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DIVERSITY OF THE GENUS *Camellia* L. (Theaceae) IN LAM DONG PROVINCE, VIETNAM

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ABSTRACT

Through field survey and morphological research, this study has determined that the *Camellia* genus in Lam Dong province, Vietnam has a high diversity of morphological, distribution and taxa characteristics. The species of *Camellia* genus in Lam Dong province are mostly shrubs and small trees. The narrow oblong leaves are a very common and typical characteristic for *Camellia* in Lam Dong province. The flowers of the species of *Camellia* are diverse with four main colours is white, yellow, pink and purple. The fruits are globose, flattened globose, wrinkled or uneven edges. Especially, the obovoid fruit only occurs in Lam Dong province. Most of the species of *Camellia* genus in this province are endemic. The study has added ten species of the *Camellia* genus, brings the total of species of *Camellia* genus to Lam Dong province to between sixteen and twenty six. This is the first study to evaluate *Camellia* diversity in Lam Dong province. It is also the first complete statistics on the number of species of *Camellia* genus in Lam Dong province to confirm that this province is the second diversity centre of *Camellia* of Vietnam following the first centre in the North of Vietnam.

Keywords: *Camellia*, Diversity, Lam Dong, Vietnam.

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INTRODUCTION

Camellia L. is a large genus in the Theaceae family with about 280 species (Chang & Bartholomew, 1984; Gao et al., 2005). This genus mainly is distributed in Northern Vietnam and Southern China (Ming & Bartholomew, 2007; Orel, 2015). Several classification systems have been used for the division of the *Camellia* genus in the world. Sealy (1958) divided the genus *Camellia* into 2 groups, including 12 sections. Chang & Bartholomew (1984) divided this genus into four subgenera, including 20 sections. Then, Ming & Bartholomew (2007) divided the genus *Camellia* into two subgenera, including 14 sections. In 2015, Orel still retained four subgenus and expanded the system of Chang & Bartholomew (1984) to 27 sections, in which there are seven new sections for Lam Dong province (Orel, 2015). Recently, many new species of *Camellia* have been discovered in Vietnam (Ninh & Dung, 2013; Orel & Curry, 2014; Luu et al., 2015; Dung et al., 2016). According to the most recent statistic, there are 95 species of *Camellia* in Vietnam (Le, 2020). Although this study recorded a large number of *Camellia* species, it did not indicate the distribution location as well as assess the diversity of this genus. The new findings led to a significant increase in the number of the species of *Camellia* genus, especially in the Southern Vietnam, for which Lam Dong province is typical.

According to the classification of vegetation types by Averyanov et al. (2003), there are eight main types of vegetation in Vietnam. According to this classification, Lam Dong has 3 types of vegetation: Evergreen lowland forests on silicate rocks at elevations 0–1,000 m, Evergreen montane and highland forests on silicate rocks at elevations 1,000–3,143 m, and Secondary, weed and agricultural plant communities, timber and industrial plantations. According to UNESCO (1973), Lam Dong has 3 types of vegetation: Broad-leaved forest, Needle-leaved forest, Bamboo forest. Lam Dong is located in the south of Truong Son Range in central Vietnam, so it has diverse terrain. This province has low terrain below 500 m in Cat Tien district and higher terrain 1000 m in the Lam Vien Plateau with Bidoup (2,287 m) and Langbian (2163 m) peaks (Averyanov et al., 2003). Lam Dong has a diversity of terrain and vegetation that can be conditioned for the diversity of the species of *Camellia* genus.

MATERIALS AND METHODS

The surveys were carried out in Lam Dong province with the main locations of natural forests, Bidoup-Nui Ba and Cat Tien National Park. The distribution characteristics of the species were recorded based on different elevations and different types of vegetation. The coordinates and elevations were recorded by Garmin GPSMAP 78 GPS (US). Vegetation types are classified according to UNESCO (1973). This study used the classification system of Orel (2015) to classify the level of taxa. The species of *Camellia* genus are identified based on the following main documents: An Illustrated Flora of Vietnam (Pham Hoang, 1991), Flora of Vietnam (Hien, 2017), and Flora of China (Ming & Bartholomew, 2007).

RESULTS

Diversity of morphological characteristics and distribution

The species of *Camellia* genus in Lam Dong are mostly shrubs and small trees, only a few species are large trees such as *C. duyana*, *C. kissii* and *C. nervosa* (Table 1). Leaf morphology species of *Camellia* genus in Lam Dong have a large variety of leaf sizes 3–80 cm. *C. flosculora* has the shortest leaf 3–7 cm and *C. cattienensis* has the longest leaf 55–80 cm. The study showed that the *Camellia* group (*C. capitata*, *C. cattienensis*, *C. dalatensis*, *C. dongnaiensis*, *C. longii*, *C. piquetiana* and *C. proensis*) with leaf size longer than 25 cm is a specific characteristic for *Camellia* Lam Dong. This characteristic is rare in species distributed in other areas of Vietnam and around the world. The species of *Camellia* genus in Lam Dong province are also diverse in other characteristics of leaf, such as the oval, elliptic, obovate, and oblong leaf blade; the acuminate, acute, obtuse, and rounded leaf

apex and the acute, obtuse, rounded, and cordate leaf base (Table 1, Fig. 1). The genus *Camellia* in Lam Dong province has diverse flower colors, including; white, yellow, red and purple. Most of them bear yellow flowers. The *Camellia* in this region is diverse in the type of styles such as free on the base, styles fused part, styles fused, styles with hairy. They also vary in size and flower arrangement such as large or small flowers, solitary or clustered flowers, in axillary or terminal (Table 1, Fig. 2). The results of the study also showed the diversity of fruits and seed morphology of the species of *Camellia* genus in Lam Dong province by fruits flattened globose, globose, wrinkled, uneven edges and obovoid; seeds globose, semi-globose or wedge-shaped (Table 1, Fig. 3).

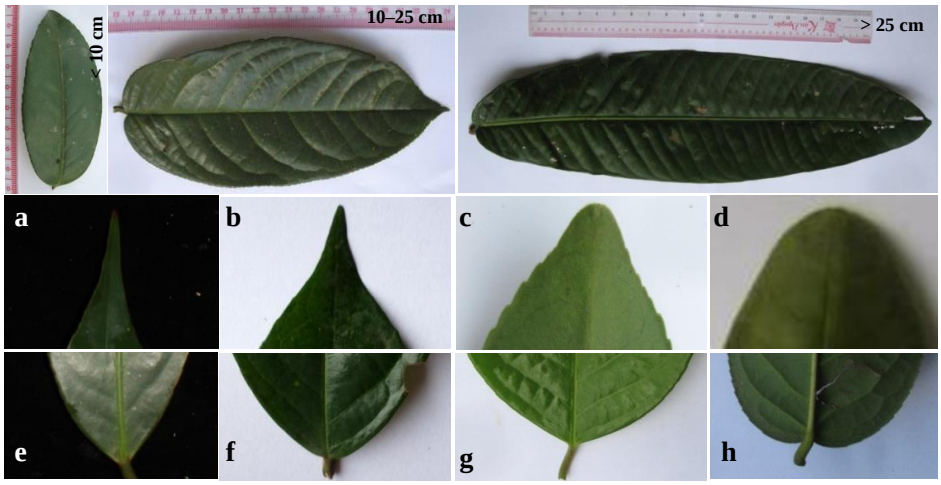

Figure 1. Diversity of leaf size (top row) (*C. kissii*, *C. dormoyana*, *C. catienensis*), the leaf apex: a. Acuminate (*C. langbianensis*), b. Acute (*C. ninhii*), c. Obtuse (*C. kissii*), d. Rounded (*C. vidalii*), and the leaf base: e. Acute (*C. langbianensis*), f. Obtuse (*C.curryana*), g. Rounded (*C. ninhii*), h. Cordate (*C. inusitata*)

Figure 2. Diversity of flower colors and the types of styles: a. Free on the base (*C. catienensis*), b. Styles fused part (*C. thuongiana*), c. Styles fused (*C. capitata*), d. Styles with hairy (*C. kissii*)

Table 1. Diversity of morphological characteristics and distribution of thhe species of *Camellia* genus in Lam Dong province

No.	Species	Forms of plants (m)	Leaves (blades, apex, base)	Size of leaves (cm)	Flowers (Colors)	Fruits and Seeds	Elevation (m)	Vegetation
1	*C. bidoupensis*	Tree, 3–7	Elliptic; acute; rounded, obtuse	8–12 × 3.5–5.5	Yellow	Ovoid; subglobose	1,550–1,600	Broad-leaved forest, Needle-leaved forest
2	*C. capitata*	Shrub, 5	Elliptic, oval; cuspidate; obtuse, cordate, acute	24–27(–32.5) × 10–12(–13)	Yellow	Not seen	200–450	Broad-leaved forest, Bamboo forest
3	*C. cattienensis*	Shrub, 5	Elliptic; acute; auriculate	55–70(–80) × 8.5–9	Red	Flattened globose; semi-globose, wedge-shaped	200–500	Broad-leaved forest, Bamboo forest
4	*C. cuongiana*	Shrub, 6	Elliptic, oval; cuspidate, acuminate; acute, obtuse	6–7 × 2.5–3	White	Ovoid (oval);-	800–1,100	Broad-leaved forest, Needle-leaved forest
5	*C. curryana*	Shrub, 2.5	Elliptic, oval; acute, obtuse; acute, obtuse	10–12 × 4–5(–6)	White	Not seen	1,500–1,700	Broad-leaved forest
6	*C. dalatensis*	Tree, 4	Oblong; acuminate; cordate	40–45 × 8–11	Yellow	Flattened globose; semi-globose	1,250–1,300	Needle-leaved forest
7	*C. dilinhensis*	Tree, 3–4	Oblong-elliptic, elliptic; acuminate; cuneate	16.0–24.5 × 5.5–9.5	Yellow	Obovoid; wedge-shaped	850–900	Broad-leaved forest
8	*C. dongnaiensis*	Shrub, 2.5	Obovate; acute, cuspidate; acute, rounded	44 × 14	Yellow	Not seen	600–800	Broad-leaved forest
9	*C. dormoyana*	Tree, 6–10	Oval, oblong, ovate; acute; rounded	11–18 × 5.5–8	Yellow	Semi-globose; globose, wedge-shaped	240–470	Broad-leaved forest, Bamboo forest
10	*C. duyana*	Shrub, 12–15	Elliptic; cuspidate; acute, cuneate	10–13.5 × 3.9–4.7	White	Not seen	1,000–1,500	Broad-leaved forest
11	*C. flosculora*	Tree, 3–8	Lanceolate, oblong-ovate; acuminate; rounded, obtuse	3–7 × 1.5–2.5	Yellow	Globose; globose	1,600–1,700	Broad-leaved forest, Needle-leaved forest
12	*C. furfuracea*	Shrub, tree, 2–3	Elliptic, oblong-elliptic; acuminate; cuneate	8.5–14.5 × 2.5–5.6	White	Subglobose; semi-globose, wedge-shaped	200–1,200	Broad-leaved forest
13	*C. harlandii*	Shrub, 2–3	Elliptic, oval; acuminate, cuspidate; acute	10–12 × 4–4.5	White	Globose; globose	1,000–1,300	Broad-leaved forest

14	*C. inusitata*	Tree, 3	Lanceolate; acuminate; cordate	18 × 3–4	Yellow	Flattened globose; semi-globose	1,500–2,100	Broad-leaved forest
15	*C. kissii*	Shrubs, tree, 13	Elliptic, oblong-oblanceolate; acuminate, caudate; cuneate, rounded	5.5–9 × 1.7–3.5	White	Subglobose, globose; semi-globose, wedge-shaped	1,000–2,000	Broad-leaved forest, Needle-leaved forest
16	*C. langbianensis*	Tree, 3–5	Oblong; acuminate; cuneate, obtuse	20–32 × 5–8	Yellow	Flattened globose; semi-globose	850–1,500	Broad-leaved forest
17	*C. ligustrina*	Shrub, 4–6	Elliptic; cuspidate; obtuse, acute	8.5 × 2.5(–3)	White	Globose; wedge-shaped	1,400–2,100	Broad-leaved forest, Needle-leaved forest
18	*C. longii*	Shrub, 2.5–4	Elliptic, oblong; acute; cordate	27–31 × 6–9(–10.5)	Red	Not seen	1,500–1,700	Broad-leaved forest
19	*C. luteopallida*	Shrub, tree, 8	Elliptic, oval; acuminate; obtuse, cuneate	16–20 × 5–9	Yellow	Not seen	400–650	Bamboo forest
20	*C. maiana*	Shrub, 5	Elliptic, ovate, obovate; acuminate, cuspidate; rounded	10–14 × 5–6	White	Globose; ovoid, semi-globose	230–800	Broad-leaved forest
21	*C. nervosa*	Tree, 15–20	Lanceolate, ovate; acute; cuneate	5–8 × 2.5–3.5	White	Ovoid	1,000–1,600	Broad-leaved forest
22	*C. ninhii*	Shrub, 2–4	Elliptic, oblong elliptic; acuminate, caudate; cuneate, rounded	14–20 × 5–7	Yellow	Flattened globose; semi-globose	500–600	Broad-leaved forest
23	*C. piquetiana*	Tree, 2–5	Oblong-elliptic; acute; obtuse, rounded	29–42 × 9.5–12.5	Purple	Flattened globose; semi-globose	200–470	Broad-leaved forest, Bamboo forest
24	*C. proensis*	Tree, 5–6	Oblong-elliptic; acuminate; acute, rounded	33–35 × 7.5–8.5	Yellow	Flattened globose; semi-globose, wedge-shaped	800–1,100	Broad-leaved forest
25	*C. sinensis* var. *assamica*	Shrub, tree, 3–5	Elliptic; cuneate; acuminate	8–14 × 3.5–7.5	White	Oblate; globose, subglobose	200–2,200	Broad-leaved forest, Needle-leaved forest, Bamboo forest
26	*C. thuongiana*	Tree, 3–5	Elliptic, oblong-elliptic; acuminate, caudate; cuneate, rounded	9–17 × 4–6.5	Yellow	Not seen	500–800	Broad-leaved forest

Figure 3. The types of fruits and seeds of the *Camellia* genus in Lam Dong province: a. Capsule flattened globose (*C. langbianensis*), b. Capsule globose (*C. furfurace*), c. Capsule wrinkled (*C. piquetiana*), d. Capsule uneven edges (*C. dormoyana*), e. Capsule obovoid (*C. dilinhensis*), f. Seeds globose (*C. sinensis* var. *assamica*), g. Seeds wedge-shaped (*C. proensis*)

Camellia in Lam Dong is distributed from an altitude of 200–2,200 m. Some species are only found at altitudes over 1,500 m such as *C. flosculora*, *C. bidoupensis* and *C. inusitata* and only found at altitudes below 500 m such as *C. dormoyana* and *C. capitata*. The four species *C. dilinhensis*, *C. bidoupensis*, *C. proensis* and *C. dalatensis* are only distributed at elevations that do not differ more than 50 m. *Camellia* in Lam Dong is presented in three vegetation types, including Broad-leaved forest, Needle-leaved forest, Bamboo forest. Twenty four of them (92.30%) are present in the vegetation type of Broad-leaved forest. Details of the distribution for each species are in Table 1. Eighteen species (69.23%) are endemic to Lam Dong province (Table 2).

Diversity of taxa

The study identified 26 species of *Camellia* genus in Lam Dong province, including four subgenus and 15 sections. (Chang & Bartholomew, 1984) Subgenus Protocamellia includes four sections: *Dalatia*, *Piquetia*, *Stereocarpus* and *Yersinia.* Subgenus Camellia includes four sections: *Capitatae*, *Furfuracea*, *Paracamellia* and *Pierrea.* Subgenus Thea includes six sections: *Bidoupia*, *Brachyandra*, *Chrysantha*, *Lamdongia*, *Obvoidea* and *Thea.* Subgenus Metacamellia only section: *Theopsis* (Fig. 4, Table 2).

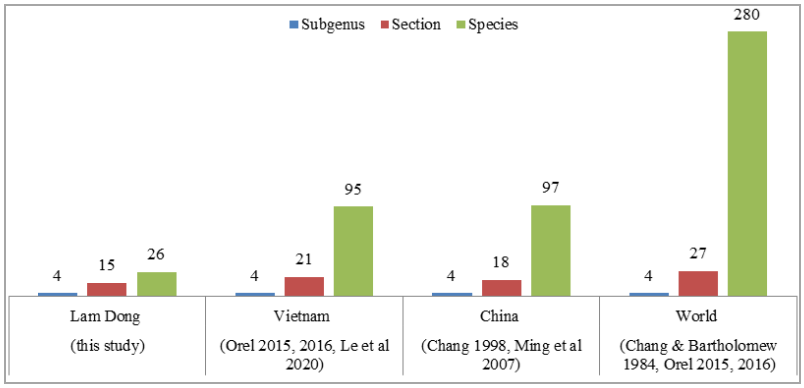

Figure 4. The graph shows the number of subgenus, sections and species of the *Camellia* genus in Lam Dong province compared to other regions

Table 2. List of the species of *Camellia* genus in Lam Dong province and recognized presence in other regions of Vietnam and other countries

Subgenera	Section	Species	Other regions of Vietnam	Other countries
PROTOCAMELLIA	*1. Dalatia*	*1. C. luteopallida*	+	-
	2. Piquetia	*2. C. dalatensis*	-	-
		3. C. dongnaiensis	+	-
		4. C. langbianensis	-	-
		5. C. longii	+	-
		6. C. piquetiana	+	-
		7. C. proensis	-	-
	3. Stereocarpus	*8. C. cattienensis*	-	-
		9. C. dormoyana	+	+
	4. Yersinia	*10. C. harlandii*	-	-
CAMELLIA	*5. Capitatae*	*11. C. capitata*	-	-
	6. Furfuracea	*12. C. curryana*	-	-
		13. C. duyana	-	-
		14. C. furfuracea	+	+
		15. C. maiana	-	-
	7. Paracamellia	*16. C. kissii*	+	+
	8. Pierrea	*17. C. ligustrina*	-	-
THEA	*9. Bidoupia*	*18. C. inusitata*	-	-
	10. Brachyandra	*19. C. nervosa*	-	-
	11. Chrysantha	*20. C. ninhii*	-	-
		21. C. thuongiana	-	-
	12. Lamdongia	*22. C. cuongiana*	-	-
	13. Obvoidea	*23. C. dilinhensis*	-	-
	14. Thea	*24. C. flosculora*	-	-
		25. C. sinensis var. *assamica*	+	+
METACAMELLIA	*15. Theopsis*	*26. C. bidoupensis*	-	-

Note: The "+" marks are present, the "-" marks are absent.

Lam Dong province has 4/4 (100%) of subgenus compared to the number of subgenus in Vietnam as well as in the world. There are 15/21 (71.43%) sections of Vietnam (Orel, 2015; 2016), 15/27 (55.65%) sections of the World (Orel, 2015; 2016), approximately equal to the number of Chinese sections (Chang, 1998). Lam Dong province has 26 *Camellia* species, accounting for 27.37% of Vietnam's *Camellia* (Le et al., 2020), accounting for 9.29% of the world's *Camellia* (Chang & Bartholomew, 1984) (Fig. 4). This result shows that Lam Dong province has a high diversity of taxa, especially high in subgenus and sections.

DISCUSSION

The morphological diversity of the *Camellia* genus in Lam Dong has been shown through a diversity of forms of plants, leaves, flowers, fruits and seeds. This diversity helps *Camellia* species to adapt to the diversity of the natural conditions of Lam Dong province. Orel & Curry (2016) explained the rationale of some of *Camellia*'s morphological characteristics. The large leaves are adapted to low light conditions. This study also showed that the remarkable distinctive characteristic the species of *Camellia* genus in Lam Dong is the oblong leaves. This characteristic is not common in other regions. Flowers with a spiral or partially spiral sepal and petal arrangement, oblongoid in their lateral section help quick drainage. The diversity of flower colors attracts insects to pollinate. Diversity of flower arrangements such as small flower arrangements of dense flowers like branches increases the target for insects to come to pollinate. The diversity of fruit morphology may be due to the variety of natural conditions. Especially, this region has the characteristic of obovoid fruit (in *C. dilinhensis*), which is only found in Lam Dong province, Vietnam. This characteristic becomes an identifiable characteristic of section *Obvoidea*. Research by Orel & Curry (2016) detected some primitive morphological characteristics in some species of southern Vietnam such as *C. harlandii, C. capitata, C. ligustrina.* From the individual perspective, he suggested that the species of *Camellia* genus originated from South Vietnam. The results of this study are reasonable with statements from the study of Orel & Curry (2016).

This study shows that some species of *Camellia* genus are present only at a specific elevation. In the conservation of species, the movement of trees between locations requires attention to elevation. The common species can grow at different elevations. Endemic species need to grow at the same elevation as the original distribution. *Camellia* genus is present in three types of vegetation in Lam Dong province. The Broad-leaved forest has the most abundant the species of *Camellia* genus because these species are shrubs and trees, which are a characteristic feature of this type of vegetation. In contrast, the Bamboo forest has a small number of trees, so it has the least number of the species of *Camellia* genus. Conservation research for the species of *Camellia* genus also needs to pay attention to the type of vegetation. Thus, according to the results of this study, the Broad-leaved forest is most suitable for the conservation of the *Camellia* genus.

Lam Dong province has a high diversity of taxa because it has many typical sections such as *Obvoidea, Lamdongia, Bidoupia, Yersinia, Dalatia* and *Piquetia,* which are present only in this region. In particular, the section *Piquetia* has a large number of species with the characteristic narrow oblong leaf type with a very large size, making this group much different from the other sections. This study shows that most of the species of *Camellia* genus in Lam Dong province are endemic with 18 species accounting for 69.23% of the region's species. The other species are present in other regions of Vietnam, or in other countries (Fig. 5). Lam Dong province is considered to be a concentration of endemic the species of *Camellia* genus. This study has identified 26 species of the *Camellia* genus in Lam Dong province, ten of them have been newly added. Previous studies recorded seven species (Pham Hoang, 1991; Ninh, 2002), 16 species (Orel, 2015) and 11 species (Hien, 2017) (Fig. 5). Many studies confirm that Northern Vietnam is a centre for diverse species of *Camellia* in the world (Ninh, 2002; Orel, 2015; Hien, 2017). Within the territory of Vietnam, Lam Dong province is the second-largest center of the country's *Camellia* species with 26 species compared with the northern center with 34 species (Ninh, 2002). There is the need for a study that covers the Lam Dong and the Southern Vietnam territory to ascertain the assertion that the Lam Dong is the second-largest center for the country's *Camellia*.

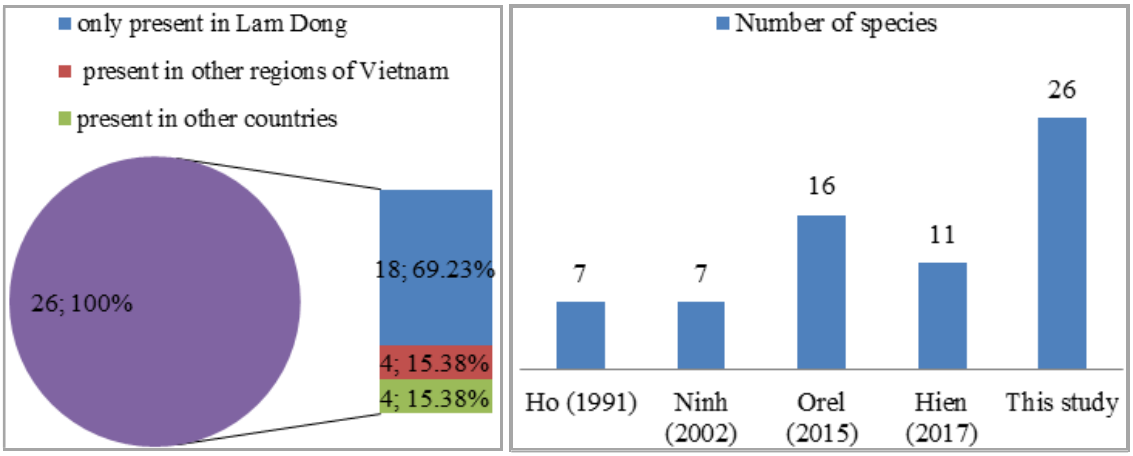

Figure 5. The diagram shows the number and percentage of *Camellia* species present in each distribution region (the first), and compared with statistics from other studies (the second)

CONCLUSION

Camellia in Lam Dong is diverse in morphology by the characteristics of an evergreen shrub and tree, 2–20 m tall; leaves elliptic, oblong, oblong-elliptic, lanceolate, ovate, obovate, oval, oblong-oblanceolate and oblong-ovate; apex acuminate, acute, caudate, obtuse and cuspidate; base rounded, cuneate, acute, obtuse, auriculate and cordate; flower white, yellow, red and purple; capsule globose, flattened globose, wrinkled, uneven edges and obovoid; seeds globose, semi-globose or wedge-shaped. *Camellia* in Lam Dong is also diverse in distribution. Their distribution presents from an elevation of 200–2200 m with Broad-leaved, Needle-leaved and Bamboo forests. Following the first *Camellia* diversity centre in the north of Vietnam, Lam Dong province is considered the second diversity center of *Camellia* in Vietnam with 26 species.

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