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Seedlings Growth Evaluation of Three NTFP Species in Community Nurseries for the Rehabilitation of Degraded Areas in the Periphery of the Douala-Edéa National Park

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Abstract

This study was conducted on the outskirts of the Douala-Edea National Park (Mouanko, Littoral Cameroon), as part of the project "The Restoration Initiative (TRI)". It aims to determine the growth rate of nursery seedlings of *Ricinodendron heudelotii*, *Irvingia gabonensis*, and *Garcinia kola*. The inventory method made it possible to identify the importance of the NTFP species chosen by the local communities in the coastal forest. The collection of the chosen species was achieved using wildlings and seeds of NTFP. The species were treated by the vegetative propagation technique between the months of April and June 2021. Forest soil was collected, the substrate was filled in the biodegradable polystyrene bags, and then the wildlings were sown. A total of 132 plants of the three species Ndjansang (98), Bush mango (24), and Bitter kola (12) were selected for the study. The analysis of the biometric data in the nursery showed that the average growth (height/diameter) rate (Tc) of the seedlings for the species was Tc = 8.97 for *Ricinodendron heudelotii*, Tc = 9.36 for *Irvingia gabonensis* and Tc = 6.64 for *Garcinia kola*. The study showed that each species has a growth limit in the nursery that must be respected to optimize the recovery of plants in plantations in order to successfully rehabilitate degraded ecosystems. Through this study, local communities could be restored in coastal forests, guaranteeing their well-being and strengthening nature conservation in protected areas.

Subject Areas

Natural Geography

Keywords

Douala-Edea National Park, NTFP, Domestication, Wildings, Biometry, Growth Rate

1. Introduction

The monomodal forest zone (Littoral) is a humid and fragile environment according to Cameroon Forestry Law No. 94-01 of 20 January, 1994, regarding the forests in the permanent forest estate (articles 21 - 24 and the implemented decrees). Due to their attractive potential, coastal forests are subject to significant anthropogenic disturbances due to logging (legal and illegal), extensive agriculture, cutting for firewood, and the excessive harvesting of non-timber forest products (NTFPs), resulting in negative environmental, social, and economic impacts. To raise awareness of this, [1] pointed out that Cameroon lost 2% of its forest cover in 14 years (2001-2014), and 3.8% between 2001 and 2018. The loss of vegetation cover in the Littoral region (13.4%) [1], illustrates the level of degradation. Despite their ability to adapt to the following disturbances, fragmentation occurred in the natural habitats of flora and fauna, and the impact of climate change increased. The rehabilitation of degraded areas must integrate the needs of local populations to optimize the success of forestry activities. To guarantee the successful healing of degraded environments, [2] mention the need to choose species that they call "keystone species" to capitalize on the different types of use. The successful establishment of plants for reforestation depends on a wide range of interacting factors, including climate, soil, competing species, and post-plantation care [3]. In this context, the recolonization of altered ecosystems must be achieved by woody species and NTFPs to restore habitats, and ecosystem services and guarantee the well-being of local populations. [4] reveal that the rural and urban populations of Cameroon are highly dependent on forest resources, particularly non-timber forest products (NTFPs), as these significantly contribute to food security, nutritional balance, and the objectives of the environmental conservation of biodiversity. [5] describe their importance by specifying that high-value NTFPs such as bush mangoes (*Irvingia gabonensis*), okok or rumba, also called eru (Gnetum spp.), honey and wax, gum arabic, raffia (*Raphia farinifera*), *Cola acuminata*, safou (*Dacryodes edulis*), and pygeum (*Prunus africana*) provide, on average, 42% of the annual income of collector households. The absence of sustainable NTFP-harvesting methods limits the population's commitment to sustainability. There is also a lack of incentives for artificial regeneration as the majority of wildlings die around seed trees. These shortcomings illustrate the inefficiency of the management of NTFP species, which is regulated in Cameroon by law 94/01, 20 January, 1994 [6]. To overcome this lack of management, several studies have been carried out, following the example of [4] [7]-[9], which demonstrate the importance of characterizing the potential, formation structure and diversity of NTFP species. With the aim of controlling growth parameters, curbing exploitation and capitalizing on the domestication of NTFP species, [8] recommend a study on the dynamics of NTFPs. [10] [11] specify the social, technical and economic importance of domestication for the silviculture and management of NTFP species. To ensure protection and conservation in protected areas, [9] shows that non-timber forest products (NTFPs) are necessary to meet the needs of local and indigenous communities in the peripheral zone of Lobeke National Park. It is therefore noted that NTFPs are of capital importance because their exploitation not only contributes to the well-being of local populations but their presence could also strengthen nature conservation in protected areas. Good-quality planting stock is an essential precondition for reforestation success and will help to achieve better results when this species is planted in other parts of the world [3]. This study aims to define the growth rate of seedlings of NTFP species in the nursery. Specifically, it involves: (1) collecting wildlings in the coastal forest; (2) characterizing young plants in the nursery and (3) evaluating the growth rate of the seedlings.

2. NTFP Species Studied

2.1. *Ricinodendron heudelotii* (Baill) Pierre ex Heckel

Ricinodendron heudelotii (Baill) Pierre ex Heckel, locally called Ndjansang, Essessang, is a diploid forest species of the Euphorbiaceae family, endemic to humid tropical Africa [7] and present in the coastal forest of Mouanko. According to [7], the natural regeneration of this species is difficult and the integumentary dormancy of the seeds constitutes one of the major constraints to its domestication, while [12] indicate that the damage caused by the psyllid *Diclidophlebia xuani* Messi *et al.* young plants, in the nursery or after planting, constitute one of the main constraints to the domestication of the species. *Ricinodendron heudelotii* has a socio-economic importance following the exploitation of its different parts and fruits in Cameroon (**Figure 1**). Fruits are marketed and used for cooking. It is on the list of forest species in the dense forests of Cameroon that are potentially exploitable at present. Its minimum logging diameter is set at 50 cm [13].

Figure 1. *Ricinodendron heudelotii* seeds.

2.2. *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill

Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill, also known as "Ndoga" or "Mia" in Bakoko and bush mango locally, belongs to the family Irvingiaceae and occurs in the coastal forest of Mouanko. It is a species found in dense humid forests, gallery forests and semi-deciduous forests. It is very plastic but is not supported in wet lowlands or marshy land [14]. It has been reported to be used as a source of wood, in making utensils, and also as food and medicine [15]-[17]. *Irvingia gabonensis* is present in the list of forest species of the dense forests of Cameroon that are currently or potentially exploitable. **Figure 2** shows its fruits and kernels, which are useful for nutrition and marketing. Its timber is also harvested for various uses. Its minimum logging diameter is set at 50 cm [13].

(a)

(b)

Figure 2. Fruits (a) and almonds (b) of *I. gabonensis.*

2.3. *Garcinia kola* Heckel

Garcinia kola, described by Heckel (1883) [8] [18], belongs to the family Clusiaceae or Guttiferae. This species is variously named "Petit cola", in the French-speaking world, "Bitter cola" in English [19], and "Nyalla" in Bakoko (one of the native languages). According to [8], herbarium samples kept at the National Herbarium of Cameroon indicate the presence of 21 species of Garcinia in Cameroon. The seeds (**Figure 3**), when eaten fresh, have a bitter taste and are used as a stimulant and aphrodisiac. Despite its socio-economic importance, the cultivation of *Garcinia kola* Heckel is very limited due to the low germination of its seeds [20]. With a view to its domestication, *Garcinia kola* is now cultivated in home gardens, agroforestry fields, degraded forests and fallow land. *Garcinia kola* appears in the list of forest species of the dense forests of Cameroon that are currently or potentially exploitable. The cylindrical trunk of this plant is used as timber [19]. Its minimum logging diameter is set at 50 cm [13]. In addition, overexploitation has led to the threat of species extinction. It is currently classified in the list of species reported as vulnerable or close to commercial extinction.

Figure 3. *Garcinia kola* seeds.

3. Materials and Methods

3.1. Study Site

This study took place in the Lobéthal district on the peripheries of the Douala-Edéa National Park (DENP). The community nursery is located in the Municipality of Mouanko, Mouanko Subdivision, Sanaga-maritime Division, Littoral Region Cameroon. The community nursery has geographical coordinates of 03˚39.335'N and 009˚47.893 E. Figure 4 shows the community nursery.

Figure 4. Community nursery.

3.2. Justification for the Choice of "Keystone" NTFPs

- The reconstitution of degraded areas by trees of interest to local populations contributes to the domestication of priority species. The sustainable harvesting of NTFP species requires that the growth and development rate of species in situ is controlled. [21] support this idea in their study of the presence of Euphorbiaceae, Irvingiaceae and Clusiaceae in the Douala-Edéa Forest Reserve, DENP. As part of this study, three native NTFP species were chosen, namely: *Ricinodendron heudelotii*, *Irvingia gabonensis*, *Garcinia kola*. [21] reported the importance of NTFP marketing income in the Mouanko market. These species are listed in the IUCN Red List. According to [22], *Ricinodendron heudelotii* (Ndjansang) is one of five native NTFP tree species identified as priorities for domestication and trade in Central Africa, along with *Irvingia gabonensis* (Bush mango), *Dacryodes edulis* (Safou), *Chrysophyllum albidum* (African star apple) and *Garcinia kola* (Bitter kola). Thus:

- *Ricinodendron heudelotii* is a threatened species of minor concern [23];
- *Irvingia gabonensis* is a species listed as slightly threatened [24];
- *Garcinia kola* is a threatened species in decline, and therefore vulnerable [25].

3.3. Data Collection Inventory

Community members identified their NTFP of interest and this made it possible to identify the mother plants in the coastal forest. Following this identification, around each seed tree, a circle of 50 cm radius was delimited to manually harvest the wildlings only, without seed measurement. All three species for the study were collected in the Atlantic Forest (Mouanko) by local communities members at the seedling stage.

3.4. Sowing in the Nursery

According to [26] [27], the soil of Mouanko is the ferralitic, hydromorphic, sandy type, with colors ranging from reddish brown to black. The substrate sampling was carried out at a depth of from 20 to 30 cm from the ground, 20 m from the nursery site. This natural substrate contains biomass (humus) from abundant vegetation. The filling of the natural substrate (forest soil) in the pots (biodegradable polystyrene bags) of dimensions that were 17 cm in diameter and 20 cm in height was carried out. The wildlings were then sown in the pots containing this substrate. To ensure sowing success, a hole was first dug in each pot; then, the root system of the seedlings was inserted, preventing taproots and secondary roots from being damaged. The plant was carefully placed in the holes at the level of the root collar of the stem. Sowing of the wildlings in the nursery was carried out in plots between the months of April and June 2021. The monitoring of young plants in the nursery included regular cleaning, watering of the plants and phytosanitary treatment (1/2 month).

3.5. Biometrics

The collection of biometric data in the nursery facilitated the analysis of an evaluation of the growth rate of seedlings of different species. We measured the collar diameter (mm) of different plants 1 cm above the ground in each pot using a vinier caliper, measured the height of the stem (cm) of each plant using the tape measure, and then observed the color of the foliage and vigor of each individual to appreciate the sanitary state of each seedling. The biometric information was collected on October 06, 2021, in the nursery. This method was inspired by [28]-[33].

3.6. Data Analysis

The collected data made it possible to determine the following parameters:

The average diameter is the sum of the collar diameters of the NTFP trees measured in each studied plot. Its value was deduced as follows:

$$Dm = \Sigma Di/N$$

The average height (Hm) of individuals is important in dendrometry, as it shows the spatial growth of stands. According to [34], it represents the average height of trees in a forest ecosystem. The average height is calculated (cm) as follows:

$$Hm = \Sigma Hi/N$$

Hi is the height of tree i and N the total number of individuals per species in the plot.

Lamhamedi *et al.* (1997) **[35]** clarify that a quality assessment of forest seedlings must have a height/diameter (H/D) ratio of less than 7. In their study, [3] used the sturdiness quotient (SQ), which relates height (cm) and root collar diameter (mm) [SQ = H/D], to determinate the morphological attribute. This ratio is called the diameter growth rate (Tc) in a nursery. Depending on the result, this ratio can be low, medium or high depending on the determined threshold. It can be used to characterize the growth rate of plants in the nursery.

Let

$$[Tc = H/D]$$

4. Results

4.1. Potential Collected Wildings

A total of 6134 wildings of the three species were collected in the coastal forest of Mouanko. This number shows the vegetative potential around the seed tree in forest and the specific richness of NTFP species. Structurally, the individuals were in the seedling stage. The identified and collected species are illustrated in **Table 1**. The results in **Table 1** show the number of seedlings of each collected species (*Ricinodendron heudelotii* 3019, *Irvingia gabonensis* 2865 and *Garcinia kola* 250).

Table 1. Species and number of sampled seedlings.

N˚	Common Name	Scientific Name	Number of Seedlings
1	Ndjansang	*Ricinodendron heudelotii*	3019
2	Bush mango	*Irvingia gabonensis*	2865
3	Bitter kola	*Garcinia kola*	250

The specific richness of NTFP species in wetlands shows the need for the domestication of the different species because the majority of the wildlings present around the seed trees are degenerated due to inadequate growth conditions.

4.2. Characterization of Young Plants in the Nursery

The description of the plants' structure on the basis of the collar diameter (Di), the stem height (H), the color of the leaves, and the sanitary state (healthy and vigorous) allowed for the selection of 132 seedlings in the community nursery 7 months after sowing. That is:

- Ninety-eight plants of *Ricinodendron heudelotii* (Ndjansang), with green leaves and vigorous shape. The average diameter was 5.90 mm;
- Twenty-two plants of *Irvingia gabonensis* (bush mango), with green leaves and vigorous shape. The average diameter was 2.89 mm;
- Twelve plants of *Garcinia kola* (bitter kola), with green leaves and vigorous shape. The average diameter was 2.53 mm.

The distribution of numbers by diameter class (**Table 2**) illustrates the structure of seedlings in the nursery 7 months after being sown. The results in **Table 2** describe the distribution of numbers according to the diameter class of the different species in nurseries. The analysis of the results shows a variation in the mode of the distribution series depending on the species. Regarding the species *Ricinodendron heudelotii* (Ndjansang), the frequent value of the mode (47) of the population is observed in the diameter class 5.0 - 7.0. The diameter classes 3.0 - 5.0, 5.0 - 7.0 have close values and represent 78.57% of the population. Similarly, for *Irvingia gabonensis* (bush mango), the mode with a frequent high value (13) is found in the diameter class 1.0 - 3.0 with a frequency of 59.09%. Finally, the population of *Garcinia kola* (Bitter kola) has a frequent modal value (9), as observed in the diameter class 1.0 - 3.0, illustrating a frequency of 75%. We note the absence of numbers of bush mango and bitter kola individuals from the diameter class 9.0–11.0. This distribution of numbers by the diameter class of each species reflects the growth indicator of seedlings in the nursery, the growth rate (Tc) in terms of diameter.

Table 2. Diameter classes of seedlings in the nursery.

Diameter Classes (mm)		[1.0 - 3.0]	[3.0 - 5.0]	[5.0 - 7.0]	[7.0 - 9.0]	[9.0 - 11.0]	[11.0 - 13.0]	[13.0 - 15.0]	Total
Effective	Ndjansang	1	30	47	15	2	1	2	98
	Bush mango	13	7	1	1	-	-	-	22
	Bitter kola	9	2	1	-	-	-	-	12

4.3. Growth Rate of the Three NTFP Species in the Nursery

The growth of the plants in the nursery is linked to good maintenance, the quality of the substrate and the supply of solar energy necessary for photosynthesis. The growth rate (Tc) in the diameter of each stem/species (**Figures 5-7**) shows the evolution in the diameter of the three species seven months after being sown. In the nursery, the variation in the H/D ratio depends on the quality of the substrate, the light energy received, the light/shade tolerance, the phytosanitary treatment and the water supply.

4.3.1. *Ricinodendron heudelotii* (Baill) Pierre ex Heckel

A variation in the Tc of *R. heudelotii* (98 individuals) was observed as a function of the diameter structure of the seedlings in the pots (Figure 5). In this cohort, the mean diameter value is 5.9 mm while the mean growth Tc is 8.97 higher than the normal (7).

An analysis of the Tc curve of *R. heudelotii* (Figure 5) shows that seedlings with a collar diameter between 2.0 and 5.8 mm have an average Tc that is 9.67 higher than the normal value (7). This value translates a low growth in the collar diameter of the stem and the root system. Additionally, plants with a collar diameter between 6.0 and 15 mm have an average Tc of 7.96 above the normal value. This observation was made directly in the nursery. The average Tc value (8.97) of the different individuals shows that the seedlings reached maximum growth in the nursery pots. This maximum growth could be observed by a robustness and a lignification of the stem leading, to a slowing down of the growth in the diameter in the pots and the overflow of the roots in the pots to infiltrate into the soil. The coefficient of determination $R^2 = 0.057$ shows that there is a very weak link between diameter growth and the growth index in the nursery. The F value observed in the Fisher test ($F = 0.277$; $p = 0.05$) at the 5% threshold shows that the growth in the collar diameter of the plants varies relative with the height and/or can become independent if plants are kept in pots in the nursery for a duration by crossing negatively.

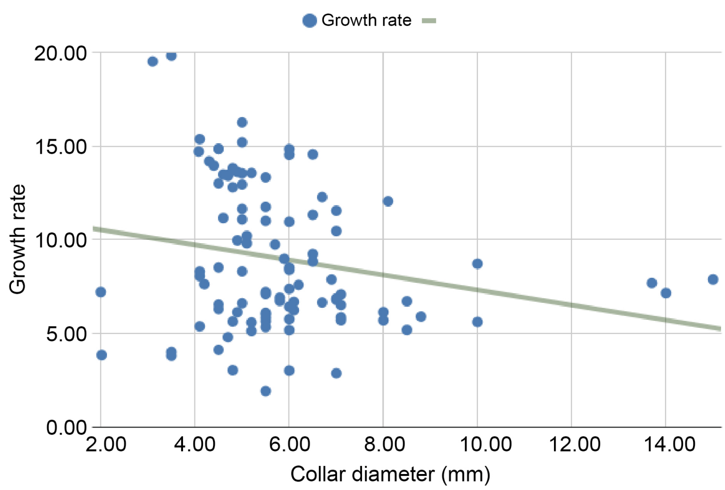

Figure 5. Curve of the diameter growth rate of *R. heudelotii* seedlings in the nursery.

4.3.2. *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill

The H/D ratio of *Irvingia gabonensis* plants in the nursery made it possible to establish a growth curve (**Figure 6**). We noted a variation in Tc of *I. gabonensis* (22 individuals) according to the diameter structure of the seedlings in the pots (**Figure 6**). In this cohort, the mean diameter value is 2.9 mm while the mean growth Tc (9.36) is above the limit value (7).

The analysis of the graph of *I. gabonensis* (**Figure 6**) describes the evolution of a slight variation in the collar diameter of the of the seedlings. Stems with a neck diameter between 1.1 and 2.5 mm have an average Tc of 11.88, well above the limit value. This value reflects the low diameter growth of *I. gabonensis* in the nursery. This high rate demonstrates that the root system of the plants is developing in the nursery pots. Similarly, seedlings with a collar diameter between 3.0 and 8.8 mm had an average Tc of 5.72 below the normal value. This result reflects the good development of the diameter structure and the root system, despite the pots not overflowing. Height growth decreases, in contrast to stem diameter. This slowdown could, therefore, be due to the depletion of mineral substances in the substrate contained in the pots despite the maintenance of the plant structure resulting from photosynthesis. This demonstrates that the growth in the collar diameter of *I. gabonensis* in the nursery impacts the spatial structure. The coefficient of determination $R^2 = 0.421$ shows a relative link between the collar diameter and the growth index. The F value observed in the Fisher test ($F = 0.12$; $p = 0.000005$) shows that the growth in diameter at the collar of the plants varies greatly in relation to the height and becomes negative due to the duration for which plants are kept in pots in the nursery at the 5% threshold.

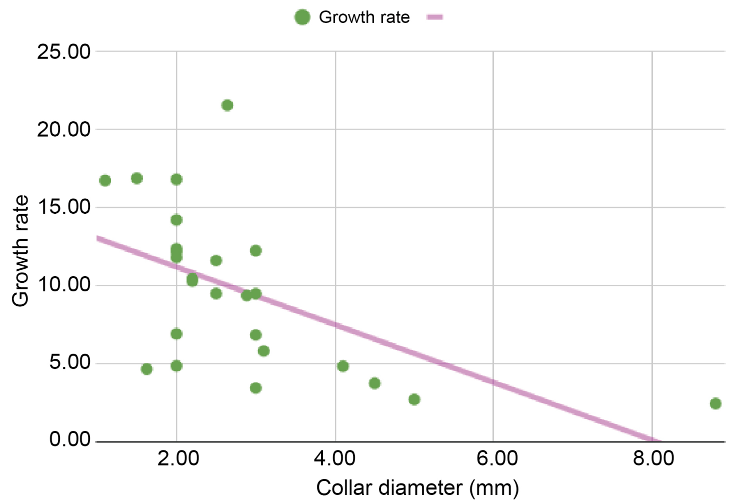

Figure 6. Curve of the diameter growth rate of *I. gabonensis* in nursery.

4.3.3. *Garcinia kola* Heckel

The structure of *Garcinia kola* plants in the nursery can be assessed through the evolution of this graph (**Figure 7**). The H/D ratio shows the growth rate for the diameter of the collar of *G. kola* plants. In this cohort, the mean diameter value is 2.5 mm while the mean growth Tc (6.64) is below the limit value.

The analysis of the curve (**Figure 7**) shows a slight variation in the diameter of the stems. Individuals between 1.5 and 2.5 mm have an average Tc of 7.21, slightly above the limit value. This result shows that the individuals of this class grow moderately in diameter, with a good increase in height in the pots. Similarly, stems with a diameter of 3.0 - 5.7 mm show good diameter growth, with an average Tc of 4.91 below the limit value. Through these results, we can estimate that the growth in the diametrical structure of *G. kola* in the nursery is linked to the time spent in the pots, but can also be influenced by the decrease in mineral substances and rootlets contained in the substrate. Consequently, *G. kola* could store the substances necessary for growth in the collar while awaiting transition to soiling. The coefficient of determination $R^2 = 0.307$ shows a weak correlation between the collar diameter and the growth index. The F value observed in the Fisher test ($F = 0.15$; $p = 0.002$) shows that the growth in the collar diameter of the plants varies depending on the height at the 5% threshold. This growth varies negatively because of the duration for which the plants remain in the nursery pots.

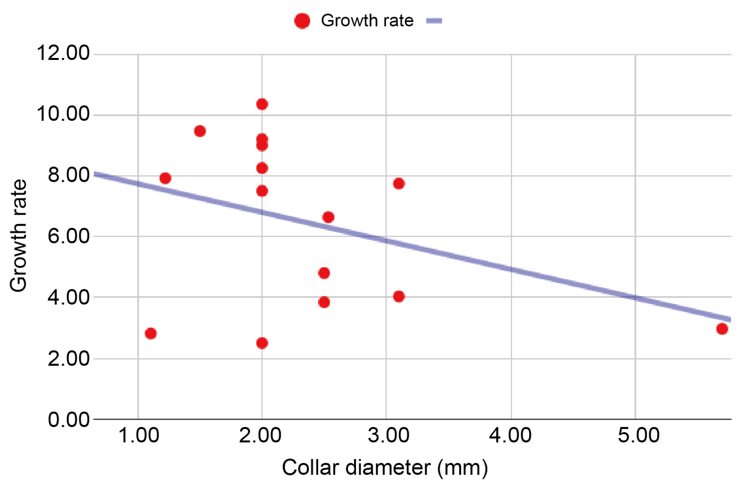

Figure 7. Curve of the diameter growth rate of *Garcinia kola* in nursery.

5. Discussion

This study aimed to contribute to the domestication of NTFP species. According to [3], the high cost of reforestation and low percentages of survival at some sites make these kinds of studies very important, especially when beginning to reforest with species that have not been previously studied in this respect. Plant growth can be defined as an increase in the volume and/or mass of plants with or without the formation of new structures such as organs, tissues, cells or cellular organelles [34] [36]. The natural regeneration of ligneous species is limited by the necrosis of the seedlings around the mother trees. According to their heliophilic, mesophilic and/or meso-heliophilic tendencies, the seedlings undergo mineral and light competition and significant biotic attacks. To capitalize on the conservation of threatened or prized woody species, the collection of seeds (seeds, wildlings and cuttings) must be mandatory in order to reduce their loss in the forest. Our thinking is similar to that of [37], who stated that plants are exposed to multiple problems, such as the amount of light received in the undergrowth, the action of phytophagous, plant competition, windthrow, and attacks by pathogenic fungi. The wildings of NTFP species collected in this study (6134 seedlings) are priorities in forest regeneration on the outskirts of the Douala-Edéa National Park. This potential vegetation is very important to collect because we need to avoid the loss of wildings in forest and to better contribute to the domestication of NTFP species.

The analysis of the structure of the plants in the nursery shows the distribution of the different species *Ricinodendron heudelotii* (98), *Irvingia gabonensis* (22) and *Garcinia kola* (12) in terms of collar diameter. With regard to collar diameter, all seedlings were acceptable for field transfer [3] [38], with an above-average collar diameter for *Ricinodendron heudelotii* (5.90 mm), *Irvingia gabonensis* (2.89 mm) and *Garcinia kola* (2.53 mm) 7 months after being sown. The distribution of numbers according to the diameter class of each species shows that most seedling populations of different species belong to 3.0 - 7.0-, 1.0 - 5.0-, and 1.0 - 3.0-diameter classes for *Ricinodendron heudelotii*, *Irvingia gabonensis* and *Garcinia kola,* respectively. These results indicate a decrease in seedlings growth in the pots. According to [36], the seedling growth decreases when the substrate nutrients become deficient after a long time in the pots.

The analysis of the plants' growth rate in the nursery shows that individuals of the different species *Ricinodendron heudelotii* (98), *Irvingia gabonensis* (22) and *Garcinia kola* (12), in terms of diameter and height, reached a height/diameter growth ratio (Tc) that indicates the need for their transplantation. This ratio (H/D) is a good indicator when evaluating the growth of seedlings in the nursery. According to [35] [39], the evaluation of the quality of forest seedlings must have an H/D ratio of less than 7. The results of the average ratio (H/D) of *Ricinodendron heudelotii* (8.97) and *Irvingia gabonensis* (9.36) show a linear decrease, while the ratio (H/D) of *Garcinia kola* (6.64), despite being lower than the limit value, also shows a linear decrease. These results mean that each forest species in the nursery could have a specific limit value that is different from that defined by the authors [35] [39]. Indeed, there are fast-growing species and moderate/slow-growing species. Therefore, this approach suggests that, for fast-growing forest species such as *Ricinodendron heudelotii*, the limit H/D ratio must be equal to 5; on the other hand, for forest species with moderate/slow development, this value must be equal to 6 to maximize the recovery of plants in plantations.

6. Conclusion

This work had the general objective of contributing to an evaluation of the growth of plant species in nurseries with a view to rehabilitating degraded areas of coastal forest, particularly at the periphery of the Douala-Edéa National Park. The potential wildings (6134 seedlings) are a great indicator of seeds in wetland forests that can be used to rehabilitate the degraded forest. The choice and description of the structure of the different forest species made it possible to determine the quality of the seedlings in the nursery. As a result, 98 plants of *Ricinodendron heudelotii*, 22 plants of *Irvingia gabonensis* and 12 plants of *Garcinia kola* were selected for transplantation. The characterization of young plants in the nursery shows that most seedlings of different species belong to the 3.0 - 7.0-, 1.0 - 5.0-, and 1.0 - 3.0-diameter classes for *Ricinodendron heudelotii*, *Irvingia gabonensis* and *Garcinia kola,* respectively, and indicate a decrease in growth. The average growth rate (height/diameter) of the different plants in the nursery shows that the three species *Ricinodendron heudelotii* (8.97), *Irvingia gabonensis* (9.36) and *Garcinia kola* (6.64) reached their growth limit in pots, justifying the need for their transplantation.

Author Contributions

J.C.M. collected the data, analysed and prepared the manuscript; C.M. helped to collect data; G.A. suggested project direction and provided support in the planning stages; H.A. supervised the work, contributed to the design of the work, and discussed and edited drafts with R.L.N.M. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Tunk, C., Hoefsloot, H. and Mougou, J. (2016) Evaluation du potentiel de restauration des paysages forestiers au Cameroun (Assessment of the Potential for Forest Landscape Restoration in Cameroon); GOPA/DFS Report; GOPA: Bad Homburg, Germany, 2016.

[2] Le Floc'h, É. and Aronson, J. (1995) Écologie de la restauration. Définition de quelques concepts de base. *Natures Sciences Sociétés*, **3**, S29-S35. https://doi.org/10.1051/nss/199503s029

[3] Luis, V.C., Peters, J., Gonzalez-Rodriguez, A.M., Jimenez, M.S. and Morales, D. (2004) Testing Nursery Plant Quality of Canary Island Pine Seedlings Grown under Different Cultivation Methods. *Python*, **44**, 231-244.

[4] Melingui, J.B.N., Angoni, H., Claude, P.A. and Kono, L. (2017) Natural Regeneration Potential of Some Priority Non-Timber Forest Products in the Akom II Production Basin (South Cameroon). *World Wide Journal of Multidisciplinary Research and Development*, **4**, 214-224.

[5] Awono, A., Ingram, V., Schure, J. and Levang, P. (2013) Guide for Small-Medium Enterprises for the Sustainable Trade of Non-Timber Forest Products in Central Africa.

[6] MINFOF (1994) Law No 94-01 of January 20, 1994 on the Forest, Wildlife and Fishing Regime; Ministry of Environment and Forests: Yaoundé, Cameroon. https://sherloc.unodc.org/cld/uploads/res/document/law-no--94-01-of-20-january-1994-to-lay-down-forestry--wildlife-and-fisheries-regulations-en_html/Law_No._94-01_on_Forestry_Wildlife_and_Fisheries_EN.pdf

[7] Djeugap, F., Bernier, L., Dostaler, D., Khasa, D., Fontem, D. and Nwaga, D. (2013) Opportunités et contraintes agroforestières de Ricinodendron heudelotii au Cameroun. *International Journal of Biological and Chemical Sciences*, **7**, 344-355. https://doi.org/10.4314/ijbcs.v7i1.30

[8] Kamga, Y.B., Nguetsop, V.F., Solefack, M.C. and Riera, B. (2018) Floristic Diversity of Woody Plants and Formation Structure in Garcinia Kola Heckel in the Center and East Regions, Cameroon. *European Scientific Journal*, **14**, Article No. 21.

[9] Tonga, K.P., Zapfack, L., Banoho, L.-P.-R.K. and Endamana, D. (2017) Availability of Basic Non-Timber Forest Products on the Periphery of Lobeke National Park. *Vertigo*, **17**, Article No. 3.

[10] Tabuna, H., Kana, R., Degrande, A. and Tchoundjeu, Z. (2009) Business Plan for a Rural Nursery for the Production and Marketing of Improved Seedlings of Non-Timber Forest Products in Central Africa.

[11] Simons, A.J. and Leakey, R.R.B. (2004) Tree Domestication in Tropical Agroforestry. In: *Advances in Agroforestry*, Springer, 167-181. https://doi.org/10.1007/978-94-017-2424-1_12

[12] Aléné, D.C., Messi, J. and Quilici, S. (2005) Quelques aspects de la biologie de Diclidophlebiaxuani Messi *et al.* (Hemiptera: Psyllidae), Ravageur de Ricinodendron heudelotii Baill. (Euphorbiaceae) au Cameroun. *Fruits*, **60**, 279-287. https://doi.org/10.1051/fruits:2005034

[13] MINFOF (2016) Directives D'inventaire D'exploitation; Ministry of Environment and Forests: Yaoundé, Cameroon.

[14] Gnahoua, G.M., Konan, A. and Louppe, D. (2003) *Irvingia gabonensis*, a Wild Fruit Tree with a Future.

[15] Mateus-Reguengo, L., Barbosa-Pereira, L., Rembangouet, W., Bertolino, M., Giordano, M., Rojo-Poveda, O., *et al.* (2019) Food Applications of *Irvingia gabonensis* (aubry-Lecomte Ex. O'rorke) Baill., the 'Bush Mango': A Review. *Critical Reviews in Food Science and Nutrition*, **60**, 2446-2459. https://doi.org/10.1080/10408398.2019.1646704

[16] Okoronkwo, C.U., Agoha, E.E.C., Alloysius, O., Ogodo, A.C. and Nwachukwu, N.O. (2014) Physical and Chemical Characteristics of the African Bush Mango (*Irvingia gabonensis* var. gabonensis) Seed Oil. *International Journal of Advances in Engineering and Management*, **1**, 28-31.

[17] Fungo, R., Muyonga, J.H., Kabahenda, M., Okia, C.A. and Snook, L. (2016) Factors Influencing Consumption of Nutrient Rich Forest Foods in Rural Cameroon. *Appetite*, **97**, 176-184. https://doi.org/10.1016/j.appet.2015.12.005

[18] Agwu, O.P., Bakayokoa, A., Jimoh, S.O., Dimobe, K. and Porembski, S. (2020) Impact of Climate on Ecology and Suitable Habitat of Garcinia Kola Heckel in Nigeria. *Trees, Forests and People*, **1**, Article 100006. https://doi.org/10.1016/j.tfp.2020.100006

[19] Kouame, N.M., Ake, C.B., Mangara, A. and N'guessan, K. (2017) Analyse de l'intérêt socio-économique des graines de Garcinia kola Heckel (Clusiaceae) dans la commune de Koumassi (Abidjan), Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **10**, 2587-2595. https://doi.org/10.4314/ijbcs.v10i6.15

[20] Kanmegne, G. and Omokolo, N.D. (2008) Germination Ofgarcinia Kola(heckel) Seeds in Response to Different Hormone Treatments. *Fruits*, **63**, 155-161. https://doi.org/10.1051/fruits:2008005

[21] Hyacinthe, A. (2015) Non-Timber Forest Products and Their Contributions on the Income of Local Residents in the Douala-Edea Wildlife Reserve of Cameroon. *Journal of Ecology and The Natural Environment*, **7**, 263-270. https://doi.org/10.5897/jene2015.0534

[22] Franzel, S., Jaenicke H. and Janssen W. (1996) Choosing the Right Trees: Setting Priorities for Multipurpose Tree Improvement. ISNAR Research Report 8. The Hague: International Service for National Agricultural Research. https://www.researchgate.net/publication/275155129_Choosing_the_Right_Trees_Setting_Priorities_for_Multipurpose_Tree_Improvement/link/59552dbca6fdcc2569d66ad2/download

[23] Beentje, H.J., Gereau, R.E., Hilton-Taylor, C., *et al.* (2020) *Ricinodendron heudelotii*. The IUCN Red List of Threatened Species 2020: e.T62459A149002362. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T62459A149002362.en

[24] World Conservation Monitoring Centre (1998) *Irvingia gabonensis*. The IUCN Red List of Threatened Species 1998: e.T33055A9754010. https://doi.org/10.2305%2FIUCN.UK.1998.RLTS.T33055A9754010.en

[25] Cheek, M. (2004) *Garcinia kola*. The IUCN Red List of Threatened Species 2004: e.T34715A9884648. https://doi.org/10.2305/IUCN.UK.2004.RLTS.T34715A9884648.en

[26] Angoni, H., Ongolo, R.S., Ngodo Melingui, J.B. and Ngo Mpeck, M.L. (2018) Composition floristique, Structure et menaces de la végétation de la ligne côtière de la Réserve de Faune de Douala-Edéa. *International Journal of Biological and Chemical Sciences*, **12**, 915-926. https://doi.org/10.4314/ijbcs.v12i2.23

[27] Letouzey, R. (1985) Carte phytogéographique du Cameroun; Institut de la recherché agronomique (Herbier national): Yaoundé, Cameroun; Institut international de la carte de végétation: Toulouse, France. http://geoprodig.cnrs.fr/items/show/178340

[28] Dickson, A., Leaf, A.L. and Hosner, J.F. (1960) Quality Appraisal of White Spruce and White Pine Seedling Stock in Nurseries. *The Forestry Chronicle*, **36**, 10-13. https://doi.org/10.5558/tfc36010-1

[29] Caspa, R.G., Tchouamo, I.R., Mate Mweru, J.P., Mbang Amang, J. and Ngang Ngwa, M. (2015) The Place of Irvingia Gabonensis in Village Communities around the Lobeke National Park in Cameroon. *Bois & Forets des Tropiques*, **324**, 5-17. https://doi.org/10.19182/bft2015.324.a31262

[30] Nygren, P., Rebottaro, S. and Chavarra, R. (1993) Application of the Pipe Model Theory to Non-Destructive Estimation of Leaf Biomass and Leaf Area of Pruned Agroforestry Trees. *Agroforestry Systems*, **23**, 63-77. https://doi.org/10.1007/bf00704851

[31] Li, Z., Ji, C. and Liu, J. (2008) Leaf Area Calculating Based on Digital Image.

Computer and Computing Technologies in Agriculture, **2**, 1427-1433.

[32] Wong, J.L.G., Thornber, K. and Baker, N. (2001) Resource Assessment of Non-Wood Forest Products: Experience and Biometric Principles. Food & Agriculture Org. https://www.researchgate.net/publication/284283587_Wong_JLG_Thornber_K_and_Baker_N_2001_Resource_assessment_of_non_wood_forest_products_Experience_and_biometric_principles_NWFP_Series_13_FAO_Rome_English_French_Spanish

[33] Wong, J.L. (2000) The Biometrics of Non-Timber Forest Product Resource Assessment: A Review of Current Methodology. Department for International Development.

[34] Clovis, K.O., Louis, Z., Claude, G., Valery, N.N. and Bernard-Aloys, N. (2018) Diversité Floristique Et Structurale de Deux Forêts Communautaires Sous Exploitation Au Cameroun: Cas De Kompia et Nkolenyeng. *European Scientific Journal*, **14**, Article No. 245. https://doi.org/10.19044/esj.2018.v14n24p245

[35] Lamhamedi, M., Fortinn, S., Ortinn, J.A., Ammari, Y., *et al.* (1997) Evaluation of Composts, Substrates and Plant Quality (*Pinus pinea*, *Punis halepensis*, *Cupressus sumpervirens* and Quercussuber) Grown in Containers; Bird 3601 Project; Technical Report: Execution of Development Works for Three Pilot Nurseries in Tunisia; Direction Générale des Forêts, Tunisia and Pampev Internationale Ltée: Longueuil, QC, Canada.

[36] Assi, E.M., Dogbo, O.D., Kassin, E., Assiri, A.A., Tahi, G.M., Guiraud, B., *et al.* (2018) Détermination de l'âge optimal en pépinière des plants de cacaoyer pour une meilleure réussite au champ. *African Crop Science Journal*, **26**, Article No. 491. https://doi.org/10.4314/acsj.v26i4.4

[37] Peters, C.M. (1994) Sustainable Harvest of Non-Timber Plant Resources in Tropical Moist Forest: An Ecological Primer.

[38] Penuelas J. and Ocana, L. (2000) Cultivo de plantas forestales en contenedor. Mundi-Prensa, Madrid, Spain.

[39] Nolet, P. and Forget, E. (2003) Étude de la relation du ratio hauteur/diamètre avec la croissance et l'âge des gaules en peuplements feuillus dégradés. Institut Québécois d'Aménagement de la forêt feuillue. https://isfort.uqo.ca/wp-content/uploads/2020/11/Nolet-et-Forget.-2003.-Etude-de-la-relation-du-ratio-hauteur-diametre-avec-la-croissance-et-lage-des-gaules-en-peuplements-feuillus-degrades.pdf