

THE DIVERSITY OF YELLOW CAMELLIAS IN THE CENTRAL HIGHLANDS, VIETNAM

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Abstract

The Central Highlands (Tây Nguyên) is a center of yellow camellia diversity in Vietnam and the world. The Central Highlands contains 18 of Vietnam's yellow camellia species, accounting for 37% of yellow camellia species in Vietnam and 28% of yellow camellia species worldwide. Moreover, all 18 yellow camellia species in the Central Highlands are endemic to Vietnam. The camellias of the Central Highlands belong to nine sections, accounting for 75% of the world. The yellow colors occur in three groups: pale yellow, yellow, and yellow with compound colors. The yellow camellia distribution is dispersed at 500–1600 m elevation in evergreen broadleaf forests and mixed wood-bamboo forests.

Keywords: Central Highlands; Diversity; Morphological features; Vietnam; Yellow camellias.

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1. INTRODUCTION

Yellow camellias are distributed mainly in China and Vietnam. Most yellow camellias are included in section *Chrysantha*, which has 10 species (Chang, 1981). Ming and Bartholomew (2007) combined and updated the classification of many *Camellia* species in China. We counted up to 13 species with yellow flowers that belong to sections *Archecamellia*, *Corallinae*, and *Stereocarpus*. Most section *Chrysantha* species were combined into section *Archecamellia* (Ming & Bartholomew, 2007). *Camellia debaoensis*, *C. mingii*, and *C. rostrata*, all with yellow flowers, were recently discovered in southern China (Hu et al., 2019; Liu et al., 2019, 2020).

Hoang-Ho Pham counted and illustrated 30 species of *Camellia* in Vietnam, but the color of the flowers of some species is not known (Phạm, 1991). According to Tran Ninh, among the 50 species of *Camellia* belonging to four subgenera, six species are distributed in the Central Highlands (Tây Nguyên), all of them in Lam Dong Province. Yellow *Camellia* (sect. *Chrysantha*) consists of 13 species, but none inhabits the Central Highlands. Only one yellow camellia (*C. dormoyana*) belonging to sect. *Archecamellia* is found in Lam Dong Province of the Central Highlands (Tran, 2002). Luong et al. (2015) counted 15 species of genus *Camellia* in Lam Dong Province, which accounts for 30% of the *Camellia* species in Vietnam. The camellias are located at elevations of 200 to 2000 m and include six groups of flower colors and four types of vegetation (Luong et al., 2015). The diversity of leaves, flowers, fruit, and taxa for 26 *Camellia* species in Lam Dong Province was reported by Quach, Luong, Doudkin, Bui, & Duy (2021).

Le and Luong (2016) compiled a list of 39 published yellow *Camellia* species in Vietnam that includes eight yellow camellias in the Central Highlands and 26 species endemic to Vietnam. Yellow camellias are evergreen and shade tolerant shrubs and small trees. About 52 species have been described in southern China and Vietnam (Tran et al., 2019). The recently updated checklist of Le et al. (2020) contains 95 species and two varieties of *Camellia* in Vietnam. Le's checklist shows 38 yellow *Camellia* species with many new yellow species in Vietnam (Le et al., 2020). Only one yellow *Camellia* species, *C. dormoyana*, was discovered in the Central Highlands between 1886 and 1998, but after that *C. vidalii*, a yellow flower camellia was published in 1998 from Bao Loc, Lam Dong Province (Gagnepain, 1943; Phạm, 1991; Rosmann, 1999). *C. langbianensis*, a light yellow flower with pink edges on its petals, was first published as *Dankia langbianensis*, a monotypic genus in 1939 (Gagnepain, 1943). *C. langbianensis* was rediscovered in early 2021 (Quach, Doudkin, et al., 2021). Thus, three yellow camellias from the Central Highlands were recognized in the literature before 1998 (Gagnepain, 1943; Phạm, 1991; Rosmann, 1999).

In recent years, new species of yellow camellia have been reported from the Central Highlands, namely, *C. capitata*, *C. dilinhensis*, *C. dongnaiensis*, and *C. inusitata* (Orel, 2006; Orel et al., 2012; Orel et al., 2014; Tran & Luong, 2013). Some new morphological characteristics and ancient morphological features were discovered in the *Camellia* genus. As a result, new sections, *Obvoidea* and *Bidoupia*, were added to genus *Camellia* (Orel et al., 2012; Tran & Luong, 2013).

Tran (2002) classified the vegetation of the camellia habitat as tropical evergreen forest, secondary forest, and karst forest. Luong et al. (2015) described four types of vegetation: mixed bamboo-wood forest, mixed wood-bamboo forest, mixed broadleaf-coniferous forest, and evergreen-broadleaf forest for all species of the *Camellia* genus in Lam Dong Province. Vegetation forms of the Central Highlands contain many features specific to mountainous tropical areas in Southeast Asia. The Central Highlands have elevations of about 500 to 1500 m and are located at the climate intersection of northern Vietnam, southern Vietnam, Lao PDR, Cambodia, and east central Vietnam near the Bien Dong Sea. This area of Vietnam can be considered central to migratory waves of plants from areas with different climates as well as to plant evolution.

The Central Highlands contains many distinguishable sub-plateaus that shape the highland climate, including Kon Tum plateau (500 m), M'Drak plateau (500 m), Buon Ma Thuot plateau (500 m), Kon Plong, Kon Ha Nung, and Pleiku plateaus (800 m), Mo Nong plateau (800–1000 m), Di Linh plateau (900–1,000 m), and Lam Vien plateau (1500 m). Thus, the Central Highlands are a center of biodiversity in Vietnam that supports vegetation ranging from that of temperate climates to tropical climates to the hot dry climate of the Asian continent. Orel and Curry suggested that the origin of *Camellia* may extend farther south in Asia (Orel & Curry, 2015). We have now updated a checklist of yellow flower camellias of the Central Highlands and their morphological diversity.

2. METHODOLOGY

An updated checklist was prepared by reviewing the scientific names of yellow camellias recorded globally and in the Central Highlands of Vietnam. The literature for global *Camellia* includes Chang (1981), Gao et al., (2005), Ming and Bartholomew (2007), and Sealy (1958). Vietnamese camellias and Central Highlands camellias were the subjects of several conferences (Gagnepain, 1943; Le et al., 2020; Le & Luong, 2016; Nguyễn, 2017; Phạm, 1991).

The morphological characteristics of *Camellia* are mainly taken from accounts in English. Illustrations are from accounts, descriptions, author's pictures, and field trips by the authors. The yellow color varies from very pale yellow to very deep yellow, and includes golden yellow, lemon yellow, sulfur yellow, and chrome yellow. Some species have two or three colors with yellow dominant, so the flower is counted as a yellow camellia.

3. RESULTS AND DISCUSSION

3.1. Species diversity

Yellow *Camellia* consists of 64 species worldwide (Do et al., 2020; Hu et al., 2019; Le et al., 2020; Liu et al., 2019; ; Liu et al., 2020; Ming & Bartholomew, 2007; Quach, Doudkin, et al., 2021; Quach, Luong, Doudkin, Averyanov et al., 2021; Quach et al., 2022; Tran, 2003; Tran et al., 2019; Tran & Luong, 2013; Truong, et al., 2022). The number of *Camellia* in Vietnam is 49 species, 76% (49/64) of the worldwide total (Do et al., 2020; Le et al., 2020; Quach, Doudkin, et al., 2021; Quach et al., 2022; Quach, Luong, Doudkin, Averyanov et al., 2021; Truong et al., 2022; Tran et al., 2019; Tran & Luong, 2013).

Camellias are distributed mainly in Vietnam and China, with 46 Vietnamese endemic species that account for 72% (46/64) of yellow camellias worldwide (Table 1). Vietnam has become a center of diversity of yellow camellias.

Table 1. The diversity of yellow camellia species

	Central Highlands	Vietnam	China	Global
Species	18	49	18	64
Sections	9	11	4	12
Endemic	18	46	15	-
References		Do et al., 2020; Le et al., 2020; Nguyen et al., 2020; Quach, Doudkin, et al., 2021; Quach et al., 2022; Quach, Luong, Doudkin, Averyanov, et al., 2021; Tran et al., 2019; Tran & Luong, 2013; Truong et al., 2022	Do et al., 2020; Hu et al., 2019; Le et al., 2020; Liu et al., 2019; Liu et al., 2020; Ming & Bartholomew, 2007; Quach, Doudkin, et al., 2021; Quach et al., 2022; Quach, Luong, Doudkin, Averyanov, et al., 2021; Tran et al., 2019; Tran & Luong, 2013; Truong et al., 2022	Do et al., 2020; Hu et al., 2019; Le et al., 2020; Liu et al., 2019; ; Liu et al., 2020; Ming & Bartholomew, 2007; Quach et al., 2022; Quach, Doudkin, et al., 2021; Quach, Luong, Doudkin, Averyanov, et al., 2021; Tran & Luong, 2013; Tran et al., 2019; Truong et al., 2022

The Central Highlands contains 18 species of yellow camellias and accounts for 37% (18/49) of yellow camellias in Vietnam (Table 1). The yellow camellia species of the Central Highlands account for 28% (18/64) of the global yellow camellia species. All 18 species of yellow camellias in the Central Highlands are endemic to Vietnam. The Central Highlands has become a center of yellow camellia diversity in Vietnam.

The years of publication show that 14 yellow camellia species from the Central Highlands have been published over period of 2010-2021 in recent decades. Only four camellia species from the Central Highlands were published before 2010, namely, *C. dormoyana*, *C. langbianensis*, *C. vidalii*, and *C. dongnaiensis* (Table 2). In China, many species of yellow camellia have been transferred or combined (Ming & Bartholomew, 2007). Thus, the number of yellow species has decreased compared to Chang (1981). In Vietnam, some species of yellow camellias, such as *C. kirinoi*, *C. tamdaoensis*, and *C. quephongensis*, are not accepted (Tran, 2003; Tran & Le, 2007). Therefore, some camellias in Vietnam need to be reviewed again to confirm the existence of the species.

Table 2. Checklist of yellow camellias in the Central Highlands

No.	Scientific name	References	Section	Color of flowers
1	<i>Camellia bidoupensis</i> Truong, Luong & Tran	Truong et al., 2020	Theopsis	Pale yellow
2	<i>Camellia capitata</i> Orel, Curry and Luu	Orel et al., 2014	Capitatae	Yellow
3	<i>Camellia dalatensis</i> Luong, Tran & Hakoda	Tran & Luong, 2012	Piquetia	Light yellow

Table 2. Checklist of yellow camellias in the Central Highlands (cont.)

No.	Scientific name	References	Section	Color of flowers
4	<i>Camellia dilinhensis</i> Ninh & V.D. Luong	Tran & Luong, 2013	Obvoidae	Light yellow
5	<i>Camellia dongnaiensis</i> Orel	Orel, 2006	Piquetia	Graduated yellow – apricot with distinct, intensely pink margins
6	<i>Camellia dormoyana</i> (Pierre) Sealy	Gagnepain, 1943; Sealy, 1958	Stereocarpus	Yellowish (golden yellow)
7	<i>Camellia inusitata</i> Orel, Curry & Luu	Orel et al., 2012	Bidoupia	Yellowish-green
8	<i>Camellia langbianensis</i> (Gagnep.) Phamhoang	Gagnepain, 1939; Quach, Doudkin et al., 2021	Piquetia	Yellow with slightly pink marginate
9	<i>Camellia luteocerata</i> Orel	Orel & Wilson, 2010	Dalatia	Intensely yellow
10	<i>Camellia luteopallida</i> Luong V. D., Luu H. T., Nguyen T. Q. T. N., & Nguyen Q. D.	Luong, Luu et al., 2016	Dalatia	Very pale yellow
11	<i>Camellia ninhii</i> Luong & Le	Luong & Le, 2016	Chrysantha	Deep yellow
12	<i>Camellia oconoriana</i> Orel, Curry & Luu	Orel et al., 2013	not known	Yellow (pinkish marginate)
13	<i>Camellia sphamii</i> Q. C. Truong & V. S. Le	Truong et al., 2022	Piquetia	The outer whorl distally light yellow and the middle and inner whorls yellow
14	<i>Camellia proensis</i> V. D. Luong, Doudkin & V. H. Quach	Quach, Doudkin et al., 2021	Piquetia	Light yellow
15	<i>Camellia quynhii</i> V. D. Luong, V. H. Quach & T. T. Hoang	Quach et al., 2022	Stereocarpus	Light yellow
16	<i>Camellia thuanana</i> T. T. Hoang	Hoang et al., 2022	Chrysantha	Light greenish-yellow color (lemon yellow)
17	<i>Camellia thuongiana</i> Luong, Anna Le & Lau	Luong, Le, et al., 2016	Chrysantha	Bright yellow
18	<i>Camellia vidalii</i> Rosmann	Rosmann, 1999	Archeamellia	Yellow

3.2. Section diversity

Yellow *Camellia* consists of 12 sections globally: *Archeamellia*, *Bidoupia*, *Capitatae*, *Chrysantha*, *Corallinae*, *Dalatia*, *Pleurocarpae*, *Heterogenea*, *Obvoidae*, *Piquetia*, *Stereocarpus*, and *Theopsis*. The yellow camellias of the Central Highland are distributed among nine sections, accounting for 75% of the *Camellia* sections worldwide (9/12) and 82% of *Camellia* sections in Vietnam (9/11) (Table 1). Sections *Piquetia* and

Chrysantha have the most species with five (28%) and three (17%) species, respectively (Figure 1). The section is unknown for only one species. Four sections are newly added for the Central Highlands and Vietnam: *Bidoupia*, *Dalatia*, *Capitatae*, and *Obvoidea* (Orel et al., 2012; Orel et al., 2014; Orel & Wilson, 2010; Tran & Luong 2013).

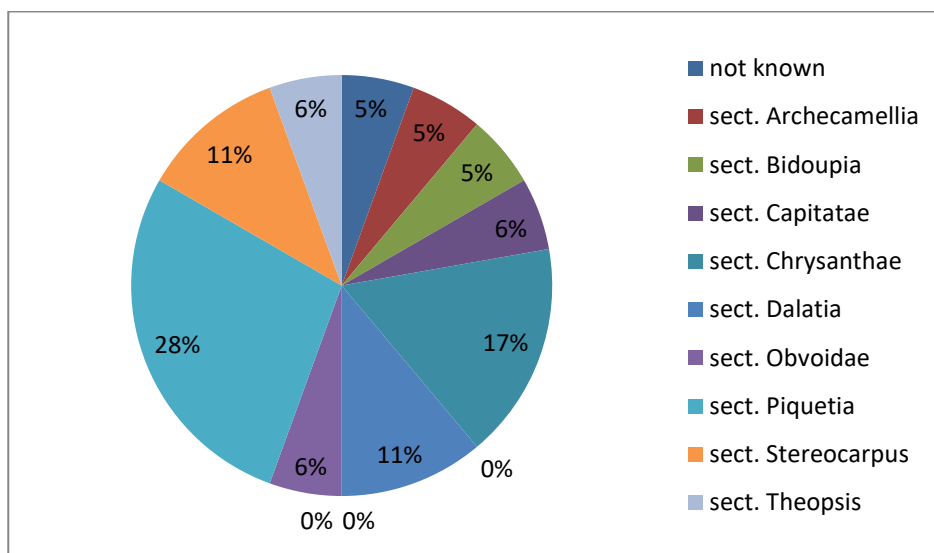


Figure 1. Distribution of *Camellia* species in the Central Highlands by section

3.3. Morphological diversity

3.3.1. Diversity of stems, branches, and leaves

All yellow camellias are small trees or shrubs. The trees are from 3 m to 10 m high. The highest recorded tree species is *C. dormoyana* at 10 m high (Sealy, 1958). Most *Camellia* trees are 3–5 m high. Branches are thin or slender; most young branches are pubescent but become glabrous when older. Only one species has a trunk shorter than 3 m. Most are branchless, but *C. inusitata* sect. *Bidoupia* has flat young branches.

Yellow camellia species mostly have large leaves and only rarely have small leaves. The size of the leaves varies from 7.5 cm to 55 cm long and from 3.5 cm to 12 cm wide. Most are about 15–30 cm long and 5–8 cm wide. The longest leaves belong to *C. dongnaiensis* (44 cm long), *C. dalatensis* (45 cm long), and *C. sphamii* (55 cm long). The widest leaves belong to *C. capitata* (11–12 cm wide) and *C. dalatensis* (8–11 cm wide). The biggest leaves belong to *C. dalatensis*, 40–45 cm long and 8–11 cm wide and *C. sphamii*, 40–55 cm long and 8.5–10 cm wide (Orel, 2006; Tran & Luong, 2012; Truong et al., 2022).

The morphology of the leaves retains the main features of *Camellia*. The blades are thick, coriaceous, stalked, and brochidodromous. The blade shapes are broadly ovoid, oval, oblong, oblong-elliptic, elliptic, narrowly obovate, or ovate. Most are elliptic to oblong-elliptic or oval. The venations are sunken above and protruding below. The margins are serrulate to serrate and sometimes shallow serrulate to shallow serrate. Apices

are acute, acuminate, or (rarely) caudate (*C. luteopallida*). The base of the leaf is nearly cuneate, cuneate, broadly cuneate, obtuse, nearly rounded, rounded, or (rarely) cordate (*C. dalatensis* and *C. quynhii*) (Figure 2).

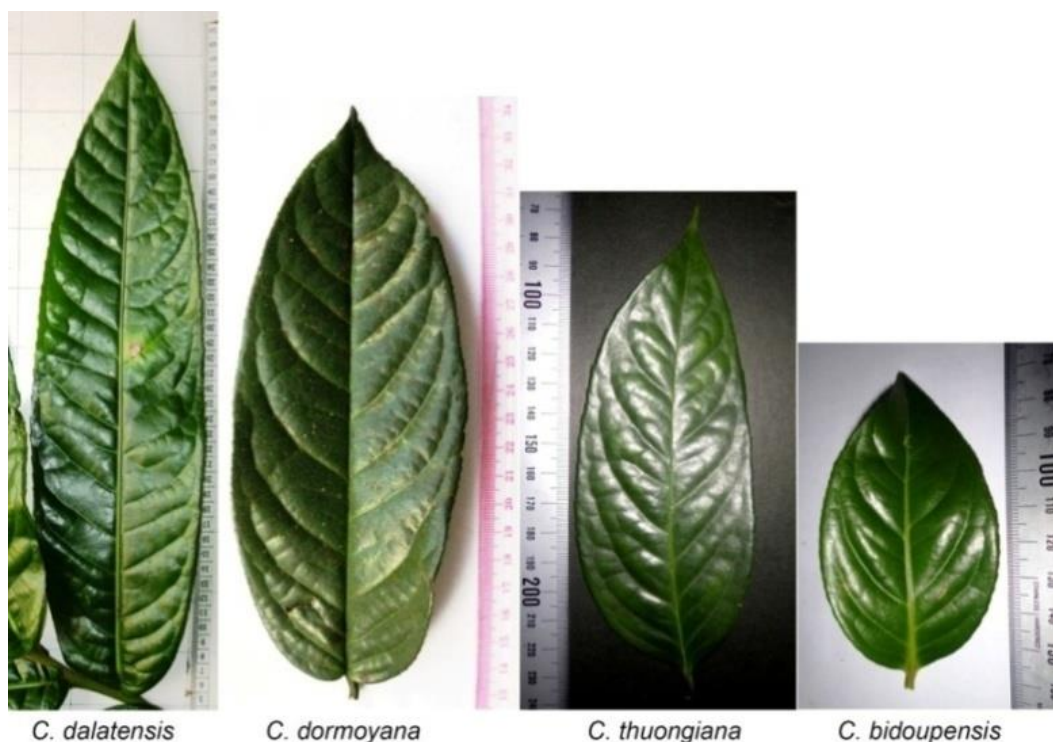


Figure 2. The leaf morphology of yellow camellias

Source: Luong Van Dung.

3.3.2. Diversity of flower positions

Flowers of yellow camellias are sessile, nearly sessile to peduncle; axillary and/or terminal; solitary, germinate (in pairs) or three in each group. The peduncle is upright (erect) or nodding (pendulous). Only one species (*C. capitata*) has inflorescences with flowers in clusters of 9–12(14) forming a simple umbellar structure (Orel, 2006) (Figure 3).

In size, the flowers mostly belong to the large flower group. Most flowers are 4–5 cm in size. The smallest flowers occur in *C. bidoupensis* (2–2.5 cm in diameter) and *C. thuanana* (2–3 cm in diameter) (Hoang et al., 2022; Truong et al., 2020). Large flowers occur in *C. proensis* (4–5.5 cm in diameter), *C. dalatensis* (4.0–4.5 cm in diameter), *C. vidalii* (5.5 cm in diameter), *C. thuongiana* (4.5–5 cm in diameter), *C. langbianensis* (5–6 cm in diameter), and *C. luteopallida* (5–6 cm in diameter) (Luong, Le, et al., 2016; Luong, Luu, et al., 2016; Quach, Doudkin, et al., 2021; Quach, Luong, Doudkin, Averyanov, et al., 2021; Tran & Luong, 2012). The largest flowers belong to *C. langbianensis*; they can be up to 6 cm in diameter and have a compound color. *C. proensis* and *C. vidalii* also have the large, completely yellow flowers up to 5.5 cm in diameter (Quach, Doudkin, et al., 2021; Quach, Luong, Doudkin, Averyanov et al., 2021; Rosmann,

1999). *C. dormoyana*, with a corolla up to 5.5 cm in diameter (*vide* Sealy, 1958), would be the species with the largest yellow flowers if its flower size was published officially.

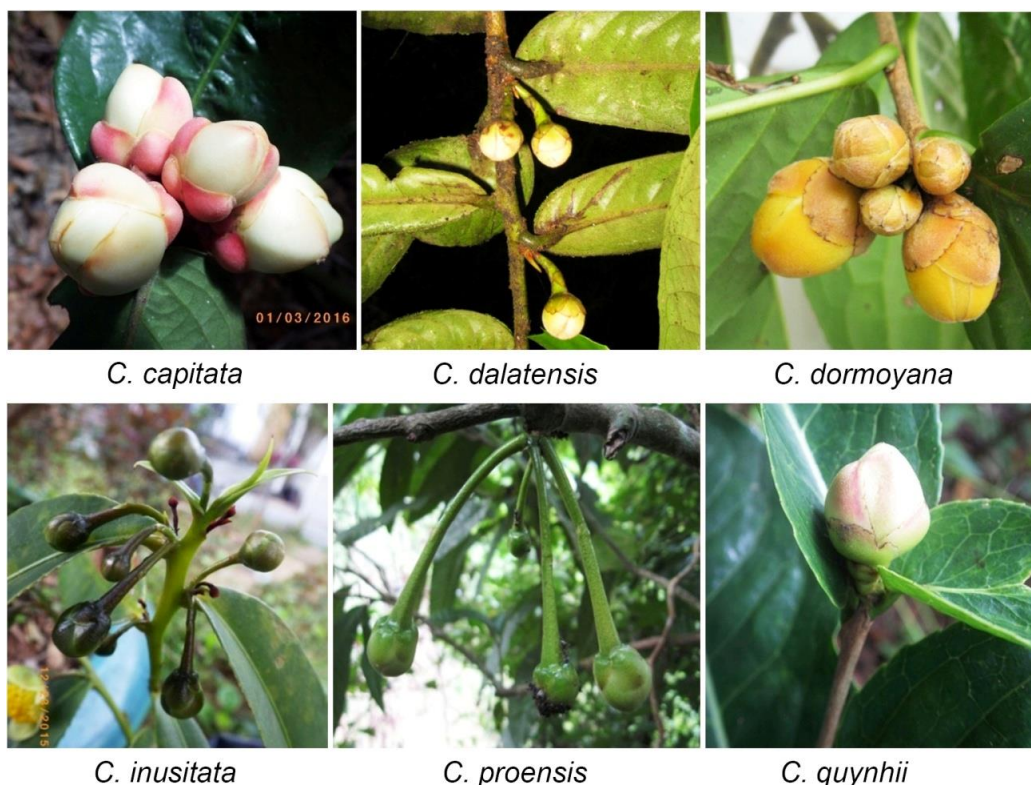


Figure 3. The flower position of yellow camellias

Sources: Luong Van Dung, Quach Van Hoi, and Hoang Thanh Truong.

3.3.3. Diversity of flower colors

The yellow colors vary between very slightly yellow and very deep yellow. The flower colors are based on the colors of the petals (Figure 4). The three color groups are listed below:

- Pale yellow (including lemon yellow, greenish yellow, light yellow, and bright yellow): *C. bidoupeensis*, *C. inusitata*, *C. luteopallida*, *C. thuanana*, *C. dalatensis*, *C. dilinhensis*, *C. proensis*, *C. quynhii*, and *C. thuongiana*.
- Yellow (including golden yellow, intense yellow, and deep yellow): *C. capitata*, *C. dormoyana*, *C. ninhii*, and *C. luteocerata*.
- Yellow with pink or orange margins on the petals (compound colors): *C. dongnaiensis*, *C. langbianensis*, *C. oconoriana*, *C. sphamii*, and *C. vidalii*.

Five species have a combination of colors: *C. langbianensis*, *C. oconoriana*, *C. dongnaiensis*, *C. sphamii*, and *C. vidalii* (Orel, 2006; Orel et al., 2013; Quach, Luong, Doudkin, Averyanov, et al., 2021; Rosmann, 1999; Truong et al., 2022). *C. langbianensis*

is yellow with slightly pink margins on the corolla. *C. oconoriana* is yellow with pinkish margins. *C. dongnaiensis* is a graduated yellow-to-apricot color with distinct, intensely pink margins. *C. sphamii* has orange-yellow petals, and *C. vidalii* is pale yellow with a light pink margin.



Figure 4. The diversity of flower colors

Sources: Luong Van Dung, Truong Quang Cuong, and Quach Van Hoi.

3.3.4. Fruit diversity

The fruits of the yellow flower species that keep the features of *Camellia* are the capsule, or more precisely, the loculicidal capsule. Capsules open 3–(4)5 valves with 1 to 5 seeds in each loculus. Capsule shapes vary between obovoid and globose, but most capsules are flattened globose. The seed shapes are mainly semi-spherical (cuneate-convex), but sometimes subglobose or globose (Figure 5). Species with large capsules are *C. dilinhensis* (3.5–4 cm wide, 5.5–6.5 cm tall), *C. proensis* (4.0–5.5 cm tall, 8.5–10.0 cm wide), and *C. dalatensis* (4.5–5.5 cm in diameter, 2.5–2.8 cm tall) (Quach, Luong, Doudkin, Averyanov, et al., 2021; Tran & Luong, 2012, 2013). Note that the capsules of many yellow species, including *C. capitata*, *C. dongnaiensis*, *C. luteopallida*, *C.*

thuongiiana, and *C. vidalii*, are not known as only immature fruits were collected (Orel, 2006; Orel et al., 2014; Luong, Le, et al., 2016; Luong, Luu, et al., 2016; Rosmann, 1998). Therefore, more work is necessary for full descriptions.

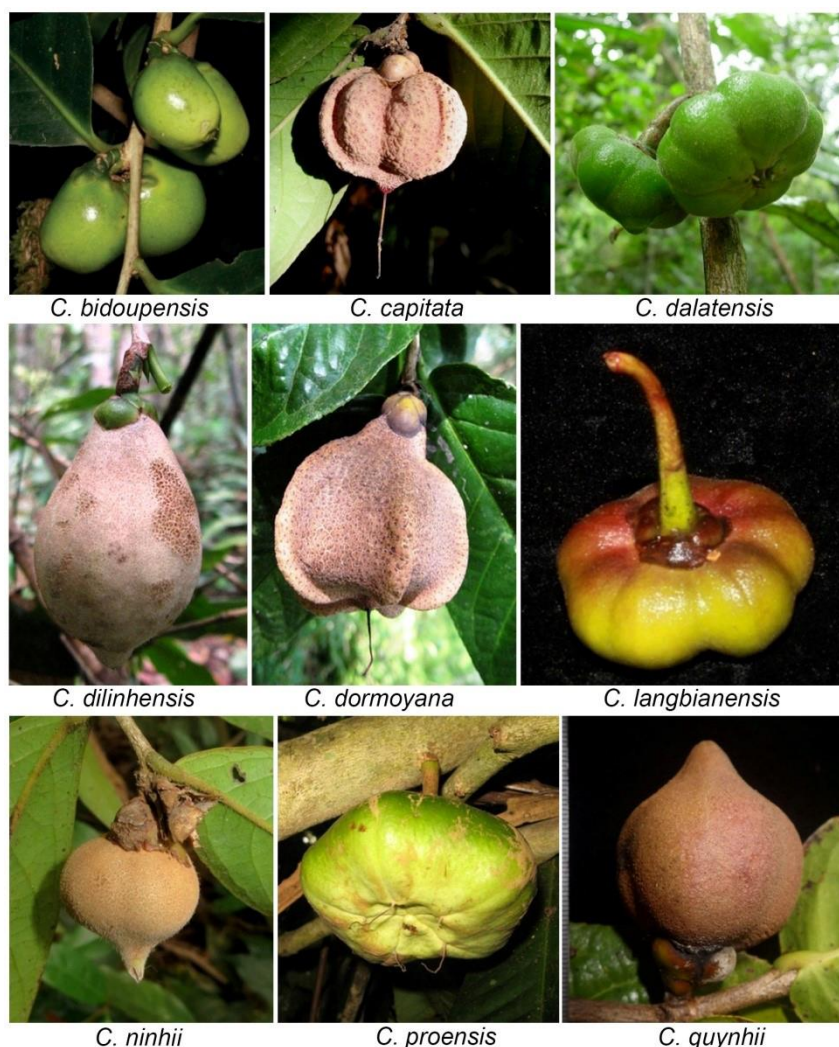


Figure 5. The capsule shapes

Sources: Luong Van Dung, Hoang Thanh Truong, Truong Quang Cuong, and Quach Van Hoi.

3.4. The vegetation diversity

All *Camellia* species are shade tolerant species able to adapt to life under the canopy of tropical forests. Yellow camellia habitats are usually near the bank of a river or stream, or in evergreen forest valleys where the climate is frequently humid. A few species are adapted to misty weather, such as *C. inusitata*, *C. bidoupensis*, and *C. dalatensis* (Orel et al., 2012; Tran & Luong, 2012; Truong et al., 2020). Yellow camellia distribution varies from 500 to 1,600 m. *C. ninhii* is recorded as the lowest elevation; it occurs in Cat Tien district at 500–600 m (Luong & Le, 2016). *C. inusitata* and *C. bidoupensis* are recorded at the highest elevations; they occur in Bidoup-Nui Ba National Park at 1600 m (Orel et al., 2012; Truong et al., 2022). The yellow camellia species grow

predominantly in evergreen-broadleaf forests. Several species grow in mixed wood-bamboo forests, including *C. luteopallida*, *C. quynhii*, and *C. thuongiana* (Luong, Le, et al., 2016; Luong, Luu, et al., 2016; Quach et al., 2022). In general, yellow camellias in the Central Highlands occur in evergreen-broadleaf and mixed wood-bamboo forests.

4. CONCLUSION

The Central Highlands contains 18 species of camellias, accounting for 37% of the yellow camellias of Vietnam and 28% of the yellow camellias globally. It accounts for more than one-third of Vietnam's yellow camellias and one-fourth of yellow camellias globally. All 18 species of yellow camellias in the Central Highlands are endemic to Vietnam.

The Central Highland's yellow camellias belong to nine sections, accounting for 75% of the sections worldwide (9/12). Four sections, *Bidoupia*, *Dalatia*, *Capitatae*, and *Obvoidea*, are newly added for the Central Highlands and Vietnam.

All yellow camellias are small trees or shrubs. The height of the trees varies from 3 to 10 m. Flowers of yellow camellias are sessile, nearly sessile to peduncle; axillary and/or terminal; solitary, germinate (in pairs) or three in each group. The three groups of colors are pale yellow, yellow, and yellow with a pink margin on the petals (compound colors). The fruits of yellow camellia species that keep the features of *Camellia* are the capsule, or more precisely, the loculicidal capsule. Capsules have 3–(4)5 valves with 1 to 5 seeds in each loculus. Capsule shapes vary between obovoid and globose, but most capsules are flattened globose.

Yellow camellias are found at elevations from 500 m to 1600 m. Yellow camellias in the Central Highlands are distributed in evergreen broadleaf and mixed wood-bamboo forests.

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