

Study of the Effects of Height, Defoliation Treatment and Light on the Growth of *Irvingia gabonensis* (Irvingiaceae) and *Ricinodendron heudelotii* (Euphorbiaceae) Regrowth in a Nursery at Soubre in Southwest Cote d'Ivoire

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Abstract

Irvingia gabonensis and *Ricinodendron heudelotii* are two species of multi-purpose trees found in the dense tropical forests of Africa. However, they are under strong pressure due to human activity because of the extension of agriculture, particularly cocoa farming in Côte d'Ivoire; the importance of food, medicine, and especially the economic value of almonds of these two species. Unfortunately, these two species are facing difficulties in natural regeneration related to the seed coat resistance of their seeds and many other constraints, thus threatening their sustainable conservation. This study conducted in Soubre in the southwest of Côte d'Ivoire aims to contribute to the production of vigorous seedlings of these two species in a nursery from regrowth with a view to their domestication through agroforestry. To do this, shoots of these two species of different height classes ([0 - 15], [15 - 30] and [30 - 50] cm) were collected and underwent a defoliation treatment with 4 modes including 0, 2, 3, and 4 leaves. They were then grown in two different light environments, one illuminated and the other shaded. Their growth was then monitored to determine the effect of sampling height, defoliation treatment and light on the recovery and growth of wildlings in the nursery. The results showed that *R. heudelotii* plants grown in a shaded environment with a height of between 0 and

15 cm and with the 4-leaves dressing mode showed the best growth. At *Irvingia gabonensis*, the regrowths with heights between 15 and 30 cm, with a cover type of 0 leaves, and those in the height class of 30 to 50 cm with 2 leaves showed the best growth in a lit environment. In conclusion, this study shows that the optimal conditions for survival and growth of regrowth are not the same for all species. The proper development of the plants after transplantation requires specific morphological, physiological, and ecological conditions for each species. Furthermore, the use of regrowth from these two species can be an alternative to the production of their plant material given the constraints of germination. Considering their economic, environmental, and ethnobotanical interest for the populations, it is necessary to ensure their sustainable conservation by integrating them into agroforestry programs.

Keywords

Ricinodendron heudelotii, *Irvingia gabonensis*, Wild Plants, Growth, Domestication

1. Introduction

Plants are natural resources essential for human food and care [1]. However, many plant species have disappeared and others have become scarce during the last century due to human activities such as logging, agricultural expansion, urbanization, etc. in Africa [2].

Ivory Coast is not exempt from this specific erosion phenomenon caused by the expansion of cocoa cultivation. This speculation is said to be responsible for the disappearance of the forest. According to [3]-[5], this country has lost almost all of its humid tropical forest area from 1960 to 2015, mainly due to the scale of cocoa cultivation [6].

The pure cultivation of cocoa trees has historically been dominant, but it is currently at an impasse because it is not very sustainable. This practice has contributed to 14% of deforestation, significantly reducing forest areas and, consequently, the specific richness of the soils [6]-[9]. Moreover, [10] and [5] state that nearly 80% of the forest area in the southwest of Côte d'Ivoire has been cleared for cocoa cultivation. It is therefore urgent to identify solutions to stabilize cocoa-growing areas, reduce pressure on forests and adapt to climate change. A balance can be found between cocoa trees and a mixture of trees chosen by farmers for their various uses, while maintaining a suitable cocoa yield in the long term [11]. Agroforestry is a sustainable resource management solution for cocoa farming. It consists of integrating trees into farms, which helps maintain and diversify agricultural production in order to promote the pillars of sustainable development [12].

Recent research shows that many forest species are conserved by cocoa farmers for their multiple uses such as food, timber, firewood, their economic and medic-

inal importance [13]-[15], as well as the agro-ecological benefits of these species such as soil moisture conservation, shading, and soil fertilization [16] [17]. *Ricinodendron heudelotii* (Baill.) Pierre ex Pax (Euphorbiaceae) and *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill. (Irvingiaceae) are among the species that have a positive impact on cocoa farming and are prized by local populations [18]. These two species are used for multiple purposes, including the exploitation of their wood and seeds, which constitutes a real threat to their survival in their natural habitat [19] and [20]. This threat is all the more concerning as the International Union for Conservation of Nature has classified them on the red list of threatened species in the "Least Concern" category for *R. heudelotii* [21] and "Near Threatened" for *I. gabonensis* [22]. The sustainable management of *R. heudelotii* and *I. gabonensis* is therefore of paramount importance both economically, socially and environmentally. Research carried out for the domestication and conservation of these two species has shown many challenges related to the irregular germination and low germination rate of seeds due to their dormancy [23]. In addition, strategies for improving seed germination and vegetative propagation techniques by cuttings have been developed using synthetic phytohormones. However, these products are not affordable for farmers due to their high cost, thus limiting initiatives to produce these plants. However, the use of wildlings by farmers appears to be an alternative for the production of plants of these two species. However, the conditions necessary to obtain vigorous plants remain poorly documented. It is with this in mind that this study is being carried out, with the aim of contributing to the production of vigorous seedlings of these two species in view of their sustainable conservation through agroforestry practices.

2. Materiel and Methods

2.1. Study Site

This study was carried out in the Soubré department, located in the Nawa region in southwestern Côte d'Ivoire (Figure 1). The Soubré department is located between longitudes 6° 19' and 6° 57' West and latitudes 5° 26' and 6° 13' North. The climate is sub-equatorial, characterized by two rainy seasons occurring between April-June and September-November, and two dry seasons occurring between July-August and December-March, with abundant rainfall between 1600 mm and 1800 mm and a temperature ranging between 26°C and 32°C throughout the year [24]. The vegetation consists of gallery forests, secondary forests, marshy formations, fallow land, and industrial plantations dominated by cocoa [25].

2.2. Vegetative Material

The plant material used in this study consisted of wildlings or resprouts of *Irvingia gabonensis* and *Ricinodendron heudelotii* of varying heights. The collar diameter of the plants was 0.50 cm and 0.86 cm for *I. gabonensis* and *R. heudelotii*, respectively.

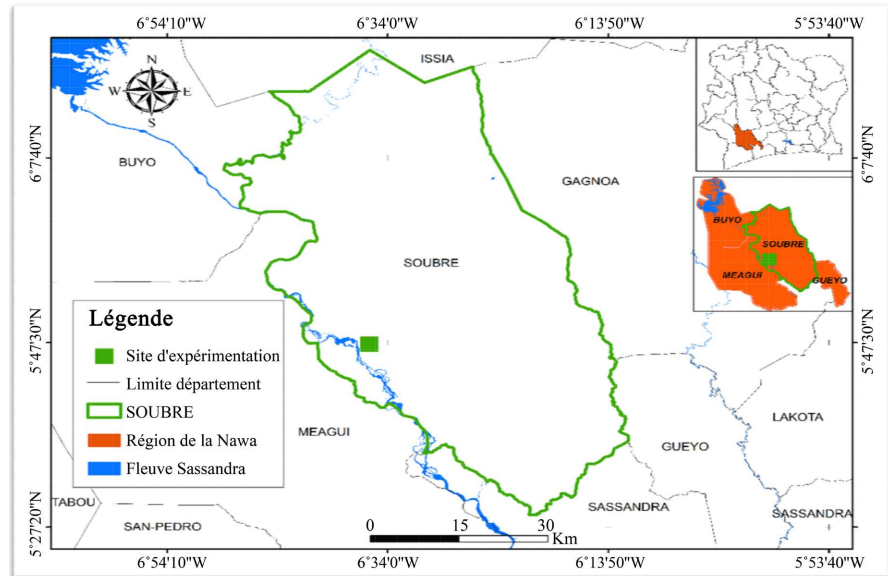


Figure 1. Study area.

2.3. Methods

2.3.1. Collection of Naturally Regenerated Seedlings

The collection of resprouts was carried out in the months of March and April 2023. The presence of rain during this period facilitated the uprooting of the plants from the soil. Thus, resprouts of *I. gabonensis* and *R. heudelotii* of varying heights were collected under mother trees in fallow land and cocoa plots in Soubré.

On the wet plots, the regrowth was directly uprooted using a palm knife while avoiding damage to the root system. In less humid terrain, a small basin about 10 centimeters deep was dug with a hoe around the plant and then filled with water to facilitate uprooting.

After collection, these resprouts were carefully packaged in coolers to facilitate their transport to the experimental plot.

2.3.2. Handling of Resprouts

The preparation of the resprouts consisted of classifying them into three height classes: H1: [0 - 15 cm], H2: [15 - 30 cm], and H3: [30 - 50 cm], in order to evaluate the effect of height on the recovery and growth of the wildlings. Subsequently, the wildlings of each height class were subjected to defoliation treatment retaining 0, 2, 3, and 4 leaves on each wildling, starting from the collar towards the apical bud. This was done to determine the effect of the presence or absence of leaves on the recovery and growth of the plants.

2.3.3. Establishing the Nursery

To study the influence of light on the recovery and growth of young plants, nurseries were set up in two different environments. The first environment was illuminated without shading, and the second environment was shaded. The shade in the

Each subplot included five wild seedlings subjected to the four defoliation treatment (0, 2, 3, and 4 leaves) (**Figure 2**).

2.3.5. Monitoring of the Trial, Data Collection, and Measured Parameters

The trial monitoring involved regularly watering the plants every two days. Weeds were manually removed from the planting bags to prevent any competition with the wild seedlings. Data collection consisted of recording the number of living and dead plants through simple counting. The height of growing plants was measured every 14 days using a measuring tape, from the collar to the sheath of the last leaf. As for the appearance of new leaves, it was observed every 14 days, and the leaves were counted through simple counting. The collected data were used to evaluate the following parameters: (i) the survival rate of the plants, (ii) the height growth of the plants, and (iii) the number of newly emerged leaves. The survival rate was determined as the ratio of the number of living seedlings to the total number of seedlings at the end of the experiment, using the formula below:

$$TS = \frac{N - nm}{N} \times 100$$

With **TS**: Survival Rate; **N**: Total number of plants placed in bags for a treatment; **nm**: number of dead plants.

The height growth of the plants was calculated at the end of the experiment using the following formula: ACH = (Final height – Initial height).

The number of leaves was determined by counting every 14 days.

2.3.6. Data Analysis

Analysis of Variance (ANOVA) was used to compare growth parameters based on the different factors studied. Additionally, MANOVA with the Wilks' test was applied to simultaneously compare growth data from the two environments (shaded and illuminated). The statistical analysis of the data was performed using RStudio Version 3.5.1.

3. Results

3.1. Effect of Height on Survival, Growth, and Leaf Emergence of *Irvingia Gabonensis* and *Ricinodendron Heudelotii* Seedlings

Effect of height on the survival rate of seedlings

The analysis of **Table 1** shows that for both species, the survival rate of the seedlings did not vary significantly according to the height classes of the plants. The survival rate is relatively high for the different height classes of *R. heudelotii* seedlings. It is 80%, 83%, and 88% for the height classes of [15 - 30] cm, [30 - 50] cm, and [0 - 15] cm, respectively. Statistical analysis reveals no significant difference ($P = 0.34$) between these results. Height has no impact on the survival rate of *R. heudelotii* seedlings. On the other hand, *I. gabonensis* seedlings had a low survival rate for all height classes, with rates ranging from 37% for the first two classes ([0 - 15] and [15 - 30]) to 53% for the [30 - 50] cm height class. These results are not

statistically different ($P = 0.17$) and indicate that height has no influence on the survival rate of the plants.

Effects of height classes on stem growth

The height growth of the seedlings in the nursery varied between species (Table 1). At *R. heudelotii*, seedling height significantly influenced their growth ($P < 0.001$), unlike *I. gabonensis*. *R. heudelotii* seedlings in the [0 - 15 cm] height class exhibited the highest growth, with an increase of 8.6 cm, compared to 5 cm and 4.85 cm for the [15 - 30 cm] and [30 - 50 cm] height classes, respectively. At *I. gabonensis*, the growth of the seedlings was the same (1 cm) regardless of the height class.

Effects of height class on the number of leaves produced

Analysis of Table 1 showed that for each species, the number of leaves produced does not vary significantly based on the height of the seedlings ($P < 0.05$). At *R. heudelotii*, all height classes have approximately the same number of leaves (4 leaves). In contrast, *I. gabonensis* seedlings produced 1 leaf.

Table 1. Survival rate, growth rate, and the number of leaves of the species.

Species	Height class (cm)	Survival rate (%)	Increase of the stem (cm)	Number of leaves issued
<i>Irvingia gabonensis</i>	[0 - 15]	37	1	1
	[15 - 30]	37	1	1
	[30 - 50]	53	1	1
	P	0.17	<0.001	<0.05
<i>Ricinodendron heudelotii</i>	[0 - 15]	80	8.6	4
	[15 - 30]	83	5	4
	[30 - 50]	88	4.85	4
	P	0.34	<0.001	<0.05

3.2. Effect of Defoliation Treatment on the Survival, Growth, and Leaf Production of *Irvingia gabonensis* and *Ricinodendron heudelotii* Seedlings

Data analysis of the effect on survival

The survival rate of seedlings from both species in the nursery varied according to the defoliation treatment method (Figure 3). At *R. heudelotii*, the survival rate of seedlings was above 80% and statistically identical regardless of the defoliation treatment method. On the other hand, the survival rate of *I. gabonensis* seedlings varied significantly based on the defoliation method ($P < 0.001$). The highest survival rate (59%) was observed for seedlings without leaves (0 leaves). The lowest survival rate was recorded for seedlings with 4 leaves. The survival of *I. gabonensis* seedlings decreased with the increase in the number of leaves.

Effect of defoliation on the growth of seedlings

The growth of *R. heudelotii* is rapid for each defoliation method. The defolia-

tion treatment method with 4 leaves shows the fastest growth, with an average increase of 8 cm. For the defoliation treatment methods of 0 leaves, 2 leaves, and 3 leaves, growth height ranges from 4 cm (0 leaves) to 6 cm (2 leaves). These statistically significant results indicate the influence of defoliation on height growth ($P = 0.000$). The average height of *I. gabonensis* seedlings is almost negligible, with an average growth of 1 cm. The defoliation treatment method of 0 leaves results in a higher average growth of 1.3 cm. These differences are not highly significant ($P = 0.02$), as shown in **Figure 4**.

Effect of defoliation treatment on leaf production of seedlings

The number of leaves for *Ricinodendron heudelotii* was higher for the different defoliation treatment methods, with an average of 3.5 leaves. defoliation treatment has no influence on leaf production. The average number of leaves was low (0.6 leaves) for *Irvingia* seedlings. This low number is consistent across the different defoliation methods, with the 0-leaf showing better results compared to the 2-leaf, 3-leaf, and 4-leaf defoliation treatment methods, as shown in **Figure 5**.

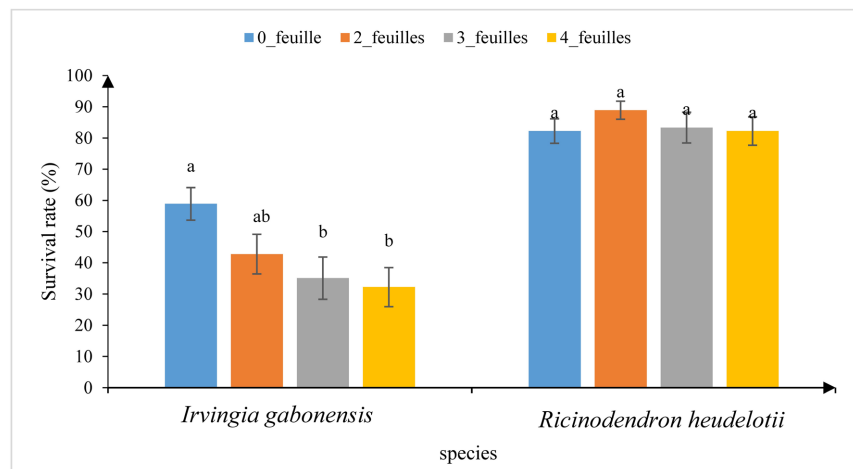


Figure 3. Survival rate of wildlings of *Irvingia gabonensis* and *Ricinodendron heudelotii* based on the defoliation treatment.

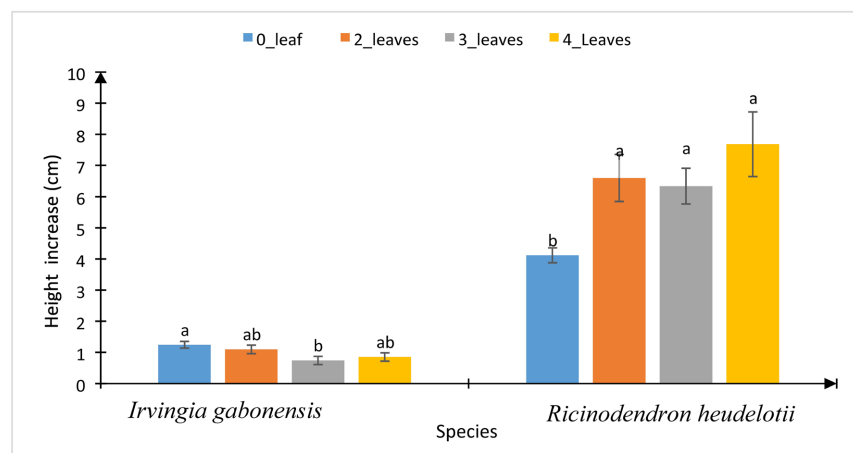


Figure 4. Stem height based on the defoliation treatment.

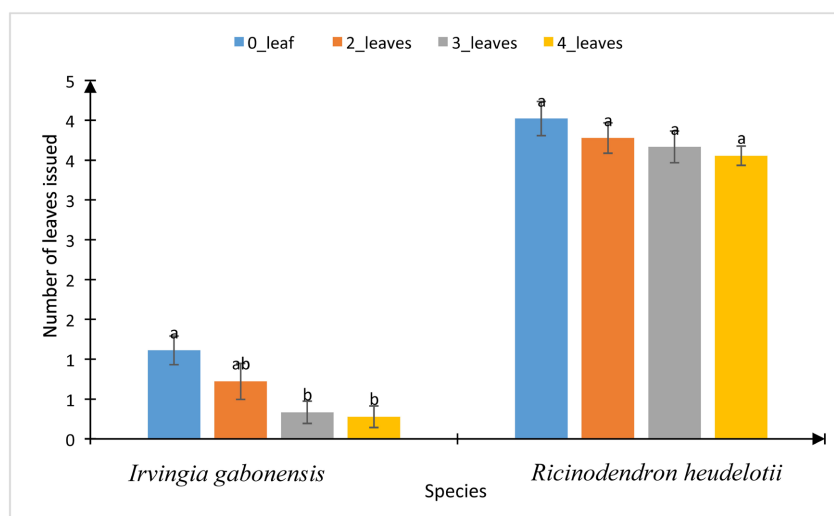


Figure 5. Number of leaves based on the defoliation treatment.

3.3. Effect of Environment on the Survival, Growth, and Leaf Production of *Irvingia gabonensis* and *Ricinodendron heudelotii* Seedlings

Effect of environment on the survival of seedlings

The survival rate as a function of the environment is specific to the species. Both environments recorded survival rates above 80% for *R. heudelotii* seedlings. In contrast, *I. gabonensis* seedlings recorded a lower survival rate, ranging from 41% in the illuminated environment to 43% in the shaded environment. Statistical analysis shows that the environments have no significant influence on the survival rate of the seedlings (**Table 2**).

Effect of environment on the growth of seedlings

The growth of *R. heudelotii* is rapid in both environments, with an average of 6 cm. The shaded environment records the highest growth, with an average height of 7.4 cm compared to 4.95 cm in the illuminated environment. Statistical analysis shows a significant impact of the environment on height growth ($P = 0.00$). The growth of *I. gabonensis* is slow, and there is no growth difference between the two environments ($P = 0.99$), as shown in **Table 2**.

Effect of environment on the number of leaves

Analysis of **Table 2** shows that leaf production in seedlings varied between species depending on the lighting conditions in the nursery. At *I. gabonensis*, the number of leaves produced (0.6) was the same in both shaded and illuminated environments. However, in *R. heudelotii*, the highest number of leaves (4.2) was recorded in the illuminated environment.

3.4. Combined Effect of Height and Defoliation Treatment on Growth and Leaf Production of *Irvingia gabonensis* and *Ricinodendron heudelotii* Seedlings

- *Ricinodendron heudelotii*

Analysis of **Figure 6** shows that height growth of seedlings was significantly

influenced ($P < 0.001$) by the interaction of the three factors (height x defoliation x environment). The highest height growth (16 cm) was recorded in the shaded environment with seedlings having a height between 0 and 15 cm and possessing four leaves. In contrast, seedlings with a height between 30 and 50 cm and having 2 leaves, grown in the illuminated environment, showed the slowest growth, with an average of 3.08 cm.

- *Irvingia gabonensis*

Analysis of **Figure 7** shows that height growth of seedlings was significantly influenced ($P < 0.001$) by the interaction of the three factors (height x defoliation x environment). The highest height growth (2 cm) was recorded in the illuminated environment for seedlings in the height classes [15 - 30 cm] and [30 - 50 cm], with 0 and 2 leaves, respectively. In contrast, no growth was observed in the different environments.

Table 2. Survival rate, growth rate, and number of leaves based on the environment.

Species	Environment	Survival rate (%)	Increase of the stem (cm)	Number of leaves issued
<i>Irvingia gabonensis</i>	[shaded]	43	1	0.6
	[lit]	41	1	0.6
	P	>0.05	>0.05	>0.05
<i>Ricinodendron heudelotii</i>	[shaded]	81	7.4	3.5
	[lit]	82	4.95	4.2
	P	>0.05	<0.05	<0.05

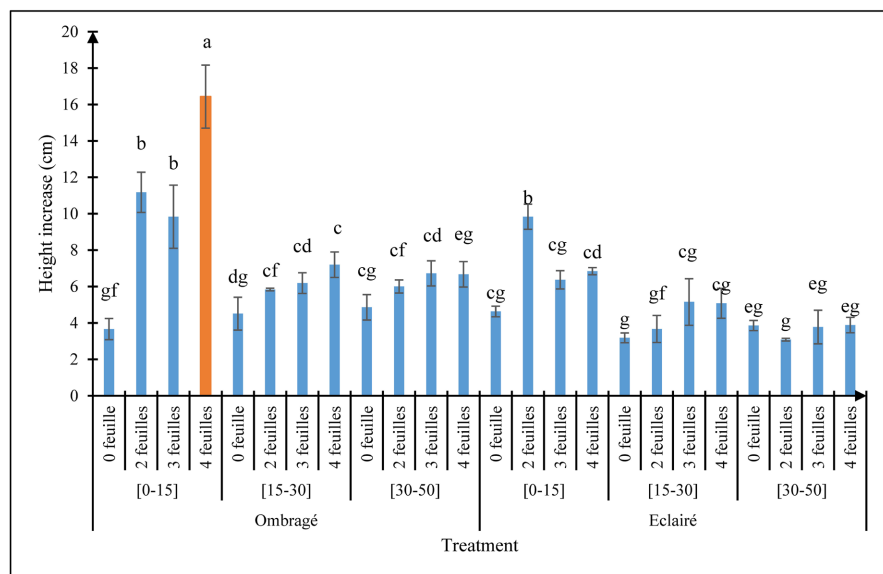


Figure 6. Height growth of *Ricinodendron heudelotii* seedlings based on the interaction of environment, size, and defoliation method.

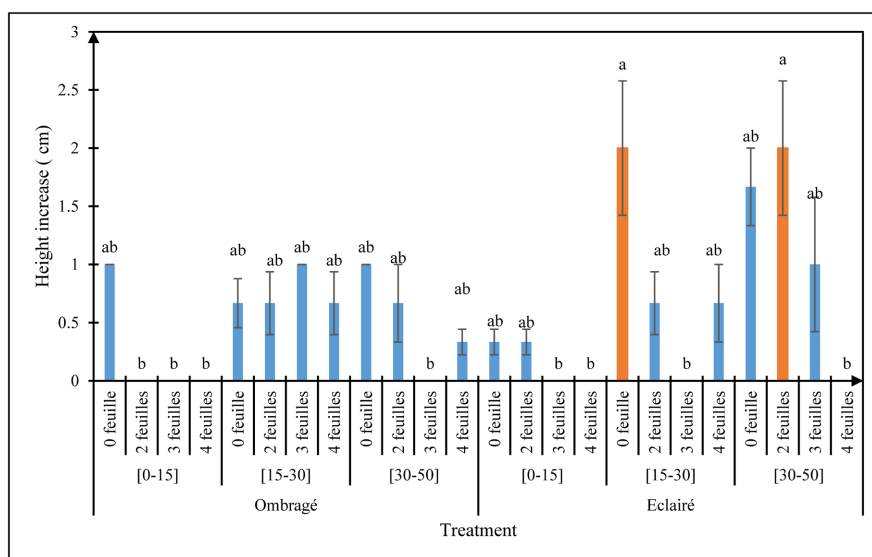


Figure 7. Height growth of *Irvingia gabonensis* seedlings based on the interaction of environment, size, and defoliation method.

4. Discussion

The growth and survival of plants in the nursery, stem height plays a crucial role. Several scientific studies have examined this complex relationship between stem height and plant survival rates, considering various environmental and biological factors [26]. Indeed, stem height is closely related to the plant's vigor. Plants with taller stems often have more developed root systems, allowing them to anchor better and absorb water and nutrients more efficiently for growth. The high survival rate (80%) recorded in our results for *Ricinodendron heudelotii* seedlings, compared to those of *Irvingia gabonensis*, could be explained by the species' performance. *R. heudelotii* is known for its rapid growth rate [26]. Its seedlings, therefore, seem to be better adapted to transplantation and exhibit rapid vegetative growth recovery, which likely contributed to the higher survival rate in the nursery.

The poor growth performance of *I. gabonensis* seedlings observed in this study is consistent with the fact that *I. gabonensis* is initially slow-growing compared with *R. heudelotii* [27]. In addition, some authors have examined the effect of stem height on the survival rate of tree seedlings in a nursery [28]. Their results revealed a significant correlation between stem height at the time of transplantation and seedling survival. Taller seedlings exhibited higher survival rates post-transplantation, suggesting that stem height can be an important indicator of plant health and resilience in the nursery. However, it should also be noted that excessively tall stems may present disadvantages. Similarly, others have reported that vegetable plants with excessively long stems had significantly lower survival rates than plants with medium height stems. This study underlines the importance of controlling stem growth to ensure successful plant production in the nursery [29].

A taller stem is often associated with faster vertical growth in many plant species. This is generally due to an increase in the leaf surface area exposed to light, which promotes more intensive photosynthetic activity, leading to higher biomass production. As a result, plants with taller stems tend to have more significant height growth in the nursery. A positive correlation between the initial stem height of maize seedlings and their subsequent height growth over time was observed by authors as [30]. Seedlings with taller stems showed faster height growth compared to those with shorter stems, suggesting that stem height can be an early indicator of future growth. These results align with our findings for *Ricinodendron heudelotii* seedlings, showing a similar pattern between initial plant height and stem growth.

Additionally, defoliation treatment which involves removing some of the leaves from a plant, is a common practice in nurseries for various reasons, such as managing plant vigor, stimulating branching, and reducing water loss and disease risk. However, the effects of defoliation treatment on plant survival rates in nurseries can vary depending on several factors [31]. Size can be a determining factor in the survival rates of certain species [31]. Proper defoliation practices can influence the ability of plants to mobilize their resources efficiently, thereby enhancing their adaptation to the nursery environment. Demonstrated that selective pruning of apple seedlings in nurseries resulted in a significant increase in survival rates after field transplantation [32]. These results align with those observed for *Irvingia gabonensis* seedlings, which show an interaction between pruning methods and survival rates, but contrast with those for *Ricinodendron heudelotii*.

Reducing the number of leaves could help the plant reduce water loss through evapotranspiration, thus preserving necessary reserves for growth despite the environmental change. These results contradict those of a number of authors who have shown that tomato leaf reduction leads to a reduction in the growth of other plant organs and a decrease in photosynthetic activity [33]. The high survival rate of *R. heudelotii* seedlings in both study environments could be attributed to the good health and physiological condition of the plants, as well as favorable environmental conditions for recovery. Seedling growth requires good conditions and care, including soil moisture, leaf reduction and shading [34]. Light is a fundamental element in nurseries, and light intensity can have a significant impact on plant survival. Optimal light conditions promote healthy development and increase the chances of survival [35].

Furthermore, the positive effect of the light environment on leaf emergence highlighted in our results can be explained by the attraction of the small bud (the gemmule), from which the leaves emerge, towards the light. Moreover, thanks to photosynthetic activity, the leaves ensure their development by accumulating biomass. This can be attributed to the high level of photosynthetic activity facilitated by the intensity of incident light. Indeed, light has an impact on leaf initiation in *Thunbergia Atacorensis* ([36] Asseh *et al.*, 2017). Furthermore, growth rate and leaf initiation in young cucumber plants increased with the amount of daily light energy [37].

Regarding the results for *I. gabonensis* seedlings, they showed no difference in growth and leaf production between the two environments. These results, in addition to contrasting with those of *R. heudelotii* seedlings, also differ from those of [36] (Asseh *et al.* 2017). The work of these two authors on the growth of *Thunbergia Atacorensis* gave similar results under the same conditions. When it comes to optimizing plant survival rates in the nursery, it is essential to consider the combined effects of several factors, including stem height, growing medium and defoliation. These factors interact in complex ways to influence the growth, vigor and resistance of nursery plants. The interaction of these factors had no influence on the survival rate of *R. heudelotii* and *I. gabonensis* plants.

These results contradict those obtained by [38] Chen *et al.*, (2020), who studied the combined effects of stem height, light, and defoliation on the survival rate of maize seedlings in nurseries. Their results showed that plants with taller stems, grown under adequate light intensity and subjected to moderate defoliation, had the highest survival rates. These plants exhibited better root development, greater stress resistance, and improved ability to absorb nutrients and water from the soil, which promoted their survival in the nursery. On the other hand, studies have also shown that the interactions between stem height, growing medium, and defoliation can vary depending on the plant species studied. Indeed, [39] Garcia *et al.*, (2018) evaluated the effects of these factors on the survival rate of fruit tree seedlings in nurseries. Their results showed species-specific responses, emphasizing the importance of considering the needs of each crop when managing nursery cultivation.

However, it is worth noting that the results of this work, based on observations over a short period of two months, could be improved by similar studies over a longer period, possibly 3 to 4 months for fast-growing species like and 6 to 8 months for slow-growing species like *Irvingia gabonensis* [40].

5. Conclusion

This study demonstrated that the propagation of *Ricinodendron heudelotii* and *Irvingia gabonensis* is possible through wildings. However, the ability of *R. heudelotii* to adapt quickly in nurseries, particularly with regrowth of 0 to 15 cm in height and having 4 leaves in shaded environments, makes it an ideal choice for agroforestry projects. In contrast, for *I. gabonensis*, the shoots measuring 15 to 30 cm in height with 0 leaf and those 30 to 50 cm in height with 2 leaves placed in a well-lit environment show good growth potential. The proper development of the plants after transplantation requires specific morphological, physiological, and ecological conditions for each species. A better understanding of the interactions between the morphological, physiological, and ecological factors of these species could significantly improve the production of their plant material through nursery regrowth, contributing to their sustainable conservation through agroforestry. However, this requires in-depth complementary studies on their environmental impact in association with cocoa cultivation and the growth of young plants in plantations.

Novelty Statement

Irvingia gabonensis and *Ricinodendron heudelotii* are forest species known to rural populations for their multiple uses, which unfortunately pose a threat to their sustainable conservation. In the face of difficulties in the natural regeneration of these two species, this study showed that the production of their plant material in nurseries is possible from shoots taken at an appropriate height, in a favorable lighting environment after suitable treatment; with a view to their domestication.

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Author Contributions

Affessi Alain Jiani GITTE and Souleymane SANOGO planned the experiments which are practiced by Brou Christian KOUAME, Jonas Patrick DAO interpreted the results, Affessi Alain Jiani GITTE made the write up statistically analyzed the data and made illustrations.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

This work was carried out in accordance with the ethics and deontology of the Université Félix Houphouët Boigny of Ivory Coast.

Conflicts of Interest

All authors declare no conflict of interest.

References

- [1] Dupriez, H. and De Leener, P. (1993) Trees and Multi-Storey Agriculture in Africa. CTA, 280 p.
- [2] Kouamé, N.M.T., Gnahoua, G.M. and Mangara, A. (2012) Germination Trials of *Ricinodendron heudelotii* (Euphorbiaceae) in the Fromager Region in the Center-West of Côte d'Ivoire. *Journal of Applied Biosciences*, **56**, 4133-4141.
- [3] FAO (2016) The Drivers of Deforestation and Forest Degradation in Côte d'Ivoire. <https://www.fao.org/>
- [4] Kalischek, N., Lang, N., Renier, C., Daudt, R.C., Adoah, T., Thompson, W., *et al.* (2023) Cocoa Plantations Are Associated with Deforestation in Côte D'ivoire and Ghana. *Nature Food*, **4**, 384-393. <https://doi.org/10.1038/s43016-023-00751-8>.
- [5] Youan, L.G., Kouadio, K.A. and Gnamba, Y.J.B. (2019) The Expansion of Cocoa Cultivation and the Degradation of the Forest Environment in the Duekoué Department. *Revues. Espagne Géographie Société*, **30**, 57-75.

- [6] Coulibaly, M., Kouamé, C., N'dri, D., Kouassi, N., Pereko, K. and Amani, G. (2018) Effect of Post-Harvest Traditional Technologies on the Nutrient Content and Anti-oxidant Compounds of Defatted Flours from *Ricinodendron heudelotti* (Baill. Pierre Ex Pax) Seed Kernels. *Technologies*, **6**, Article 37. <https://doi.org/10.3390/technologies6020037>
- [7] Chatelain, C., Gautier, L. and Spichiger, R. (1996) A Recent History of Forest Fragmentation in Southwestern Ivory Coast. *Biodiversity and Conservation*, **5**, 37-53. <https://doi.org/10.1007/bf00056291>
- [8] Koulibaly, A.V. (2008) Characteristics of Vegetation and Regeneration Dynamics under the Influence of Land Use in the Forest-Savannah Mosaic of the Lamto Reserve and the Comoé National Park Region, in Côte d'Ivoire. Doctoral Thesis, University of Cocody-Abidjan, 137 p.
- [9] Goetze, D., Koulibaly, A., Porembski, S. and Traoré, D. (2010) Land Use Practices and Biodiversity: Recent Dynamics of Vegetation. In: Konaté, S. and Kampmann, D., Eds., 2010: *Biodiversity Atlas of West Africa*, Volume III: Côte d'Ivoire. Abidjan & Frankfurt/Main, 342-348.
- [10] Tano, A.M. (2012) Cocoa Crisis and Strategies of Producers in the Sub-Prefecture of Méadji in Southwestern of Côte d'Ivoire. Ph.D. Thesis, Université Toulouse 2 Le Mirail, 261.
- [11] Clough, Y., Barkmann, J., Jührbandt, J., Kessler, M., Wanger, T.C., Anshary, A., *et al.* (2011) Combining High Biodiversity with High Yields in Tropical Agroforests. *Proceedings of the National Academy of Sciences*, **108**, 8311-8316. <https://doi.org/10.1073/pnas.1016799108>
- [12] Akpovo, A.H., Fandohan, A.B. and Djossa, A.B. (2021) Conservation and Sustainable Management of *Ricinodendron heudelottii* (Baill.) Pierre ex Heckel: Knowledge, Gaps and Perspectives. *Sciences and Technologies for Sustainable Agriculture*, **2**, 1-17.
- [13] Leakey, R.R.B., Tchoundjeu, Z., Schreckenber, K., Shackleton, S.E. and Shackleton, C.M. (2005) Agroforestry Tree Products (AFTPs): Targeting Poverty Reduction and Enhanced Livelihoods. *International Journal of Agricultural Sustainability*, **3**, 1-23. <https://doi.org/10.1080/14735903.2005.9684741>
- [14] Asase, A., Ofori-Frimpong, K. and Ekpe, P.K. (2010) Impact of Cocoa Farming on Vegetation in an Agricultural Landscape in Ghana. *African Journal of Ecology*, **48**, 338-346. <https://doi.org/10.1111/j.1365-2028.2009.01112.x>
- [15] Gockowski, J. and Sonwa, D. (2011) Cocoa Intensification Scenarios and Their Predicted Impact on CO2 Emissions, Biodiversity Conservation, and Rural Livelihoods in the Guinea Rain Forest of West Africa. *Environmental Management*, **48**, 307-321. <https://doi.org/10.1007/s00267-010-9602-3>
- [16] Tchoundjeu, Z., Duguma, B., Fondoun, J.-M. and Kengue, J. (1998) Strategy for the Domestication of Indigenous Fruit Trees of West Africa: Case of *Irvingia gabonensis* in Southern Cameroon. *Cameroon Journal of Biological and Biochemical Sciences*, **4**, 21-28
- [17] Leakey, R.R.B., Tchoundjeu, Z., Smith, R.I., Munro, R.C., Fondoun, J., Kengue, J., *et al.* (2004) Evidence That Subsistence Farmers Have Domesticated Indigenous Fruits (*Dacryodes edulis* and *Irvingia gabonensis*) in Cameroon and Nigeria. *Agroforestry Systems*, **60**, 101-111. <https://doi.org/10.1023/b:agfo.0000013259.95628.22>
- [18] Sunderland, T.C.H., Harrison, S and Ndoye, O. (2009) The Role of Non-Timber Forest Products in the Cocoa Agroecosystem.
- [19] Djeugap, F., Bernier, L., Dostaler, D., Khasa, D., Fontem, D. and Nwaga, D. (2013) Opportunités et contraintes agroforestières de *Ricinodendron heudelottii* au Cameroun. *International Journal of Biological and Chemical Sciences*, **7**, 344-355.

<https://doi.org/10.4314/ijbcs.v7i1.30>

- [20] Kouamé, N.M.T., Mangara, A. and N'Guessan, K. (2015) Study of the Germination of *Irvingia gabonensis* Seeds, Center-West of Côte d'Ivoire in the Gôh Region. *Biodiversity and Conservation*, **13**, 545-555.
- [21] IUCN (2020) The IUCN Red List of Threatened Species. Version 2020-3. www.iucnredlist.org
- [22] Oldfield, S., Lusty, C. and MacKinven, A. (1998) The World List of Threatened Trees. World Conservation Press.
- [23] Atangana, A.R., Tchoundjeu, Z., Asaah, E.K., Simons, A.J. and Leakey, R.R.B. (2006) Domestication of *Irvingia gabonensis*. I. Phenotypic Variation in Fruits and Kernels in Two Populations from Cameroon and Nigeria. *Agroforestry Systems*, **67**, 183-192.
- [24] Louan, O.B., Tanina, D.S., Marie, P.H. and Gnamba, S.D. (2022) Effect of the Application of Agricultural Inputs on the Water-Sediment Relationship in Cocoa-Growing Areas in Yabayo, Soubre Department, Southwest Ivory Coast. *Revue Ivory Scientific Technology*, **40**, 43-56.
- [25] Gédéon, S.S. and Tozan Bi, Z. (2021) Contribution of Immigrants to the Socio-Economic Development of the Commune of Soubre, Côte d'Ivoire. *Geovision*, **10**, 404-417.
- [26] Mapongmetsem, P.M., Du Guma, B., Nkongmeneck, B.A. and Selegny, E. (1999) Germination of Seeds, Development, and Growth of Some Local Species in Forest Areas. *Tropicultura*, **17**, 175-179.
- [27] Tchoundjeu, Z., Leakey, R.R.B., Schreckenber, K. and Shrestha K. (2002) The Participatory Domestication of Indigenous Fruits. *Agroforestry Systems*, **54**, 201-211.
- [28] Jones, B., Smith, A. and Johnson, C. (2018) The Effect of Stem Height on Survival Rates of Young Tree Seedlings. *Journal of Horticultural Science*, **35**, 145-158.
- [29] Garcia, M., Lopez, S. and Martinez, E. (2020) Effects of Excessive Stem Height on Survival Rates of Vegetable Seedlings in a Nursery Setting. *Journal of Agricultural Science*, **48**, 275-288.
- [30] Li, J., Wang, S. and Zhang, L. (2019) Effects of Stem Height on Height Growth Rate of Maize Seedlings in a Nursery Setting. *Journal of Plant Physiology*, **56**, 189-201.
- [31] Wang, N., Ji, T., Liu, X., Li, Q., Sairebieli, K., Wu, P., *et al.* (2022) Defoliation Significantly Suppressed Plant Growth under Low Light Conditions in Two Leguminosae Species. *Frontiers in Plant Science*, **12**, Article ID: 777328. <https://doi.org/10.3389/fpls.2021.777328>
- [32] Martinez, E., Lopez, S. and Garcia, M. (2020) Combined Effects of Stem Height, Substrate, and Defoliation on Survival Rates of Nursery-Grown Grapevine Seedlings. *Journal of Plant Science*, **48**, 401-415.
- [33] Zhang, H., Wang, Q. and Liu, Y. (2017) Effects of Selective Defoliation on Survival and Growth of Container-Grown Apple Seedlings. *Journal of Horticultural Science*, **44**, 189-202.
- [34] Navarrete, M. and Jeannequin, B. (1995) Hétérogénéité dans des populations de tomate sous serre et répercussions sur la conduite technique. II. Effets de la conduite plante à plante sur la production de fruits. *Agronomie*, **15**, 265-275. <https://doi.org/10.1051/agro:19950502>
- [35] Verheij, E. (2004) To Multiply and Plant Trees. Agrodok 19, Manuel Technique, 110 p.
- [36] Smith, J. (2019) Impact of Light Intensity on Seedling Survival in Nursery Conditions. *Journal of Horticulture Science*, **28**, 201-215.

- [37] Asseh, E.E., Aké-Assi, E., Koffi, K.J., Kouassi, A.F. and N'guessan, K.E. (2017) Domestication of *Thunbergia Atacorensis* Akoegninou & Lisowski (Acanthaceae): Effect of Substrate Type and Lighting Mode on the Ability to Regenerate Vegetatively from Cuttings and the Growth of Plants. *European Scientific Journal*, **13**, 1857-7881.
- [38] Klapwijk, D. and Tooze, S.A. (1982) The Effect of Season and Artificial Light on Young Cucumber Plants. Intern verslag nr. 59, 5 p.
<https://edepot.wur.nl/432511>
- [39] Chen, X., Liu, W. and Wang, H. (2020) Effects of Stem Height on Leaf Emergence in Nursery Grown Tomato Seedlings. *Journal of Plant Growth Regulation*, **42**, 301-315.
- [40] Garcia, M., Martinez, E. and Lopez, S. (2018) Interactive Effects of Stem Height, Substrate Composition, and Defoliation on Survival Rates of Nursery-Grown Fruit Tree Seedlings. *Journal of Horticultural Research*, **35**, 275-289.