

Study of the Natural Regeneration of *Paraberlinia bifoliolata* (Pellegrin) in the Congolese Rainforest (Case of the Yangambi Natural Forest, Democratic Republic of Congo)

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Abstract

This study was conducted in the Yangambi Biosphere Reserve, located in the Isangi district, 100 km west of the city of Yangambi, at 0°49'12" N; 24°27'22" E. To conduct this study, six one-hectare plots were established in Yangambi, within which seedlings of different height classes were measured and their x and y coordinates recorded. Each of the six plots contained a seed plant, except for plots 1 and 5. A total of 769 seedlings were recorded, averaging 128.1 stems/ha. Height class S1 had the highest number of individuals (358 stems across all six hectares, or 59.6 stems/ha) compared to the other classes, and their numbers decreased as the size of the individuals increased. The variability in the number of seedlings observed between plots confirms that there is a strong correlation ($r \approx 0.79$), it is observed that plots with more seed trees generally have more seedlings; however, for dendrometric characteristics such as the diameter at breast height (DBH) of seed trees, which directly influences the abundance of seedlings under their canopy, the correlation is weak ($r \approx 0.27$).

Keywords: Regeneration, *Paraberlinia bifoliolata*, forest stands, Yangambi, DR Congo.

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INTRODUCTION

Forests are one of the most important terrestrial ecosystems for maintaining the planet's ecological balance. They play a vital role in conserving biodiversity, regulating the climate, and protecting soil and water resources. According to the Food and Agriculture Organization of the United Nations, forests cover approximately 31% of the world's land area and are home to a large proportion of known animal and plant species. They also provide numerous goods and services essential to human populations, including timber, non-timber forest products, and ecosystem services (FAO, 2020).

In tropical regions, forests play a particularly important role due to their rich flora and fauna. They represent major reservoirs of biodiversity and contribute significantly to the regulation of the global carbon cycle. However, these ecosystems are severely threatened by human activities such as logging, shifting cultivation, and population growth (MALHI *et al.*, 2014).

Sustainable forest management is therefore a major challenge for the conservation of these ecosystems and for the socioeconomic development of local communities. It aims to ensure the rational use of forest resources while guaranteeing their renewal and long-term viability. From this perspective, understanding forest dynamics, particularly the natural regeneration of

tree species, is essential for guiding forest management and conservation strategies (LAMPRECHT, 1989).

Furthermore, studying the functioning of forest ecosystems provides a better understanding of the interactions between plant species, environmental factors, and human activities. This scientific knowledge contributes to the development of appropriate management policies and the implementation of silvicultural practices that promote the conservation and restoration of tropical forests (DUPUY *et al.*, 1999).

Furthermore, the survival and growth of *Paraberlinia bifoliolata* seedlings appear to depend heavily on the ectomycorrhizal networks associated with the roots of mature trees, which promote the nutrition and survival of young plants in tropical forests (ONGUENE *et al.*, 2002).

However, a better understanding of these regeneration mechanisms—which remain largely unknown for most tree species—is essential from both scientific and practical perspectives for their sustainable management. This understanding is needed to guide the restoration of forests disturbed in various ways by human activity (KATUSI, 2015) and to identify realistic management options, particularly in the context of forest plantations (ALEXANDRE, 1977; ALKEMADE *et al.*, 2009).

Thus, understanding the ecological factors that influence the natural regeneration of this species remains essential for improving strategies for the sustainable management and conservation of tropical forests.

Paraberlinia bifoliolata (Pellegrin) is found in the Tshopo Province of the Democratic Republic of the Congo (LOBELA *et al.*, 2019; PELLEGRIN, 1943). Among species of interest, *Paraberlinia bifoliolata* (Fabaceae) is a species of tropical rainforest tree, particularly in the Central African region. It is found mainly in evergreen tropical rainforests and in semi-deciduous or submontane forests. Knowledge of its

natural regeneration is essential for sustainable management.

This study determines the abundance of seedlings ranging in height from 0 to 10 cm, 10 to 30 cm, and 30 cm to 1 m. The height-class structure, in relation to canopy cover and mature trees, allows for an assessment of the species' regeneration capacity following disturbances and helps guide management and restoration measures. To conduct this study, the following questions were posed: (i) How does the regeneration of *Paraberlinia bifoliolata* occur under the conditions of the natural forests of Yangambi? (ii) To what extent does the density of mature trees (seed trees) influence the variability in the number of seedlings of this species? (iii) Do the dendrometric characteristics of seed trees have a measurable effect on the abundance of regenerants located beneath their canopy? To answer all these questions, the following specific objectives were pursued, among others: (i) to determine the regeneration rate of this species in the natural forests of Yangambi; (ii) Count the number of seedlings of this species from the selected seed trees; and (iii) Determine the level of correlation between the dendrometric values of the seed trees and the number of seedlings under the canopy.

MATERIALS AND METHODS

Study Area

On the outskirts of the city of Kisangani in the Central Basin of the Democratic Republic of the Congo (DRC), growing human pressure on peri-urban forest ecosystems threatens the sustainability of the goods and services they provide. Slash-and-burn agriculture, bushfires, and the production of firewood are the main causes.

To preserve this forest, this study was conducted in Yangambi, located in the Isangi territory, 100 km west of the city, at 0°49'12" N; 24°27'22" E (KASONGO *et al.*, 2023) (Fig. 1). Located in the equatorial zone, the study site has an equatorial climate with an average temperature of 24.9 °C (KOMBELE, 2004) and average annual precipitation of 1,837 mm (KOMBELE, 2004).

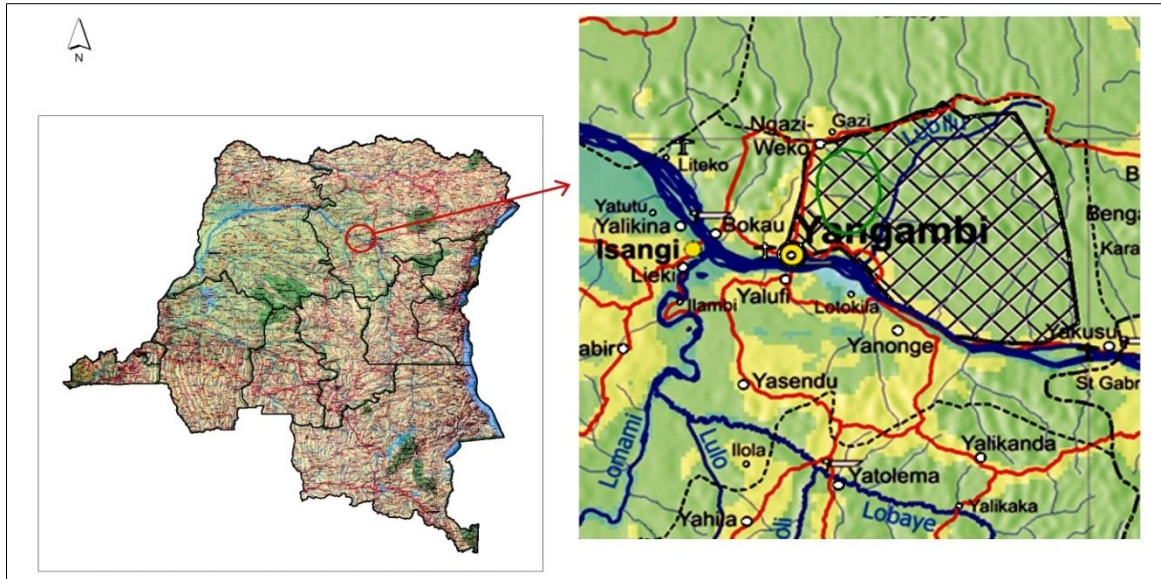


Figure 1: Study area

Methodological approach

A total of six 1-hectare plots were established for this species in Yangambi (Fig. 2). Each 1-hectare plot is subdivided into 100 10 m x 10 m transects, within which all individuals with a diameter at breast height

(dbh) \geq 10 cm and of different height classes were inventoried and positioned using Cartesian coordinates x, y. It should be noted that, within a plot, any individual with a BHD \geq 10 cm is considered a seed tree.

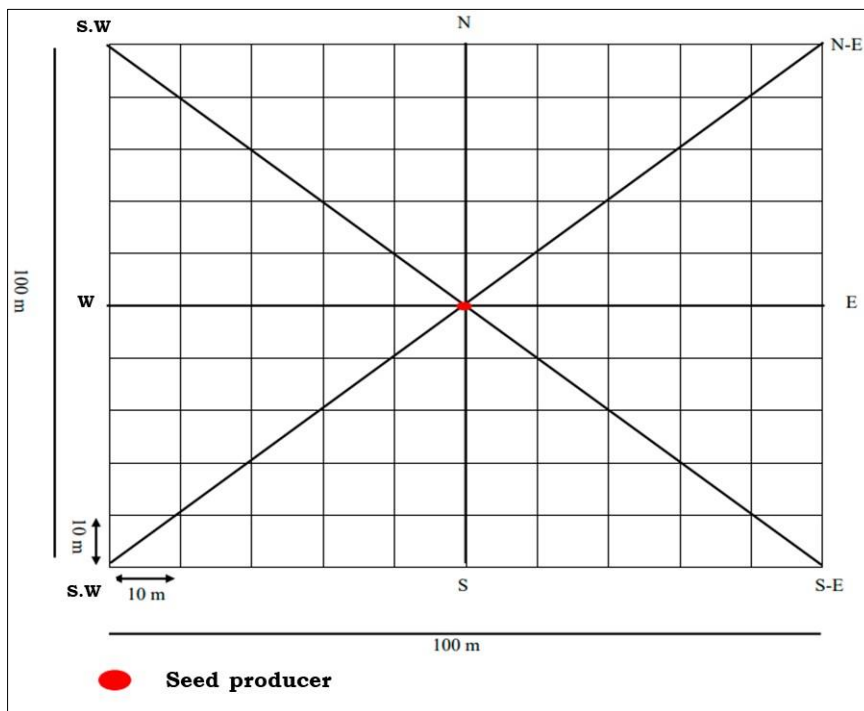


Figure 2: Regeneration inventory method in the Yangambi Forest.

Legend: E= East, W= West, N= North, S= South, NE= Northeast, NW= Northwest, SE=Southeast, SW= Southwest

If a plot has a single seedling stand, the stand occupies the center of the plot. Seedlings were categorized into three height classes: 0–10 cm (S1); 10–30 cm (S2); and 30 cm–1 m (S3).

in Yangambi, the chi-square (χ^2) test was used to compare seedling numbers, and Pearson’s correlation was used to measure the relationship between two quantitative variables.

Regarding statistical tests, the ANOVA (F) test was used to compare plant density across different plots

RESULTS

Seedling density as a function of seedling diameter(s) Among the 6 plots studied in Yangambi, all plots contained a single seedling. The largest diameter at breast height (DBH) was observed in the seedling of plot 1 (DBH = 47.4 cm) and the smallest diameter in those of plot 6 (DBH = 27.3 cm).

The highest density was observed in plot 1 (180 stems/ha), while the other plots had fewer than 150 stems/ha (Table 1). It was noted that there was no difference in seedling numbers between different plots at the 0.05 significance level (Kruskal-Wallis chi-squared = 85.632, df = 3; $p < 2.2e-16$).

Table 1: Planting density by seedling diameter

<i>Paraberlinia bifoliata</i>			
Plot	Semencier	Dhp (cm)	Densité
Plot 1	2	47,4	180
Plot 2	1	44,4	93
Plot 3	1	44,3	130
Plot 4	1	31,2	128
Plot 5	2	27,3	141
Plot 6	1	30,3	97
Total	8		769
Average	128,1		
Standard deviation	31 ,8		

Table 1: shows that the average seedling density per hectare is 128.1 stems, with a standard deviation of 31.8.

Seedling density by height class

The highest density is observed in class S1 with 14.9 stems/ha and the lowest in class S3 with 7.2

stems/ha. Statistical tests reveal a significant difference between growth stages at the 0.05 level (chi-squared = 85.632, df = 3, p-value < 2.2e-16) (Fig. 3). In other words, the numbers are not distributed equally across all growth stages.

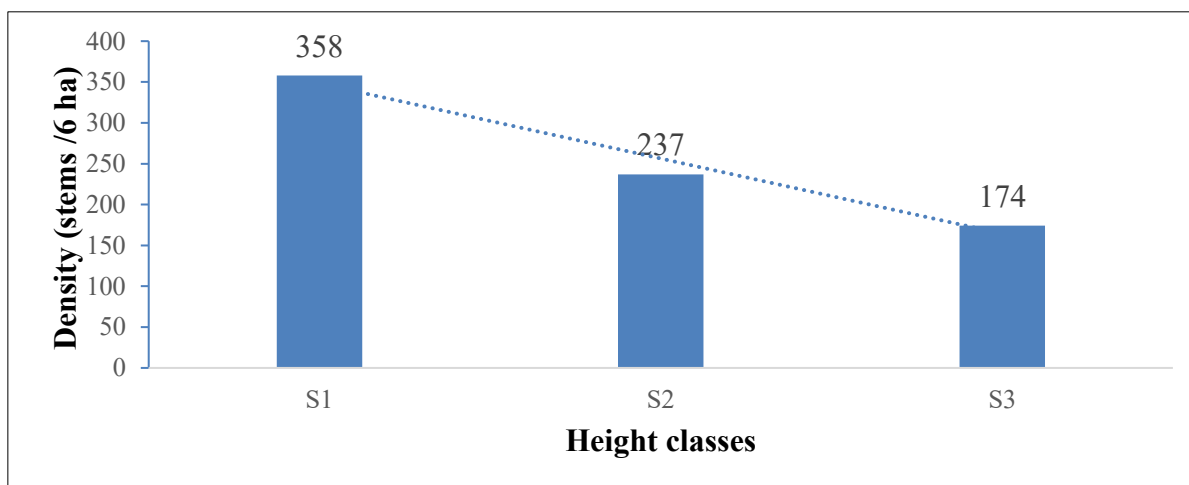


Figure 3: Stem density (per 6 ha) by height class

Correlation between seed plants and seedling density

A strong positive correlation ($r \approx 0.79$) was observed between the number of seed plants and seedling

density at Yanga mbi (Table 2). It is observed that plots (1 and 5) with more seed plants generally have more seedlings.

Table 2: Correlation between seed plants and seedling density

	Seed companies	Seedlings
Seed companies	1	0 ,79
Seedlings	0 ,79	1

Table 2 shows that the correlation coefficient is ($r \approx 0.79$).

Correlation between stem diameter at breast height (DBH) and seedling density

The correlation is weak ($r \approx 0.27$) between diameter at breast height (DBH) and seedling density, indicating that the dendrometric parameters of the seed trees have a limited influence on this regeneration (Table 3).

Table 3: Correlation between stem diameter at breast height and seedling density

	DHP	Seedlings
Dhp	1	0,27
Seedlings	0,27	1

DISCUSSION

The various results obtained in this study provide a better understanding of seedling regeneration at heights ranging from 0 to 10 cm, 30 cm, and up to 1m.

Demographic analysis

The average density for all height classes is 128.1 stems/ha, which appears to be lower. Class S1 has a very high density compared to the other height classes, and density decreases as seedling size increases. These results suggest that natural regeneration of the species is limited, as individuals in the smaller height classes (S1, S2, and S3) fail to reach a diameter of 1 m. These results confirm the observations made by LIEBERMAN (1996) and JESEL (2005), who state that the early stages of a tree's life, from seed to seedling, are demographic stages that generally exhibit very high mortality.

Overview of the Regeneration of *Paraberlinia bifoliolata* in the Yangambi Forests

The results show that the average density of *Paraberlinia bifoliolata* seedlings is approximately 128.1 ± 31.8 stems, indicating relatively active natural regeneration in the study plots. The presence of seedlings under the canopy of mature trees indicates that the species has the capacity to regenerate under the ecological conditions of the Yangambi tropical rainforest. In tropical forests, natural regeneration depends heavily on micro-ecological conditions such as light, soil moisture, and seed availability. According to JANZEN (1970), the distribution of seedlings in tropical forests is often concentrated around seed trees due to limited seed dispersal and the availability of microsites favorable to germination. Similarly, WRIGHT (2002) emphasizes that the natural regeneration of tropical species depends heavily on local environmental conditions and the dynamics of gaps in the canopy.

Influence of mature tree density on seedling numbers

The results on variability ($r \approx 0.79$) indicate that seed trees strongly influence seedling variability. The variation in seedling numbers observed across plots is linked to the density and presence of seed trees. Indeed, the more mature trees present at a given site, the higher the seed production can be, which increases the chances

of germination and seedling establishment. According to HUBBELL (2001), the density of mature trees directly influences the structure of juvenile populations in tropical forests, as the proximity of seed trees promotes seed accumulation in the soil. However, JANZEN (1970) also explains that seedling survival may decrease near mature trees due to competition, pathogens, and specialized predators. This phenomenon is known as the JANZEN-CONNELL effect.

Thus, the variability observed in your plots could be explained by the balance between seed production by seed trees and the ecological factors that influence the survival of young plants.

Influence of the dendrometric characteristics of seed trees

The results regarding dendrometric characteristics ($r \approx 0.27$) clearly show that, while a relationship exists, it is weak and not statistically significant; they suggest that dendrometric characteristics have a limited influence on regeneration. The diameter at breast height (DBH) of seed trees can influence the abundance of seedlings beneath their canopy. Trees with larger diameters generally have higher reproductive capacity and produce more seeds. According to LOWMAN (1995), large dominant trees play an essential role in the regeneration dynamics of tropical forests due to their high seed production and their influence on the microclimate beneath the canopy. Furthermore, TERBORGH (1992) indicates that large-diameter trees contribute significantly to the renewal of forest populations, as they are the primary sources of seeds in tropical ecosystems.

Thus, the variations observed in seedling abundance beneath *Paraberlinia bifoliolata* seed trees could be related to differences in the diameter of the trees studied.

Understanding the Importance of *Paraberlinia bifoliolata* Regeneration

The species *Paraberlinia bifoliolata* is found within the Yangambi Biosphere Reserve in Tshopo Province, Democratic Republic of Congo. According to Troupin (1950) and data from the timber trade in Central Africa, its wood is valued for its mechanical and aesthetic properties, which explains its widespread commercial exploitation. *Paraberlinia bifoliolata* is among the species harvested for timber production, and its exports increased significantly in the 1990s, demonstrating its economic importance in the forestry sector. Its appearance and finishing possibilities make it an excellent wood for cabinetmaking, decorative veneers, framing (primarily for local use), and fine interior joinery.

In several tropical forests of Central Africa, *Paraberlinia bifoliolata* also plays an important ecological role in the structure and composition of the

forest stand. Studies have shown that this species can be dominant in certain forest formations, to the point that some types of forest are classified as *Paraberlinia bifoliolata* forests, indicating its structuring role in the ecosystem.

However, several studies show that natural regeneration of this species can be poor in certain forest environments, and some studies have observed very low regeneration rates in disturbed or logged areas. Poor regeneration, combined with logging, can lead to a progressive decline in natural populations, which poses a threat to the species' sustainability.

Nevertheless, researchers are interested in quantifying natural regeneration to understand population dynamics and guide sustainable forest management.

CONCLUSION

The results obtained show that *Paraberlinia bifoliolata* exhibits relatively significant natural regeneration in the Yangambi forests, with an average density of 128.1 ± 31.8 seedlings ranging from 0 to 10 cm in height and from 30 cm to 1 m in height under the studied seed trees. Although this density is low, it demonstrates the species' ability to maintain itself within the forest ecosystem.

The variability observed between plots indicates that seedling density depends not only on the presence of seed trees but also on several ecological factors such as seed dispersal, predation, and microenvironmental conditions.

The dendrometric characteristics of the seed trees, particularly diameter at breast height (DBH), can also influence seed production and thus seedling abundance. However, this relationship is not always direct, as the survival and establishment of seedlings are strongly affected by biotic interactions and local environmental conditions.

Thus, the regeneration of *Paraberlinia bifoliolata* in the Yangambi forest results from the interaction between the characteristics of the seed trees, the ecological dynamics of the forest and the natural processes of seedling dispersal and mortality.

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