture. J Food Nutr Agric 1 (1): 40-46. DOI: 10.21839/jfna2018.v1i1.220.

World Flora Online. 2022. http://www.worldfloraonline.org/