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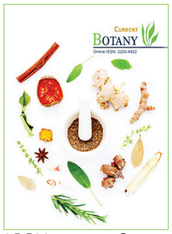

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Studies on carbon sequestration potential of trees with epiphytic orchid association

A. S. Deepthi[1]*, Nisha Joseph[1], Rogimon P. Thomas[2], Preetha Karnaver[3], Maria Susan Binu[1]

[1]Department of Botany, Catholicate College, Pathanamthitta-689645, Kerala, India, [2]Department of Botany, CMS College, Kottayam-686001, Kerala, India, [3]Department of Zoology, Christian College, Chengannur-689122, Kerala, India

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***Corresponding author:**
A. S. Deepthi
E-mail: deepthibotanymgu@gmail.com

ABSTRACT

Epiphytic orchids are a fascinating group of plant species that thrive on the branches and trunks of trees, forming intricate symbiotic relationships with their host. They contribute to the vibrant biodiversity of forest ecosystems and play a crucial role in carbon dynamics and storage. The study aims to estimate carbon sequestrations of phorophytes and associated epiphytic orchids by quantifying the above ground biomass (AGB), total biomass (TB), and amount of carbon stored. It has been found that 97 trees from nine different tree species are associated with epiphytes in the study area. Among the nine species examined, *Alstonia scholaris* exhibited the highest biomass for above ground, below ground, and total biomass, with values of 24,043.35 kg/tree, 6,251.27 kg/tree, and 30,294.62 kg/tree, respectively. In addition, *Cocos nucifera* had the lowest values. The highest biomass, carbon storage, and rate of carbon sequestration were recorded for the epiphyte species associated with the phorophyte A. *scholaris*. When the phorophytes were associated with epiphytic orchids, their carbon sequestration rates rose from 1.94% to 15.07%. This study provides empirical evidence and analytical perspectives to create a model that mitigates the consequences of climate change and global warming while maintaining current land usage.

KEYWORDS: Epiphytic orchids, Carbon storage in trees, Carbon storage capacity of epiphytes, Mitigating climate change via flora

INTRODUCTION

In the face of the global climate crisis, the urgent need to mitigate the accumulation of atmospheric carbon dioxide (CO_2) has become a pressing concern for researchers, policymakers, and the general public alike. One promising strategy that has garnered significant attention is the sequestration of carbon dioxide through the management and expansion of terrestrial ecosystems (Sheikh *et al.*, 2014; Domke *et al.*, 2020).

Trees play a crucial role in the global carbon cycle, serving as both sources and sinks for this important greenhouse gas. Through the process of photosynthesis, trees and other vegetation effectively remove carbon dioxide from the atmosphere and store it within their biomass, as well as in the soils that support them (Sedjo & Sohngen, 2012). This natural process of carbon sequestration has the potential to offset a portion of human-induced carbon emissions, thereby contributing to the stabilization of atmospheric greenhouse gas concentrations (Adiaha *et al.*, 2020).

Several studies have explored the potential of terrestrial carbon sequestration, highlighting the various mechanisms and challenges involved. For instance, research has demonstrated that forest management practices, such as afforestation and reforestation, can significantly enhance the rate and capacity of carbon storage within these ecosystems (Sedjo & Sohngen, 2012; Adiaha *et al.*, 2020).

Addressing the growing concern over rising atmospheric carbon dioxide levels, researchers have increasingly focused on the potential of terrestrial ecosystems to act as carbon sinks (Houghton, 2002). Among these ecosystems, urban areas present a unique challenge and opportunity. Urban vegetation, including roadside trees and other greenery, can play a crucial role in mitigating the carbon footprint of cities through the process of carbon sequestration (Dugaya *et al.*, 2020; Lahoti *et al.*, 2020). Urban vegetation, in particular, has been recognized for its ability to offset a portion of a city's carbon emissions through the natural process of photosynthesis, which transfers atmospheric CO_2 into the terrestrial carbon pool (Zhuang *et al.*, 2023).

The management of roadside vegetation has become an increasingly important consideration in efforts to mitigate the environmental impact of transportation infrastructure. One particularly promising approach is the cultivation of roadside trees that support epiphytic orchid communities, which can play a significant role in the sequestration of atmospheric carbon dioxide. Epiphytic orchids, which grow on the branches and trunks of trees, can contribute to this carbon sequestration process by adding to the overall biomass of the ecosystem. Studies have shown that the additional biomass provided by epiphytic orchids can significantly increase the total carbon storage capacity of individual trees (Sheikh *et al.*, 2014; Cedric *et al.*, 2021). Furthermore, the unique ecological niche occupied by epiphytic orchids, which often thrive in areas with high light availability and limited soil resources, can make them particularly well-suited for growth along roads and other transportation corridors.

MATERIALS AND METHODS

Study Area

The present work was carried out in Manarcad grama panchayat in Kottayam district, Kerala, India. The study area is located between longitude 76.522171 and latitude 9.591441. The present study was carried out during the period between January 2023 to June 2024.

Estimating the Carbon Dioxide Sequestration of Phorophytes

Due to the importance of trees, a non-destructive approach was used for estimating the carbon stock of vegetation. The diameter of the trees was 1.37 m above average ground level (DBH) and was measured with measuring tape (Lahoti *et al.*, 2020). Field data were recorded in spreadsheets. For estimating the carbon stock of the phorophytes above ground biomass (AGB), belowground biomass (BGB) and total biomass (TB) were calculated.

Above ground biomass (AGB) = 42.69 - 12.800×DBH + 1.242×DBH^2 (Salimon *et al.*, 2011)

Belowground biomass (BGB) = AGB×0.25 (Cairns *et al.*, 1997)

Total biomass (TB) = AGB+BGB (Sheikh *et al.*, 2011).

Weight of carbon in the tree = Biomass × 50% or Biomass/2 (Návar, 2009).

Weight of CO_2 sequestered = Weight of carbon in the tree × 3.6663 (Vishnu & Patil, 2016).

Estimation of Biomass and Carbon Stock of Epiphytic Orchids

The destructive method was used for determining the biomass of epiphytic orchids. Epiphyte biomass on a target phorophyte was obtained by removing and weighing of all epiphytes present on it with the help of a garden knife. A suspension balance was used to weigh epiphytes collected and packed up into appropriate bags in the field. Considering the diffculty in drying all these samples, sub-samples of orchid biomass were collected for each tree sampled and sealed in an appropriate dry polythene bag and weighed with an electronic balance. Sub-samples were oven-dried to constant weight at 60 °C for 48hrs. Then, the following formula was used to estimate the total biomass of orchid per phorophyte (Nfornkah *et al.*, 2018).

Total biomass epiphytic orchids =Total fresh mass × Sub-sampled dry mass/Sub-sampled fresh mass.

Weight of carbon in the epiphytic orchid = Biomass × 50% (Návar, 2009).

Weight of Carbon dioxide sequestrated by epiphytic orchid: Weight of carbon in the tree × 3.6663 (Vishnu & Patil, 2016).

Statistical Analysis of the Data

All the data are represented as mean±standard deviation (mean±SD). All data were analysed, including descriptive statistics, with IBM SPSS software version 19.0

RESULTS

Diversity of the Phorophytes with Epiphytic Orchid Association

In the study area, it has been found that 97 trees from 9 distinct tree species are associated with epiphytic orchids. *Cocos nucifera*, *Lannea coromandelica*, *Tectona grandis*, *Alstonia scholaris*, *Albizia saman*, *Swietenia macrophylla*, *Ficus benghalensis*, *Mangifera indica*, and *Samanea saman* are among the tree species observed (Table 1). The most dominant family, Anacardiaceae comprises 19.59% of all recorded species. Fabaceae and Moraceae comprise 18.56% each of all recorded species. All of the phorophyte species in the study area were found to be associated with a single species of epiphytic orchid, *Acampe praemorsa*. The phorophyte species have a total biomass ranging from 763.65 kg/tree to 30,294.62 kg/tree (Table 2). Among the nine phorophyte species that were examined, *A. scholaris* exhibited the highest biomass for above ground biomass, below ground biomass, and total biomass (24,043.35 kg/tree,

Table 1: Diversity and abundance of the phorophytes

Scientific name	Common name	Family	Number of plant species
Alstonia scholaris	Blackboard tree	Apocynaceae	15
Cocos nucifera	Coconut tree	Arecaceae	8
Ficus benghalensis	Banyan tree	Moraceae	18
Lanneacoromandelica	Indian ash tree	Anacardiaceae	7
Mangifera indica	Mango tree	Anacardiaceae	12
Samanea saman	Rain tree	Fabaceae	8
Swietenia macrophylla	Mahogany	Meliaceae	7
Tamarindus indica	Tamarind	Fabaceae	10
Tectona grandis	Teak	Lamiaceae	12

Table 2: Diameter and biomass of the phorophytes

Phorophyte	Diameter (cm)	AGB (kg/Tree)	BGB (kg/Tree)	TB (kg/tree)
Albizia saman	113.05±25.78	14468.78±302.22	3761.88±57.88	18230.66±407.56
Alstonia scholaris	144.26±32.98	24043.35±403.23	6251.27±156.22	30294.62±405.78
Cocos nucifera	27.07±4.78	606.31±97.79	157.64±40.67	763.95±99.87
Ficus benghalensis	51.59±11.87	2687.95±77.98	698.86±67.98	3386.81±206.56
Lanneacaromandelica	39.8±8.96	1500.62±104.85	390.16±56.87	1890.78±97.79
Mangifera indica	98.72±15.76	108883.15±196.87	28289±204.67	13712.77±338.98
Swietenia macrophylla	70.06±13.87	5242.15±108.76	1362.95±76.98	6605.1±305.67
Tamarindus indica	73.24±10.22	5767.42±98.97	1499.52±88.96	7266.94±342.56
Tectona grandis	42.03±13.87	1698.72±99.87	441.66±56.89	2140.38±104.87

6,251.27 kg/tree, and 30,294.62 kg/tree respectively). The lowest biomass for above ground biomass, below ground biomass, and total biomass was seen in *C. nucifera* (606.31 kg/tree, 157.64 kg/tree, 763.95 kg/tree respectively).

The carbon sequestration of nine tree species ranges from 1,400.41 kg to 55,534.58 kg. Of all the tree species examined, *A. scholaris* has stored and sequestered the highest amount of carbon (15,147.31 kg and 55,534.58 kg, respectively). *A. scholaris*, is followed by *A. saman* with the second highest carbon sequestration amount (33,389.45 kg), whereas the rate of *C. nucifera* was found to be the lowest (Table 3).

The epiphytic orchids that are associated with *M. indica* have the highest biomass, carbon storage, and carbon sequestration rate (761.04 kg, 380.52 kg and 1393.85 kg respectively). Conversely, the epiphytic orchids associated with *C. nucifera* have the lowest biomass, carbon storage, and carbon sequestration rate (90.32 kg, 45.16 kg and 165.42 kg respectively). In terms of carbon sequestration, orchid species associated with *A. scholaris* exhibited the second highest level in biomass, carbon storage, and carbon sequestration rate (600.58 kg, 300.29 kg and 1099.96 kg respectively). The phorophytes' carbon sequestration rates increased from 1.94% to 15.07% by association with epiphytic orchids (Table 4).

Table 3: Carbon storage and carbon sequestration by the phorophytes

Phorophytes	Carbon storage (kg)	Carbon sequestration (kg)
Albizia saman	9115.33±304.89	33389.45±678.98
Alstonia scholaris	15147.31±407.99	55534.58±342.87
Cocos nucifera	381.97±54.87	1400.41±306.98
Ficus benghalensis	1693.4±209.78	6208.53±409.78
Lannea caromandelica	945.39±67.90	3466.08±209.89
Mangifera indica	6856±89.08	25137.56±478.78
Swietenia macrophylla	3302.55±290.67	12108.13±507.76
Tamarindus indica	3633.47±205.98	13321.39±345.90
Tectona grandis	1070.19±205.78	3923.63±234.89

DISCUSSION

The aim of this study is to estimate carbon sequestrations of phorophytes and associated epiphytic orchids. The discovery of 97 phorophytes from nine different tree species with an association with epiphytic orchids highlights the intricate and symbiotic relationships that exist within tropical ecosystems. The tree species observed, including *C. nucifera*, *L.coromandelica*, *T. grandis*, *A. scholaris*, *A. saman*, *S. macrophylla*, *F. benghalensis*, *M. indica*, and *S. saman*, reflect the diversity of host trees that can support the growth and proliferation of epiphytic orchids (Morales-Linares *et al.*, 2016).

In the present investigation, carbon sequestrations of phorophytes and associated epiphytic orchids by quantifying the above ground biomass (AGB), total biomass (TB) and amount of carbon sequestrated. Most of the research works revealed that AGB is strongly correlated with tree diameter (Návar, 2009). Also, it is accepted that a simple model with the only diameter as the input is a good estimator of above-ground biomass (Liu *et al.*, 2017).

The provided information highlights the significant variations in biomass across different tree species, with a range spanning from 763.65 kg/tree to 30,294.62 kg/tree. Among nine phorophytes examined, *A. scholaris* exhibited the highest biomass for above ground, below ground, and total biomass, while *C. nucifera* recorded the lowest. Research on urban home-garden agroforestry systems has shown that fruit trees, such as *Persea americana* and *Mangifera indica*, can account for a substantial proportion (around 36%) of the total biomass produce, up to 36% (Mulatu, 2019; Asfaw & Zergaw, 2022). Strategic tree planting and maintenance in urban areas can enhance green spaces, regulate temperatures and ultimately support regional and global climate change mitigation goals (Sharma *et al.*, 2024). This suggests that the selection and management of tree species in settings can great impact in the overall carbon sequestration potential (Enríquez-de-Salamanca, 2024).

Larger tree with a greater breadth tends to be more efficient at carbon sequestration, but it takes time for the tree to reach that breadth and planting trees for carbon sequestration in populated areas without land can be a significant challenge. So, to overcome these challenges an efficient way is to use epiphytic orchids. By symbiotically combining with trees, epiphytic orchids can amplify the carbon sequestration potential of trees, creating a more efficient and resilient carbon sink.

Epiphytic orchids are a fascinating group of plant species that thrive on the branches and trunks of trees, forming intricate symbiotic relationships with their host. These orchids not only contribute to the vibrant biodiversity of forest ecosystems, but also play a crucial role in carbon dynamics and storage. A recent study has shed light on the remarkable differences in biomass, carbon sequestration, and storage exhibited by epiphytic orchids associated with various tree species (Martínez-Meléndez *et al.*,

Table 4: Biomass, carbon storage and carbon sequestration in epiphytic orchid and increased rate of carbon sequestration of phorophytes by epiphytic orchid association

Phorophytes	Biomass of epiphytic orchids (kg)	Carbon storage by epiphytic orchids (kg)	Carbon sequestrated by epiphytic orchids (kg)	Carbon sequestration of the phorophyte with epiphytic orchid association (kg)	Increase in the rate of carbon sequestration of phorophytes by epiphytic orchid association (%)
Albizia saman	456.25±67.87	228.13±29.35	835.62±53.87	34225.07±527.65	2.44
Alstonia scholaris	600.58±65.78	300.29±54.78	1099.96±68.77	56634.53±254.52	1.94
Cocos nucifera	90.32±12.76	45.16±16.78	165.42±24.76	1565.83±143.76	10.56
Ficus benghalensis	419.03±26.88	209.52±56.99	767.45±54.66	6975.98±224.99	11.00
Lannea caromandelica	335.83±34.56	167.92±35.98	615.07±56.77	4081.15±82.77	15.07
Mangifera indica	761.04±50.78	380.52±45.22	1393.85±156.99	26531.4±154.88	5.25
Swietenia macrophylla	438.09±46.88	219.05±34.99	802.36±35.77	12910.49±117.88	6.21
Tamarindus indica	516.29±30.89	258.12±26.87	945.58±67.99	14266.98±234.98	6.63
Tectona grandis	206.51±12.87	103.26±25.87	378.22±94.78	4301.85±143.88	8.79

Table 5: Pearson correlation coefficients between the above ground biomass and diameter of phorophytes with the biomass of epiphytes

	Diameter of the phorophytes	AGB of the phorophytes
Biomass of the epiphytic orchids	0.33	0.735*

*Correlation is significant at $P<0.05$ (2-tailed)

2022). The present investigation reveals that epiphytic orchids associated with the tree species *A. scholaris* exhibit the highest biomass, carbon storage, and carbon sequestration rate, with values of 600.58 kg, 300.29 kg, and 1099.96 kg, respectively. On the other hand, the orchids associated with *C. nucifera* display the lowest biomass, carbon storage and carbon sequestration. Biomass of the epiphytic orchids has a significant positive correlation with the AGB of the phorophytes (Table 5).

The presence of epiphytic orchids on the phorophytes enhances their ability to capture and store carbon from the atmosphere by 1.94% to 10.56%. This increase in carbon sequestration can be attributed to the symbiotic relationship between the phorophytes and the epiphytic orchids. These findings highlight the potential role of epiphytic orchids in mitigating carbon emissions. This study offers empirical evidence and analytical perspectives to create a model that mitigates the consequences of climate change and global warming while maintaining current land usage.

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