Research Article

Regeneration Status of *Diospyros melanoxylon* Roxb. in Forests of Central Western Ghats, India

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ABSTRACT

Aim/Background: *Diospyros melanoxylon* Roxb. constitutes one of the commercially significant tree species within the Indian subcontinent. Commonly referred to as Coromandel ebony or Tendu, the foliage of this species is extensively employed in the wrapping of 'Bidi', a cigarette variant prevalent in India. Moreover, the fruits produced by these trees are edible and possess significant nutritional value, thereby being utilized by the local community. Given their commercial relevance, it is imperative to frequently assess their status within forest ecosystems. **Materials and Methods:** Consequently, the current study is directed towards the examination of the regeneration status of these trees across six selected regions with belt transect method in the central Western Ghats of Karnataka state. **Results and Conclusion:** The findings indicate that the Gonibidu locality within the Shivamogga district exhibits a pronounced regeneration potential, with a ratio of regenerating individuals to adult trees being fivefold. The Tarikere locality in the Chikkamagaluru district also demonstrated a substantial presence of regenerating individuals. This study provides foundational knowledge regarding the regeneration and persistence of these trees within forest environments, which may prove beneficial for conservation strategies and sustainable resource utilization.

Keywords: Bidi, *Diospyros*, Ebenaceae, Regeneration.

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INTRODUCTION

Diospyros comprises the most comprehensive genus in the Ebenaceae family, including more than 500 species, thereby categorizing it as one of the largest genera within angiosperms. Notably, the highest species diversity is concentrated in the Asian and Pacific regions, with nearly 300 species identified. Species within the *Diospyros* genus are typically shrubs or trees that inhabit a majority of tropical and subtropical ecosystems, where they frequently serve as significant and characteristic components.[1] In the context of India, *Diospyros* encompasses 66 taxa,[2] with 24 species documented within the Western Ghats,[3] and 15 species identified in the state of Karnataka.[4] *Diospyros melanoxylon* Roxb., a representative of the Ebenaceae family, is distributed across subtropical and tropical areas of China, India, Sri Lanka, Nepal, Bhutan, Myanmar, Bangladesh, Indonesia and the Malay Peninsula. In the English language, it is commonly designated as Coromandel Ebony, Malabar Ebony, or East Indian Ebony.[5] *Diospyros melanoxylon.* is also commonly referred to as Tendu in the vernacular Indian. dialect. The fruits of Coromandel ebony are consumable and exhibit a high nutritional profile. The fruit is characterized by an ovoid or globose shape, transitioning from yellow to light orange upon ripening. The pulp of the fruit is yellow, glutinous, soft, gently sweet and astringent. Fruits of these trees are rich in proteins, sugars, dietary fibres and vitamin C. Composition of fruits depicted nearly carbohydrates-81%, proteins-2%, fats-2% and 11% of fibres, with 349 Kcal of caloric value. Additionally, the are rich source of minerals like 11.8% of calcium, 62% of magnesium, 3.4% of iron, 1.28% of zinc and 0.2% of copper. Furthermore, the ripe fruit of *D. melanoxylon* is reported to contain 49 mg % of vitamin C and 260 µg % of β-carotene. Tendu fruit wine enjoys

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popularity among tribal communities. Moreover, the fruit may act as a genuine euglycemic sweetener in contrast to sucrose and has the potential to alleviate oxidative stress.[6]

Every year, an incredible array of materials apart from wood products are gathered from worldwide forests. The products include palm foliage for roof covering, woody lianas for preparing rope or strings, the sap of chicle tree used to make chewing gum, copal and damars for hard coating, wood of some trees for boat making and in textile industries, seeds are used for cooking and oil extraction, several tree roots and bark are used for medicinal purpose namely the drugs like quinine and ipecac and leaves and flowers for various herbal tea. The Tendu tree, as one of the predominant species, is markedly prominent and holds significant economic relevance. The Tendu is known for its deep black core wood and dull grey or brown sapwood. The sapwood can be refined to a high quality and is lightweight, therefore it may be utilized for a range of items, such as cue stick for billiard, poles of the cart, rooftops, shafts and agricultural implements.[7]

India is a nation where countless individuals engage in forest-gathering endeavours at various times throughout the year. The prominence of these harvests is emphasized by the gathering and preparing of the Tendu tree, *Diospyros melanoxylon* Roxb. leaves, which are utilized to create wrapping material for "bidis," a widely consumed cigarette in India, serving as a unique and culturally distinctive illustration. Leaves of the trees are extensively employed for the wrapping of bidis. Bidi represents the preferred tobacco product of the working group in India, constructed by encasing tobacco within a specially prepared leaf from *Diospyros melanoxylon*. The other essential raw materials include tobacco and cotton strings. Great-quality of bidi leaves are those that are harvested immediately after transitioning from a crimson to a green hue, achieving a leathery texture. The selection process is greatly impacted by the qualities of smoothness, flexibility and the absence of excessive pubescence.[7]

It is estimated that yearly yield of Tendu leaves exceeding 450,000 tons, sustains the livelihoods of more than 12 million individuals within the Indian bidi-making sector. Nonetheless, only a limited number of investigations have been undertaken regarding the harvesting of Tendu leaves, as well as the productivity, renewability and comprehensive biodiversity implications associated with the management practices implemented to enhance Tendu leaf production across Indian forests.[8]

Given the extensive utilization of these trees for their products, comprehending their regeneration patterns within the forest ecosystem is a crucial aspect of conservation and sustainable utilization. "The capacity of a species to complete its life cycle" is one way to define regeneration potential. Adequate growth and survival rates of seedlings and saplings are indicative of an effective regeneration. Conversely, poor regeneration of a tree species is indicated by low numbers of seedlings and saplings, whereas its absence indicates no regeneration at all. The regeneration potential within forests not only indicates their current and prospective composition but also reflects their long-term sustainability. Regular evaluations of the regeneration status of forest communities are of paramount importance, as they provide essential insights for the effective maintenance and management of natural populations, thereby enhancing their productivity.[9]

Based on this particular aspect, the current investigation endeavoured to examine the natural regeneration status of *Diospyros melanoxylon* in several selected localities within the central Western Ghats region of Karnataka. The research also focused on the enumeration and documentation of the various phases of regeneration exhibited by these trees. The regenerative capacity of the mature trees across the different study sites was also scrutinized.

MATERIALS AND METHODS

Study area

The study area encompassed selected regions of the Central Western Ghats. This included two significant districts within the state of Karnataka, namely Shivamogga and Chikkamagaluru. Both districts are characterized by their verdant vegetation and constitute integral components of the Central Western Ghats. The forest types prevalent in this region range from wet evergreen to deciduous and scrubby forests. The density of vegetation increases as one moves westward. In light of historical data regarding the distribution of *Diospyros melanoxylon*, the decision was made to concentrate the research on specific moist deciduous and dry deciduous forest patches within the study area (Figure 1).

Field survey

The field survey was undertaken across six distinct regions of the designated study area (Figure 1). Each region was named as R1, R2, R3, R4, R5, R6 (Table 1). A random sampling methodology was employed for the investigation, wherein 3 belt transects named as T1, T2, T3 measuring 250×4 m were established to assess the

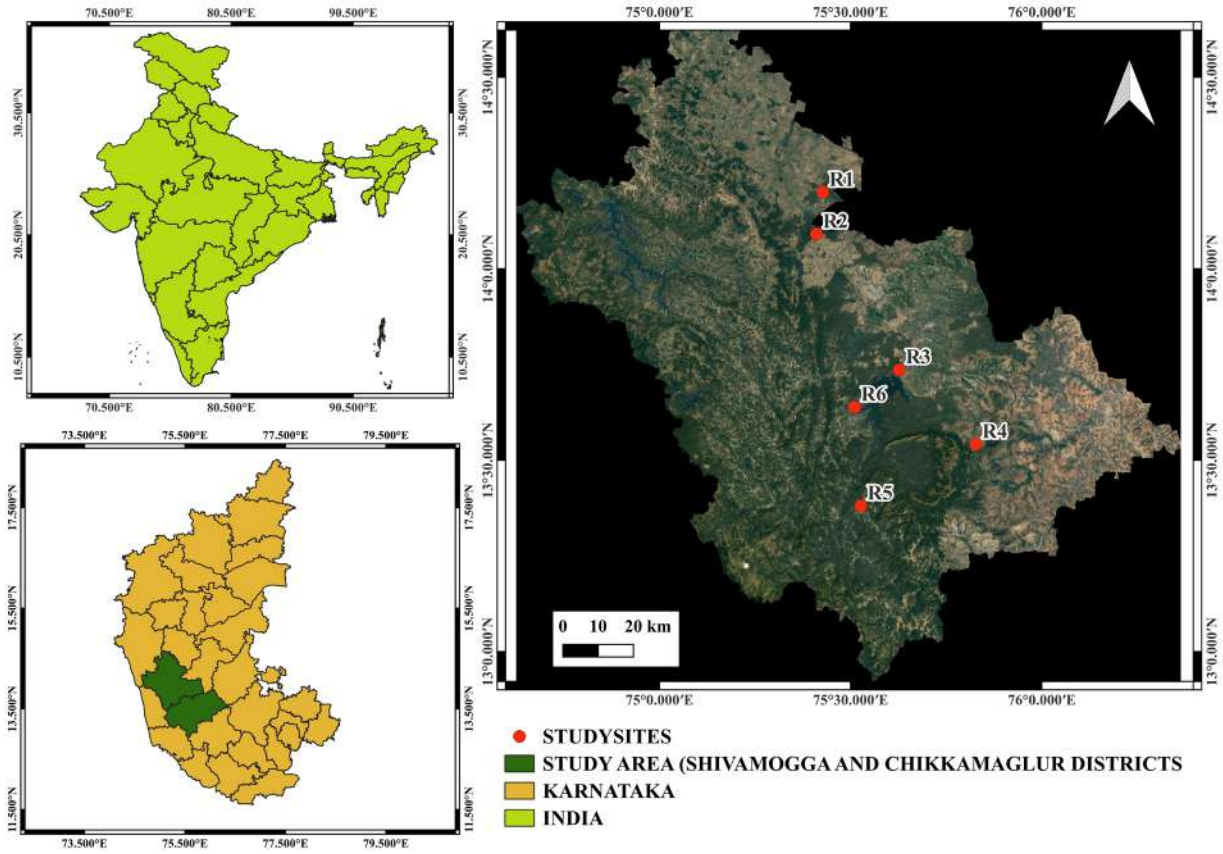

Figure 1: Map showing details of the study area.

regeneration of the trees alongside the adult specimens. Based on the size of the regenerating individuals, they were categorized into three distinct classes.

Class 1-Seedlings, defined by a height not exceeding 40 cm and a girth of less than 2.5 cm.

Class 2-Saplings, characterized by a height ranging from 40 to 100 cm and a girth between 2.5 and 5 cm.

Class 3-Poles, distinguished by a height surpassing 100 cm and a girth ranging from 5 to 10 cm.

Observation and analysis

The regeneration of *Diospyros melanoxylon* was meticulously recorded and the number of individuals was enumerated in each transect alongside the adult trees. Statistical analyses for frequency, density and abundance of the regenerating flora were conducted utilizing Microsoft Excel.

The calculations were done using formulae

$$\text{Frequency} = \frac{\text{(Number of transects in which the species occured)}}{\text{(Total number of transects studied).}}$$

$$\text{Density} = \frac{\text{(Number of individuals of the species)}}{\text{(Total number of transects studied).}}$$

$$\text{Abundance} = \frac{\text{(Total number of individuals of a species in all transects)}}{\text{(Number of transects in which the species occurred).}}$$

Table 1: Details of the study sites selected in Central Western Ghats.

Study regions	Name of the region	Latitude	Longitude	Forest type
R1	Shikaripura	14.19972	75.427222	Dry deciduous
R2	Ayanoor	14.09056	75.410556	Dry deciduous
R3	Gonibidu	13.73639	75.627222	Moist deciduous
R4	Tarikere	13.54167	75.827222	Dry deciduous
R5	Balehonnur	13.38083	75.527222	Moist deciduous
R6	N R Pura	13.63889	75.510556	Moist deciduous

Additionally, herbarium collection of adult specimens was compiled and preserved at the Department of Applied Botany, Kuvempu University.

RESULTS

Distribution of seedlings of *Diospyros melanoxylon* in different study sites

The investigation concerning the regeneration of *Diospyros melanoxylon* was carried out across six distinct regions of the Central Western Ghats, with three belt transects established in each region. The cumulative number of individual seedlings regenerating across all sites amounted to 73. Among the six study regions, the Tarikere region-R4 exhibited the highest level of regeneration, with 17 individuals in the seedling phase; notably, within the three belt transects established in the R4 region, the third transect T3 recorded the highest number of regenerating individuals in the seedling stage. Following this, the Gonibidu-R3 region displayed a substantial number of seedlings, with 14 regenerating individuals. Within R3, the third transect T3 recorded the most significant quantity of regenerating seedlings, with 8 individuals. The lowest number of seedlings was documented in the N R Pura R6 region, with only 9 regenerating individuals, where transect 1-T1 recorded 4 individuals (Figure 2).

Distribution of saplings of *Diospyros melanoxylon* in different study sites

In total, 48 saplings were identified across all six examined regions. The Tarikere region-R4 exhibited the greatest quantity of regenerating saplings of *Diospyros melanoxylon*, comprising 18 individuals, with the highest concentration located in the third transect, which accounted for 8 individuals. Following this, the Gonibidu region -R3 recorded a significant presence of saplings, with total 13 individuals, of which 9 individuals were located in second transect -T2 of Gonibidu. Conversely, the N. R. Pura region -R6 demonstrated the lowest count of saplings, with a mere two individuals observed (Figure 3).

Distribution of poles of *Diospyros melanoxylon* in different study sites

A comprehensive observation yielded a total of 83 individuals classified as poles across the six study sites. The Tarikere region -R4 recorded the highest number of individuals, totalling 28, with 12 individuals noted within the second transect T2 of R4. Subsequently, the Gonibidu region R3 also exhibited a notable presence of poles of *Diospyros melanoxylon*, comprising 23 individuals, with the second transect T2 of R3 documenting 12 individuals. The Balehonnur Region (R5) exhibited the least number of poles, with only 6 regenerating individuals recorded (Figure 4).

Frequency, Density, Abundance of regenerating *Diospyros melanoxylon*

The quantitative parameters of frequency, density and abundance were systematically assessed for the regenerating individuals of *Diospyros melanoxylon*. The findings indicated that the frequency values for seedlings and poles were equivalent, both recorded at 0.94. In contrast, the frequency of seedlings and poles significantly exceeded that of saplings, which was recorded at 0.78. The pole stage of regeneration exhibited the highest density value at 4.61, followed

Figure 2: Transect Vise Distribution of seedlings of *Diospyros melanoxylon* in six study sites.

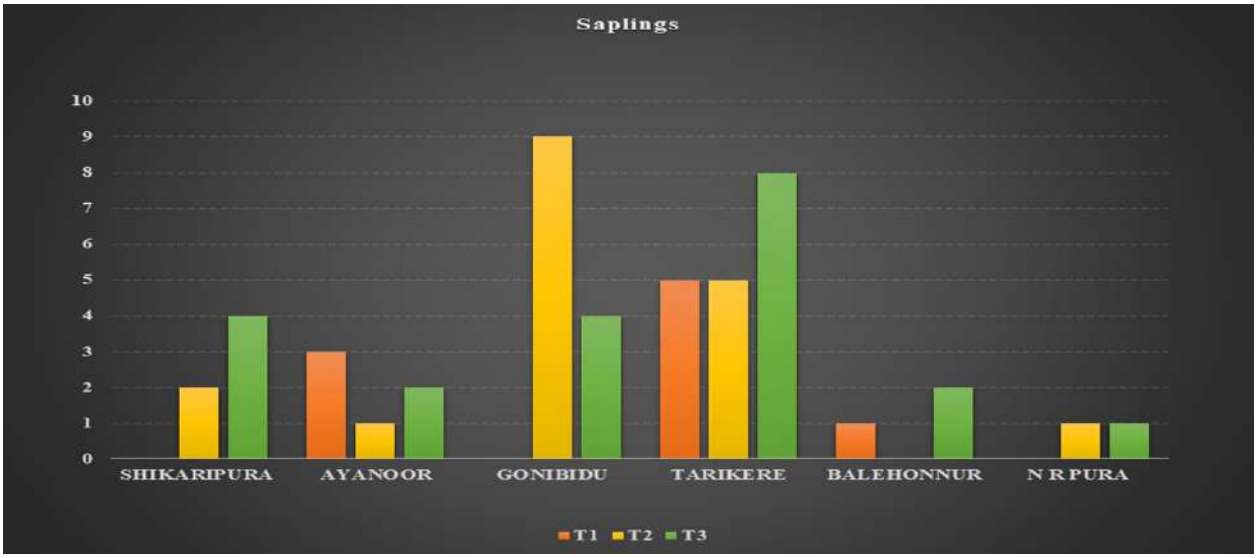

Figure 3: Details of regenerating saplings of *Diospyros melanoxylon* in six study sites along with the transects.

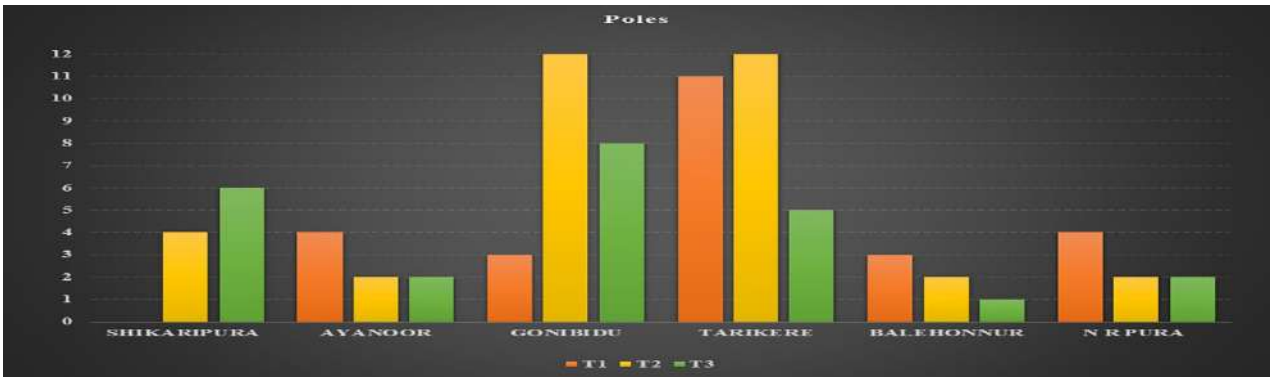

Figure 4: Details of regenerating poles of *Diospyros melanoxylon* in six study sites along with their transects.

closely by seedlings at 4.06. The sapling stage displayed the lowest density, quantified at 2.67. Notably, the pole stage of regeneration represented the most abundantly distributed category across all study sites, with an abundance value of 4.88, followed by seedlings and saplings with abundance values of 4.29 and 3.43, respectively (Figure 5).

Comparison of regeneration of *Diospyros melanoxylon* with adult trees

A comparative analysis of regenerating individuals across all developmental stages was conducted against the number of adult trees of *Diospyros melanoxylon* present in each study site. The initial study site, R1 (Shikaripura), reported a total of 28 regenerating individuals alongside

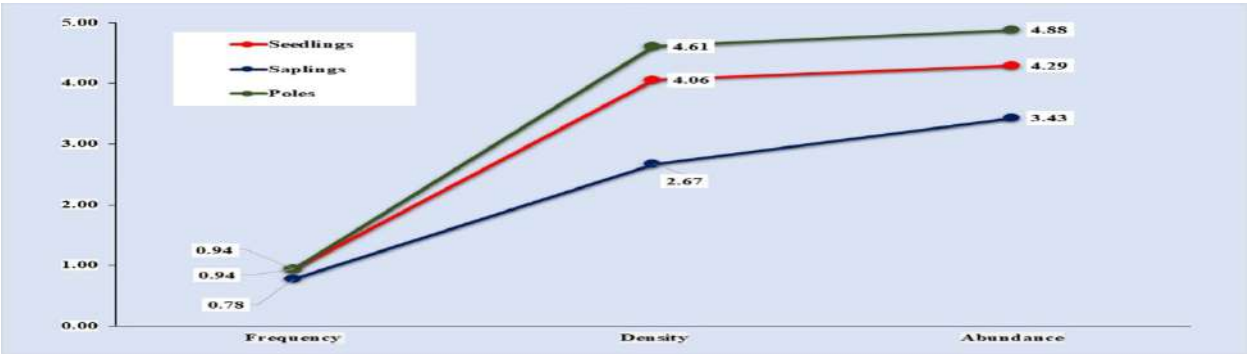

Figure 5: Frequency, density, abundance of the different regenerating stages of *Diospyros melanoxylon.*

Figure 6: Chart showing the regenerating individuals and number of adult trees.

13 adults across all three transects. This observation suggests that the number of regenerating individuals is 2.3 times greater than that of adult trees. In site R2 (Ayanoor), the ratio of regenerating individuals to adults is approximately 3.1 times greater. In the Gonibidu region (R3), the regeneration-to-adult ratio is recorded at 5. In R4 (Tarikere), regenerating individuals outnumber adult trees by a factor of 3.9. The Balehonnur Region (R5) illustrates a regeneration rate that is 2.7 times greater than that of adult trees, while in R6 (N. R. Pura region), regenerating plants are 4.7 times more numerous than adults. A comprehensive comparison of overall regeneration ratios to adult trees across the study sites reveals that R3 (Gonibidu) exhibits the highest ratio.

DISCUSSION

The current investigation was conducted to examine the regeneration dynamics of *Diospyros melanoxylon* within the selected sites deciduous forests of the central Western Ghats. Six discrete study areas were delineated and three belt transects were instituted within each designated area. The belt transect methodology is noted for its efficiency and extensive applicability, demonstrating robustness across varying levels of observer expertise and facilitating the formulation of wildlife-habitat models. This approach evidently provides considerable flexibility for the periodic evaluation of plant community composition, identification of vegetative issues and strategic management planning.[10] In densely vegetated settings, the application of belt transect methodologies yields significantly more precise assessments of species richness and encompasses a greater number of individuals; however, the principal drawback lies in its relative lack of time efficiency.[11]

The present study on regeneration status of *Diospyros melanoxylon* in six different study areas of central Western Ghats categorised regenerating plants into seedling, sapling and pole stages. The plants were enumerated in all stages at study sites which revealed totally 204 (seelings-73, saplings- 48, poles-83) regenerating individuals were observed. Among the study sites the Tarikere region, designated as study site R4, exhibited the highest number of regenerating individuals across all stages with total 63 individuals (seelings-17, saplings-18, poles-28) (Figures 2-4). It is plausible that the environmental conditions and elevation gradient in this region favour the growth and regeneration of these trees. For systematic study the quantitative characters like frequency, density and abundance of regeneration were calculated. The frequency exhibited by seedlings and poles (0.94) were higher than saplings (0.78). Density values depicted that the poles (4.61) with high density which was followed by seedlings (4.06) and saplings (2.76). Among the three categories the most abundantly distributed one was poles (4.88) followed by seedlings (4.28) and saplings (3.43) (Figure 5).

The current investigation indicates that across all surveyed locales, the number of regenerating individuals exceeds that of adult specimens, thereby reflecting a favourable regeneration status for *Diospyros melanoxylon*. An analysis of the overall regeneration dynamics across all study sites reveals that the Gonibidu region, designated as R3, exhibited regenerating individuals (n=50) at a rate fivefold greater than that of adults (n=10). The Tarikere region-R4, presented the highest

count (*n*=63) of regenerating individuals compared to any other site; however, when compared with the adult trees (*n*=16) in the same locale, the ratio was merely 3.9 times greater. In the R6-N R Pura region, the quantity of regenerating individuals (*n*=19) is notably low in contrast to other sites; nonetheless, they are 4.7 times more numerous than adult trees (*n*=4) within that specific location. Consequently, it can be posited that the regenerative capacity of *Diospyros melanoxylon*. is more pronounced in the Gonibidu-R3 region than in any other examined study site (Figure 6).

The vegetation inter-relationship and regeneration status in tropical forest stands of central India was studied in different types of forest.[12] This study included regeneration of different plants. Among them *Diospyros melanoxylon* seedlings and saplings exhibited (0-20%) which is rare, (20-40%) represents low frequency, (40-60%) represents intermediate frequency in different type of forests. The current study showed that the seedlings and poles indicated high frequency 0.94 which is 94%. Saplings showed 78%. This suggest that the regeneration of these trees in parts central Western Ghats are comparatively better.

The studies on variation in species composition, structural diversity and regeneration along disturbances in tropical dry forest of northern India depicted the regeneration potential of a species by comparing with adult trees. In their study, *Diospyros melanoxylon* trees showed good regeneration potential in different study sites with more than 30%.[13] In the current study regeneration potential of trees in Gonibidu region is the regenerating individuals are five times greater than adults indicating 20% which is fair regeneration but it is less when compared to their previous studies in North India.

Several studies have been conducted regarding regeneration of trees in forests. Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka showed that regeneration of tree species in the tropical evergreen forests was higher in southern part of Western Ghats compared to that of northern part of Western Ghats of Karnataka.[14] But the current study is unique because it has concentrated on the regeneration of single economically important tree species in Central part of Western Ghats.

The current study was conducted on these particular trees because *Diospyros melanoxylon* Roxb. represents a chief Non-Timber Forest Product (NTFP) in India, predominantly utilized for enveloping 'Bidi' or local Indian cigarettes, attributable to its unique texture, flavour and workability. Its extensive utilization is fundamentally predicated upon its substantial production, palatable flavour, pliability, durability against decay and its propensity to retain combustion. The foliage serves as a crucial economic resource for state forest departments, yielding seasonal income and employment across twelve states within the country.[15] Furthermore, these trees possess not only commercial significance but also contribute fruits that are nutritionally rich. The fruits are primarily harvested and consumed by tribal communities and forest inhabitants. In spite of their significance, tropical forests consistently endure anthropogenic pressures, leading to forest fragmentation and a decline in biodiversity across various global regions. Given the considerable importance of *Diospyros melanoxylon* trees, it is imperative to ascertain their current status within forest ecosystems.

The availability of significant regenerative capacity reflects the adaptability of a species to its ecological niche. The current investigation indicates that across all surveyed locales, the number of regenerating individuals exceeds that of adult specimens, thereby reflecting a favourable regeneration status for *Diospyros melanoxylon*.

The successful regeneration of a species can be conceptualized as a function of three principal components: the capability to generate new seedlings, the survival rates of seedlings and saplings and the growth potential of these juvenile stages.[16] The regenerative efficacy of a species is also influenced by an array of factors, including the germination and growth competencies of seedlings and saplings, light availability, soil properties, nutrient accessibility, landscape characteristics, seed dispersal mechanisms and ecological disturbances.[17] *Diospyros melanoxylon*, being dioecious, has its regeneration influenced by factors such as pollination mechanisms, the number of reproductively viable trees, the recruitment of seedlings, as well as the patterns of flowering and fruiting, seed viability and consumption by both human and wildlife populations. The findings of the present study afford critical insights into the regeneration status and actual distribution of these trees. This information holds potential utility in guiding conservation initiatives and sustainable management practices, given the economic significance of this tree species.

CONCLUSION

The present investigation encompasses an analysis of the natural regeneration status of *Diospyros melanoxylon* trees. The regeneration evaluations conducted across the six designated study sites in the central Western Ghats indicated that the most significant regenerative capacity

was recorded at Study site R3 (Gonibidu). Consequently, the investigation underscores the economic importance of this tree species. Furthermore, our results may be utilized in various contexts to ascertain the optimal locations for the thriving of *D. melanoxylon* trees. This research provides invaluable insights for the academic community and society regarding one of India's economically vital and indigenous tree species. It has established a foundational knowledge base essential for the conservation management of this tree species and its sustainable utilization.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

SUMMARY

This research article provides the significant details on the *Diospyros melanoxylon* Roxb. trees, which are commonly named as Bidi leaf tree in India. These trees are exhibiting high economic value as their leaves are utilised for wrapping Indian traditional cigarettes. The study concentrates on natural regeneration of these trees in some parts of central Western Ghats in three different stages. Quantitative parameters like frequency, density and abundance of the regenerating individuals were calculated. The number of these regenerating individuals in different study sites were determined and were compared with number of adult trees. This resulted that Gonibidu region of Shivamogga district, Karnataka depicted better regeneration potential when compared to other regions. The study provided basic knowledge about these trees, their distribution and their status in forests.

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