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Occurrence of *Calophyllum apetalum* Willd., in the coastal plains of Alappuzha district and evaluation of its population characteristics with respect to an evergreen forest ecosystem of the Southern Western Ghats

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Abstract

Calophyllum apetalum Willd., commonly known as "Poon spar of Travancore", is an evergreen tree endemic to the Western Ghats of India, thrives in riparian habitats of evergreen forests and coastal sandy regions. In this study, we investigated its distribution in Alappuzha district (coastline area) and the Kallar forest region (evergreen forest). The study analyzed relative dominance, frequency, density and the Importance Value Index (IVI) of *C. apetalum*, along with soil composition. This study concludes that, despite variations in terms of diversity and species richness, *C. apetalum* remains dominant on both the studied locations (with the highest IVI). however, there is a concerning decline in its population, additionally, this species can thrive in different soil compositions of coastal plains as well as evergreen forest, also dominant in their respective habitats.

Keywords

Calophyllum apetalum; Importance Value Index; Western Ghats; Alappuzha

Introduction

Calophyllum apetalum Willd., known as 'Poon spar of Travancore' and commonly called "Cherupunna" or "Aattupunna" in Malayalam, is an evergreen tree endemic to the Western Ghats of India. Previously classified under the family Clusiaceae, the species is now included in the family Calophyllaceae (28). The plant is often denoted by several synonyms such as *C. decipiens* Wight., *C. wightianum* Wall. ex Planch., *Calophyllum calaba* L. and *Calophyllum spurium* Choisy (2). It is important to note that although many authors from India used the name *C. calaba* L. to denote *C. apetalum*, whilst distribution of the tree *C. calaba* is restricted to Sri Lanka and the Western Ghats species of India are all *C. apetalum* (26).

C. apetalum is a medium sized tree attaining a height of about 20 m. Leaves are thick and shining and variously coloured from scarlet (when young) to dark green (on maturity); (4-8 X 2-3.5) cm in dimension, obovate, ovate to rhomboid, obtuse at apex and broadly alternate at base. Flowers are in axillary or lateral racemose panicles; pedicels (1-1.5) cm long; sepals biseriate (0.2-0.4) cm, inner ones slightly larger and petaloid; petals 0; stamens (0.2-0.3) cm long; ovary globose, (0.6-0.8) cm in diameter (Fig. 1). Seeds are ovoid, (0.4-0.6) cm x (0.15-0.2) cm; endosperm is oily (15). The flowering and fruiting period is usually September/October to March/April (29).

The tree has important medicinal properties and its seed oil is used in the treatment of rheumatism and leprosy (2). The leaf juice is used to treat gastric ailments (5). The species is abundant in various xanthonoids like apetalinones (14). In fact, many bioactive compounds of the genus *Calophyllum* are found to be having

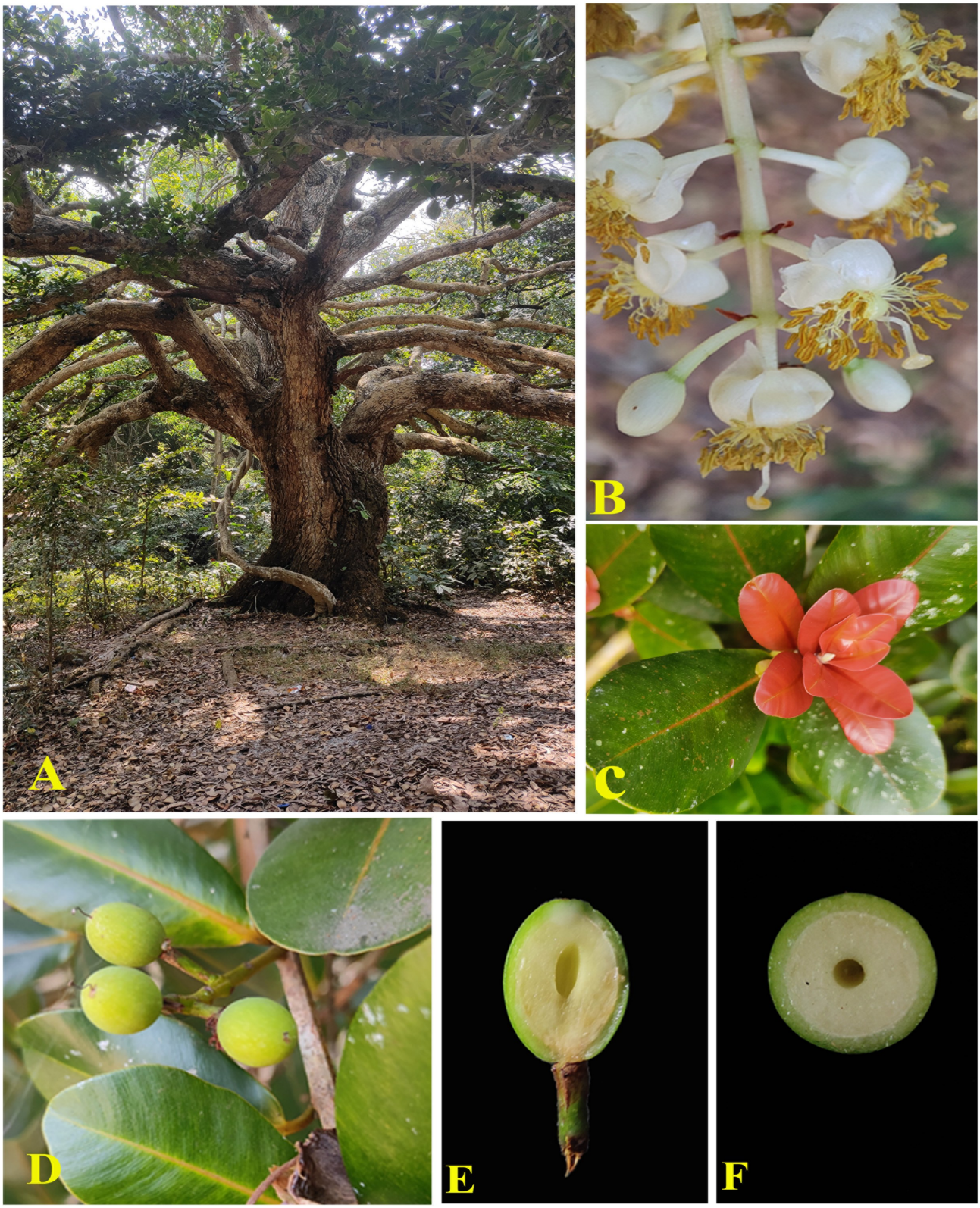

Fig. 1. *Calophyllum apetalum* Wiild.

(A) Habit (B) Flower with floral buds (C) Leaf-flushing (D) Fruit (E) L.S of fruit (F) C.S of fruit.

antiviral, antibacterial, hypotensive and antiretroviral activities (7). Coumarin extracted from several *Calophyllum* species is found to have the capacity to inhibit the reverse transcriptase enzyme of HIV-1 (4). Additionally, endophytic fungi (*Myrothecium* sp.) associated with *C. apetalum* also possess bioactive potentials (23). Apart from the medicinal value, wood of the species was used as timber and provided a good raw material in ship building (17; 24). Seed is also used to extract lamp oil (28).

The plant is commonly distributed along riverbanks of the Western Ghats to an elevation up to 1300 meters and found in the sandy plains (15). However, the population of *C. apetalum* has declined significantly in the wild over the last few decades. The species is listed as “Vulnerable” under criteria A 2cd by IUCN (IUCN 2014). The seeds have a low germination capacity <40% and the seed loses its viability over time due to its oily nature. Additionally, since it has a riparian habitat often the seeds are lost in floods (17). *C.*

apetalum has shown poor growth and survival potential for early establishment in an open degraded land that was transformed due to deforestation; several biotic and abiotic factors like herbivory, termite attack, pest and pathogen attack, availability of light and other favourable weather conditions also affect early survival and establishment (16). Other factors, such as inappropriate flowering periods, premature fruit abortion, floral pests, are also negatively affecting fruit set of the plant (12).

Isolated populations of *C. apetalum* are spotted in several areas of Alappuzha District in Kerala (8; 25). The sandy coastal plains of Alappuzha are a different ecological landscape comparable to the wet evergreen littoral forests. Alappuzha is the smallest district in Kerala geographically located between latitudes 9° 05' N and 9° 52' N and longitudes 76° 17' E and 76° 48' East. West to Alappuzha is the Arabian sea with 82 km of coastline: the general elevation being less than 6 m from sea level (3). Alappuzha district has a wide network of rivers, backwaters and lagoons. The drainage density is 0-6 km/km^2; the annual rain fall is 2965.4 mm and the soil of the region is mostly clayey, gravelly clay, loam and sandy (21). Only 7% of its total geographical area comes under reserve forest (State Planning Board, 2016).

The present study was mainly aimed at assessing the distribution of *C. apetalum* in Alappuzha district involving identification of populations and re-assessment of the previously recognized ones. Quantitative characteristics, such as relative dominance, relative frequency, relative abundance and Importance Value Index (IVI) of *C. apetalum* were determined in the areas of occurrence. The results were compared with IVI of the tree distributed in a relatively high-altitude location of Western Ghats - Kallar Forest area (in Thiruvananthapuram District, Kerala), which has an elevation up to 250 m. The soil characteristics of both locations were also analysed as part of habitat assessment.

Materials & methods

Field surveys were carried out periodically from January 2023 to January 2024 to locate *C. apetalum* population in the coastal belt of Alappuzha District and in the lower elevation forest tracts of the Western Ghats (Kallar region). Distribution/occurrence of the species in the areas was also verified with authentic secondary information contained in the state/regional flora and checklists (18). Two sample plots of size 50 m x 10 m were laid out covering 1000 m^2 area in each location to analyse quantitative characteristics. All species of trees having more than 50 cm Girth Breast Height (GBH) (>50 cm) were counted and measured species diversity, frequency and dominance/basal area (27). Approximate number of seedlings (GBH <30 cm) were also noted. Recorded photographic data about tree, habit, habitat, flower, fruit, etc., Gathered other additional data from local individuals from the locations. The distribution map was constructed using qGIS software (version 3.34). The important Value Index (IVI) was calculated using 'R' programming, that is the sum of relative frequency, relative density abundance and relative dominance.

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of an individual species}}{\text{Total frequency of all species}} \times 100 \quad \text{(Eqn. 1)}$$

$$\text{Relative Abundance (RA)} = \frac{\text{Density of an individual species}}{\text{Total density of all species}} \times 100 \quad \text{(Eqn. 2)}$$

$$\text{Relative Dominance (RD)} = \frac{\text{Basal area of a species}}{\text{Total basal area}} \times 100 \quad \text{(Eqn. 3)}$$

$$\text{Importance Value Index (IVI)} = RF + RA + RD \quad \text{(Eqn. 4)}$$

Soil samples were collected from these locations following standard method of sampling and analysed for physico-chemical characteristics such as texture, pH, soil organic carbon, phosphorus, potassium etc, in the State Soil Testing Laboratory, Thiruvananthapuram, Kerala.

Results

A total of 13 locations of *C. apetalum* populations were spotted in Alappuzha district (Fig. 2). Number of *C. apetalum* trees varies from 1 to 34 in each location, a total of 120 trees recorded. Only trees with more than 50 cm GBH were spotted from all the locations. However, numerous seedlings were found in some locations. Illathukavu in Kanjikkuzhi had the highest number of seedlings, with over 500 seedlings spotted during multiple visits. Most of the populations in the area are part of sacred groves. *C. apetalum* is the dominant species in some sacred groves as in the case of Aikkarakavu, Kalavoor and Illathukavu, Kanjikkuzhi. *Hopea parviflora* is frequently spotted together with *C. apetalum.* The presence of waterbodies such as ponds and streams is common adjacent to the populations, apparently revealing its preference for riparian habitats. The flowering and fruiting period of the species is between September to March.

Location Illathukavu Kanjikkuzhi (9^{0}62' 54. 91" N and 76 ^{0}35' 06. 90" E) was selected as a site for IVI studies based on the number of available trees. Location Kallar, Thiruvananthapuram (8^0 71' 07.03'' N, 77^0 13' 91.54'' E) was the other site for IVI study as it represented a different habitat of *C. apetalum* in the Western Ghtas. It is situated at a higher elevation, distant from the sea with different climatic and soil conditions representing evergreen forest ecosystem. However, the similarity in population is that it is also found along riverbanks and association with *Hopea ponga*. The IVI calculated for both the locations Illathukavu, Alappuzha (Table.1) and Kallar, Thiruvananthapuram (Table.2) are given in the table.

Important Value Index (IVI) of *C. apetalum* was the highest in both locations,142.47 and 82.32 respectively (Table -01). *Hopea parviflora* is the second most abundant species in

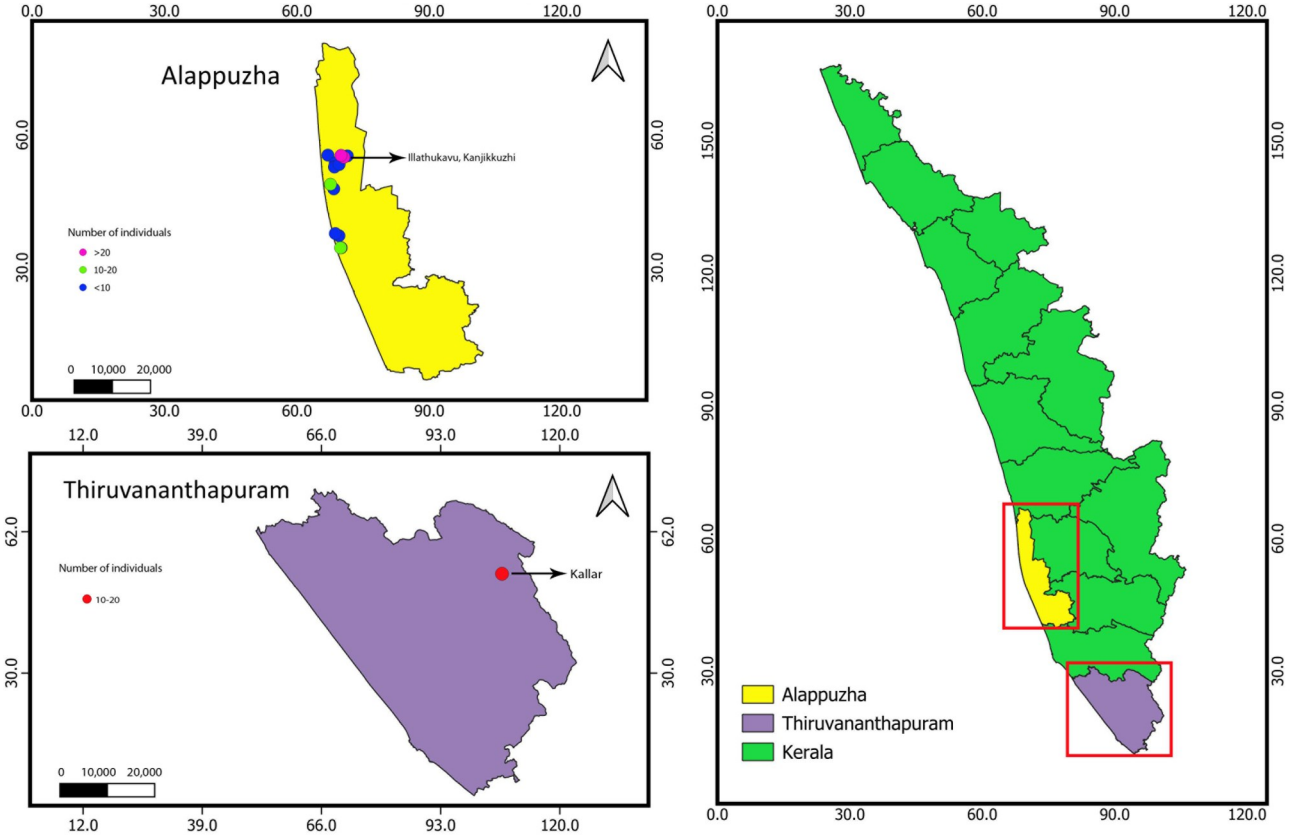

Fig. 2. Distribution map of *C. apetalum* in Kerala,
(a) Distribution in Alappuzha District (b) Kallar Forest Region

Table 1. *Calophyllum apetalum*: Population diversity analysis of Illathukavu, Kanjikkuzhi, Alappuzha.

Species	Relative Frequency (%)	Relative Density (%)	Relative Dominance (%)	Importance Value Index (%)
Calophyllum apetalum Willd.	25	47.22	70.24	142.47
Hopea parviflora (Dennst.) Mabb.	25	47.22	26.74	98.96
Persea macrantha (Nees) Kosterm	25	2.78	2.77	30.55
Ailanthus excelsa Roxb.	25	2.78	0.24	28.02
Total	100	100	100	300

Table 2. *Calophyllum apetalum*: Population diversity analysis of Kallar Forest Region, Thiruvananthapuram.

Species	Relative Frequency (%)	Relative Density (%)	Relative Dominance (%)	Importance Value Index (%)
Calophyllum apetalum Willd.	10	27.03	45.2	82.32
Hopea parviflora (Dennst.) Mabb.	10	13.51	26.11	49.62
Terminalia paniculata Roth.	10	16.22	8.0	34.22
Madhuca neriifolia (Moon) H.J. Lam.	10	18.99	3.99	32.91
Artocarpus hirsutus Lam.	10	5.41	6.39	21.79
Vitex altissima L.f.	10	5.41	2.97	18.37
Canarium strictum Roxb.	10	2.7	3.93	16.63
Xanthophyllum flavascens Roxb.	10	5.41	0.69	16.09
Vateria indica L.	10	2.7	1.97	14.67
Hydnocarpus alpinus Wight	10	2.7	0.65	13.35
Total	100	100	100	300

both the locations. Species with the least IVI in Illathukaavu is *Ailanthus excelsa* and *Hydnocarpus sp.* in Kallar. Relative frequency is same for all the species because all the species occurred within the sample plot. All the species including *C. apetalum* of Kallar location is much taller compared to the species in Alappuzha. Species diversity is higher in Kallar region, recorded 10 tree species from this location compared to the 4 species in Alappuzha. Therefore, in Alappuzha, species have very large IVI values while Kallar IVI values are relatively less and distributed more evenly among the species.

Results of soil analysis are represented in Table-3. Soil of Kallar, Thiruvananthapuram is loamy and less acidic. It also has very low electrical conductivity and relatively higher amounts of nitrogen and potassium, which are essential for plant growth. On the other hand, soil from Illathukavu, Alappuzha is sandy and comparatively more acidic (pH is 4.1). Nitrogen and phosphorus content are slightly less as compared to the soil of Kallar site; However, potassium (K) content is comparatively very low.

Table 3. Soil test results of Illathukavu, Alappuzha and Kallar Forest, Thiruvananthapuram

Parameter	Location	
	Kallar Forest	Alappuzha
Soil Textures	Loamy	Sandy
Soil pH	6	4.1
T.S.S EC in mhos/cm	0.03	0.1
Organic Carbon (%) Indicator of Nitrogen	0.94	0.86
Phosphorous (Kg/ha)	13	15
Potassium (Kg/ha)	134	58

Discussion

Alappuzha region has a high number of *C. apetalum* population compared to other regions of southern Western Ghats. Soil in the coastal regions usually provide poor rooting condition, which makes trees susceptible to environmental changes (11). Also, dendrological studies on *Pinus* sp. show that the more distance from sea line correlates to reduction in mean growth compared to the ones that are far away from sea line. However, in the case of *C. apetalum* both are not true as the species is well adapted to normal range of temperature, salinity, soil pH and moisture of the coastal region of Alappuzha; also, their GBH is comparable with the ones in distant inland regions. It is interesting to note that although numerous seedlings were spotted, young trees (GBH < 50cm) are low in number. This reflects to the decline in early survival and establishment of *C. apetalum* seedlings. *C. apetalum* has relatively average to poor survival and establishment rates for young progenies (59.2%) compared to some common tree species in the Western Ghats, particularly in areas with annual rainfall of 3500 mm (16). In Alappuzha, the rainfall is lower than this figure (2965.4 mm) and the altitude is close to sea level. However, the relationship between altitude and rainfall in terms of seedling survival is not straightforward; other factors such as climate, disturbances and soil characteristics must also be considered.

C. apetalum seeds are dispersed through anemochory (wind mediated), hydrochory (water mediated) and mammalochory (mammals based) (12). The common seed dispersing mammals listed are porcupine, barking deer, giant squirrel and sambar which are not common in Alappuzha region, therefore anemochory and hydrochory would be the most functional mode of seed dispersal. The extensive network of water bodies in Alappuzha could have helped to spread out the population because the seed can be dispersed through water up to several kilometres. Presence of coastline provides regular wind which could also help seed dispersal.

One of the contrasting characteristics between the population of the coastline and inland area is the height of trees. *C. apetalum* trees from Kallar forest are much taller. Competition among the forest trees for sunlight is the major factor driving the increase in height. Study in Amazon rainforest noted that the trees in the dense central Amazonia region is much taller than the trees in open South-West Amazonia region and they also remain high in biomass (19). Their study also correlates with the current results. Trees in general from Kallar forest are taller and have high mean average GBH compared to those in Alappuzha.

October to February is the period of flowering and fruiting on the studies conducted in Someshwara Wildlife Sanctuary of the Western Ghats, Karnataka region which almost correlates with observations of Alappuzha populations in the present study, however the leaf flushing is observed even before in November, a slight deviation from the study (13). Greater species diversity occurred in Kallar Forest region, as it is evident in the IVI values. The fertile soil and the climate of evergreen forest would naturally promote greater species diversity. Idukki Forest region of the Western Ghats report have *Calophyllum calaba* L. (synonym of *C. apealum*) along with *Calophyllum polyanthum* Wall ex Choisy is the highest IVI holding species in some regions (27). These results are similar the findings of the present study, where *C. aeptalum* is the most abundant in both sites of Alappuzha and Kallar. Although IVI values for endemic species are generally low (9), it cannot be true for all the species, as in this case of *C. apetalum*. However, a lack of significant number of populations below 50 cm GBH is an indication that population of this species is on the decline. Also, they are abundant in their habitat but less in number and low survivability on a different habitat, adaptability to different habitats and tolerance to disturbances are probably limited.

In the sacred groves of coastal areas, the soil acidity increases possibly due to large amount of organic matter incorporation and the salt content decreases with the distance inland (22). In the present study also the salt concentration of soil decreases for inland forest area of Kallar as compared to coastal Alappuzha. Soil changes in a coastal habitat can be detected through the disturbances in vegetation (1), therefore changes in the *C. apetalum* population can also be used to detect changes in the soil, or vice-versa. More in-depth data regarding chemical changes of the soil is required for the analysis. Unsurprisingly soil from forest region is loamy in texture, has less salt concentration and greater Nitrogen and Potassium content. In case of Alappuzha, sacred grove's location provides nitrogen to the

soil, nitrogen content probably low in locations other than sacred groves for *C. apetalum* populations. For Kallar the abundant vegetation in evergreen forests provide sufficient nitrogen to the forest soil. Utilization of Potassium varies with species; however, their presence generally enhances the plant growth, therefore soil in Kallar region is probably more ambient for C. *apetalum* population.

Conclusion

C. apetalum populations are found in both riparian habitats of evergreen forests and sandy coastal regions. The Alappuzha district hosts numerous populations of *C. apetalum*. This study concludes that, while there is variation in diversity and species richness across these locations, C. apetalum is dominant in its habitat, evidenced by the highest Importance Value Index (IVI). The chemical composition of the soil in these distinct habitats differs in terms of pH, salt concentration, and other elements, yet the species manages to thrive in both environments. However, a significant finding of this study is the overall decline in population numbers. The low number of seedlings and surviving young trees indicates this troubling trend. Future investigations should focus on understanding the reasons behind this decline and developing conservation strategies. The adaptability and dominance of this species in the studied locations raise further questions: What other conditions or locations might support its growth? Why is the population not more widely distributed? How do challenges in seed dispersal and seedling establishment affect population dynamics? In what ways have geographical and climatic changes caused by human activities impacted seed dispersal mechanisms and growth?

Addressing these questions in future research will enhance our understanding of *C. apetalum* population ecology and studies from a broader range of locations will provide a more comprehensive perspective.

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Authors' contributions

RM and KS together conceptualized the research and carried out experiments and data collection. RM supervised the project and edited the manuscript. KS performed the statistical analysis, RM programming and wrote the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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