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Research Article

Growth and Development Dynamics Among *Khaya senegalensis* Progenies in Côte d'Ivoire

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Abstract

Mastering nursery production is a critical step for improving the silviculture of *Khaya senegalensis*, a major commercial forest species in Côte d'Ivoire. However, limited information is available on early-stage variability among progenies and the identification of reliable traits for selection at the nursery stage. This study aimed to analyze growth and developmental variability among six progenies of *K. senegalensis* in order to identify key morphological traits that can support early selection of superior genotypes. Thirty seeds collected from six mother trees were sown according to genotype using a randomized experimental design. Seedlings were monitored under nursery conditions, and ten agromorphological parameters related to growth and development were measured. The data were analyzed using multivariate statistical approaches, including discriminant analysis, to assess variation among progenies and determine the most informative traits. The results revealed significant variability among the progenies, highlighting the influence of genetic origin on early growth performance. Among the parameters studied, four traits: plant height, leaflet width, number of leaves, and number of internodes were identified as the most discriminant variables, effectively differentiating the progenies. These traits showed strong potential as early indicators of growth vigor and developmental performance. The identification of these key traits provides a practical basis for early selection in nursery conditions, which can enhance the efficiency of seedling production. Ultimately, this approach contributes to the optimization of nursery practices and supports the development of improved silvicultural strategies for *K. senegalensis* in Côte d'Ivoire.

Keywords

Khaya senegalensis, Nursery Production, Genetic Variation, Agromorphological Traits, Côte d'Ivoire

1. Introduction

African tropical forests remain globally significant reservoirs of biodiversity and key providers of ecosystem services, yet they are experiencing persistent and accelerating decline due to anthropogenic pressures such as agricultural expansion, logging and fuelwood extraction. Recent continental-scale assessments show that forest and woody savanna ecosystems in Africa have shifted from a net carbon sink to a net carbon source over the last decade, largely as a consequence of deforestation and forest degradation [1].

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In West and Central Africa, smallholder agriculture, selective timber harvesting and unsustainable extraction of non-timber forest products are among the dominant drivers of forest degradation, leading to structural changes in forest stands and the decline of high-value timber species [2, 3]. These pressures are particularly pronounced in countries where forest governance and restoration capacities remain limited.

In Côte d'Ivoire, forest ecosystems have undergone extensive deforestation and fragmentation over recent decades, mainly driven by agricultural expansion (notably cocoa-based systems), infrastructure development and uncontrolled resource extraction. As a result, a large proportion of the original forest cover has been lost, with significant implications for biodiversity conservation and ecosystem functioning. Although the forestry sector currently contributes less than 1% to national gross domestic product, timber production remains economically and socially important, providing export revenues and employment opportunities [3].

In response to ongoing forest degradation, sustainable forest management and ecological restoration strategies increasingly emphasize the use of native tree species in reforestation and agroforestry programs. Recent studies highlight that the success of such initiatives strongly depends on species selection, seed traits and early seedling performance, particularly for indigenous multipurpose timber species [4]. Agroforestry systems, which integrate trees with crops and/or livestock, are recognized as effective land-use options for restoring degraded landscapes while maintaining agricultural productivity and ecosystem services.

Khaya senegalensis (Desr.) A. Juss., commonly known as African mahogany, is a native West African timber species of high ecological, economic and socio-cultural value. The species is widely used for timber, fodder and traditional medicine, and is increasingly promoted for restoration and agroforestry purposes. Recent research has demonstrated that seed morphology and handling significantly influence germination success and early growth of *K. senegalensis* seedlings, underlining the importance of improved silvicultural practices at the nursery stage [4, 5]. In addition, studies on natural and planted populations have shown that stand structure, habitat conditions and management context can influence regeneration dynamics and associated biodiversity [6, 7].

Despite these advances, there remains limited information on early growth performance and genetic variability among progenies of *K. senegalensis* under nursery conditions in Côte d'Ivoire. Such knowledge is essential for optimizing seedling production, supporting tree improvement programs and enhancing the effectiveness of reforestation and agroforestry initiatives. *senegalensis* by conduct Therefore, the present study aims to improve the silviculture of *K.* ing a comparative assessment of growth and development among six progenies. Specifically, the objectives are to (i) evaluate key growth and developmental parameters at the nursery stage and (ii) assess the effect of progeny on seedling growth vigor.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted from October to December 2019 in the central-western region of Côte d'Ivoire, located between latitudes 4°30′N and 10°30′N, and longitudes 2°30′W and 8°30′W. The study site is situated 21 km from the town of Daloa, at coordinates 6°39′1″N and 6°30′48″W. The region experiences a tropical climate characterized by four distinct seasons: a long rainy season (April to mid-July), a short dry season (mid-July to mid-September), a short rainy season (mid-September to November), and a long dry season (December to March). The average annual rainfall is approximately 1200 mm. During the study period, temperatures ranged from 24.65°C to 27.75°C, and the mean relative humidity was around 95%.

2.2. Plant Material, Treatments, and Experimental Design

2.2.1. Plant Material and Experimental Design

The plant material used in this study consisted of *Khaya senegalensis* seedlings raised from seeds collected from six mother trees. All seeds originated from northern Côte d'Ivoire, specifically from the Lataha research station (CNRA, Korhogo). Seeds were sown directly at the experimental site without any pre-sowing treatment, following a progeny test design.

The experiment was laid out in a randomized block design. For each maternal parent, thirty seedlings derived from open-pollinated seeds were arranged in three rows, with ten seedlings per row. Spacing between seedlings and between rows was 30 cm, while a minimum distance of 50 cm was maintained between seedlings from different progenies. In this study, the term genotype (maternal parent) refers to the seed source. Genotypes G1, G2, G3, G4, G5, and G6 represent the six maternal parents evaluated. Seed sowing was conducted initially, and growth measurements were recorded at 15-day intervals on nine-month-old seedlings.

2.2.2. Nursery Management and Data Collection

Seedlings were watered daily throughout the experiment. Insect infestations were controlled using Decis® (Bayer) insecticide, applied at a concentration of 8 mL per 16 L of tap water. Weeding was carried out manually as needed. To monitor growth and organ development (leaves and internodes), measurements were taken at two-week intervals on thirty seedlings per genotype over a three-month period (October to December 2019). Observations began from the first internode at the base of the stem, as active growth and leaf emergence were occurring.

The following agromorphological parameters were measured on each seedling to assess growth and development (Table 1): internode length, internode diameter, leaf length, and leaf width, among others. Measurements were performed using standard agronomic procedures. Internode diameters were measured using a caliper, while lengths and widths were measured with a 30 cm graduated ruler. Data collection at regular intervals allowed the assessment of growth dynamics and variability among the six genotypes.

Table 1. *List of parameters used for seedling characterization.*

Parameters	Unit	Description
Height	m	Vertical length from the soil base to the seedling apex
Number of leaves	-	Total count of fully expanded leaves per seedling
Number of internodes	-	Total count of stem segments between successive nodes
Collar diameter	m	Diameter of the stem at the base of the seedling
Leaf length	m	Distance from leaf base to leaf tip (lamina)
Leaf width	m	Maximum width of the leaf lamina
Petiole length	m	Length of the stalk connecting the leaf blade to the stem
Number of leaf tiers	-	Total number of foliar tiers (nodes) along the main stem
Leaflet length	m	Length of individual leaflets in compound leaves
Leaflet width	m	Maximum width of individual leaflets

m: meter

2.3. Statistical Analysis

Descriptive statistics (minimum, maximum, mean and standard deviation) were calculated for all agromorphological traits to summarize data distribution and variability. Genotype effects were first assessed using multivariate analysis of variance (MANOVA). When significant multivariate effects were detected, one-way analysis of variance (ANOVA) was applied to individual traits, and mean comparisons were performed using the Least Significant Difference (LSD) test at the 5% significance level.

Principal Component Analysis (PCA) was conducted on standardized data to explore relationships among traits and to identify patterns of genotype structuring, a widely used approach in forestry and plant science studies [8, 9]. Hierarchical Cluster Analysis (HCA) was subsequently applied using the Unweighted Pair-Group Method with Arithmetic Mean (UPGMA) to classify genotypes into homogeneous groups based on their multivariate similarity [10]. Discriminant Factor Analysis (DFA) was then used to characterize and validate the groups obtained from the cluster analysis [11]. All statistical analyses were performed using the R statistical software [12].

3. Results

3.1. Characterization of Agromorphological Variability

Multivariate analysis of variance (MANOVA) revealed a significant difference among genotypes ($F = 50.551$; $p < 0.05$). Subsequent one-way ANOVA tests indicated that this overall difference was attributable to all ten measured traits. Mean values of the evaluated parameters and the results of the statistical tests are presented in Table 2.

Table 2. *Mean values of measured parameters for the six genotypes and results of comparison tests.*

Parameters	Minimum value	Maximum value	Mean ± Standard deviation	*F*	*p*
Ha	12,00	123,00	45,21 ± 19,15	6,463	< 0,001
NoFe	10,00	72,00	24,92 ± 10,66	2,308	0,002
NoEn	10,00	53,00	23,38 ± 6,81	4,421	< 0,001

Parameters	Minimum value	Maximum value	Mean ± Standard deviation	*F*	*p*
DiCo	1,2	43,00	20,26 ± 48,35	3,949	< 0,001
LoFe	3,60	44,30	16,83 ± 10,45	12,057	< 0,001
LaFe	4,50	123,40	20,79 ± 7,29	1,701	0,039
LoPe	2,00	48,00	21,73 ± 11,79	7,995	< 0,001
NoFo	3,40	59,00	15,99 ± 9,56	5,160	< 0,001
LoFo	2,3	39,6	7,91 ± 3,77	3,265	< 0,001
LaFo	0,8	16,7	6,31 ± 3,24	4,793	< 0,001

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; LaFe: Leaf width; LoPe: Petiole length; NoFo: Number of leaf tiers (nodes); LoFo: Leaflet length; LaFo: Leaflet width

3.1.1. Morphological Comparison of *Khaya Senegalensis* Genotypes

Following the multivariate analyses, individual traits were examined using one-way ANOVA to identify genotype-specific differences. Significant variation was observed among the six genotypes for all measured traits (p < 0.001). Genotype 6 consistently exhibited the highest values for plant height, number of leaves, number of internodes, and number of leaf tiers, indicating its superior growth performance. Genotypes 3 and 4 showed intermediate values for leaf length and leaflet dimensions, while Genotypes 1, 2, and 5 generally displayed lower values across most traits. Variations in collar diameter and petiole length were also evident, with Genotypes 1 and 5 showing the largest diameters and longest petioles. These results confirm substantial morphological variability among the six genotypes and highlight the potential for selecting superior genotypes for silvicultural improvement.

3.1.2. Correlation Analysis Among Traits

Table 3 presents the correlation matrix of the analyzed agromorphological traits. Trait interrelationships were also used to select variables included in the identification of principal components. Most correlation coefficients were below 0.7, indicating weak to moderate associations among traits. Only the trait pairs NoEn–Ha (0.83) and NoFo–LoFe (0.70) showed strong and significant positive correlations (≥ 0.7), indicating redundancy between these variables. In such cases, only one variable from each correlated pair was retained for subsequent analyses. Correlation coefficients below 0.7 were not considered.

Table 3. Correlation matrix.

Parameters	Ha	NoFe	NoEn	DiCo	LoFe	LaFe	LoPe	NoFo	LoFo	LaFo
Ha	1,00									
NoFe	0,5*	1,00								
NoEn	0,83**	0,61*	1,00							
DiCo	0,08	0,09	0,14	1,00						
LoFe	0,24	0,11	0,22	-0,04	1,00					
LaFe	0,03	0,01	0,02	0,05	0,09	1,00				
LoPe	-0,03	0,01	-0,01	0,09	-0,73*	0,18	1,00			
NoFo	0,43	0,24	0,42	-0,01	0,70**	-0,11	-0,53*	1,00		
LoFo	-0,13	-0,06	-0,16	-0,01	0,31	0,23	-0,18	0,20	1,00	
LaFo	0,17	0,10	0,22	0,06	-0,28	0,15	0,51*	-0,14	-0,43	1,00

* Significant but weak correlations

** Significant and strong positive correlations

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; LaFe: Leaf width; LoPe: Petiole length; NoFo: Number of leaf tiers (nodes); LoFo: Leaflet length; LaFo: Leaflet width

3.2. Structuring of Agromorphological Variability

3.2.1. Interpretation of the First Two PCA Axes

Examination of the factor loading matrix allowed the retention of the first two principal components, which together explained 81.55% of the total observed variability (Table 4). All ten traits contributed significantly to the formation of these two axes and were therefore considered relevant for explaining variability among the six *Khaya senegalensis* genotypes.

Table 4. *Eigenvalues and percentage of variance of the analyzed parameters on the first two principal axes.*

Principal Component	Axis 1	Axis 2
Eigenvalue	6.05	2.11
Total variance (%)	60.49	21.06
Cumulative variance (%)	60.49	81.55
Ha	0.88	-0.33
NoFe	0.95	0.001
NoEn	0.85	-0.21
DiCo	-0.11	0.84
LoFe	0.87	0.11
LaFe	-0.03	0.78
LoPe	-0.77	0.13
NoFo	0.95	-0.01
LoFo	0.62	0.76
LaFo	-0.99	-0.13

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; LaFe: Leaf width; LoPe: Petiole length; NoFo: Number of leaf tiers (nodes); LoFo: Leaflet length; LaFo: Leaflet width

Axis 1 accounted for 60.49% of the total variance and was defined by all measured traits. Petiole length (LoPe) and leaflet width (LaFo) were negatively correlated with Axis 1, whereas plant height (Ha), number of leaves (NoFe), number of internodes (NoEn), leaf length (LoFe), number of foliar tiers (NoFo), and leaflet length (LoFo) were positively correlated with this axis. Axis 2 explained 21.06% of the variability and was positively correlated with collar diameter (DiCo), leaf width (LaFe), and leaflet length (LoFo).

Genotypes located on the positive side of Axis 1 were characterized by taller seedlings with numerous and relatively wide leaves. Conversely, genotypes positioned on the negative side of Axis 1 exhibited seedlings with long petioles and wide leaflets. Genotypes positioned at the upper part of Axis 2 corresponded to seedlings with thicker stems and broader leaves (Figure 1).

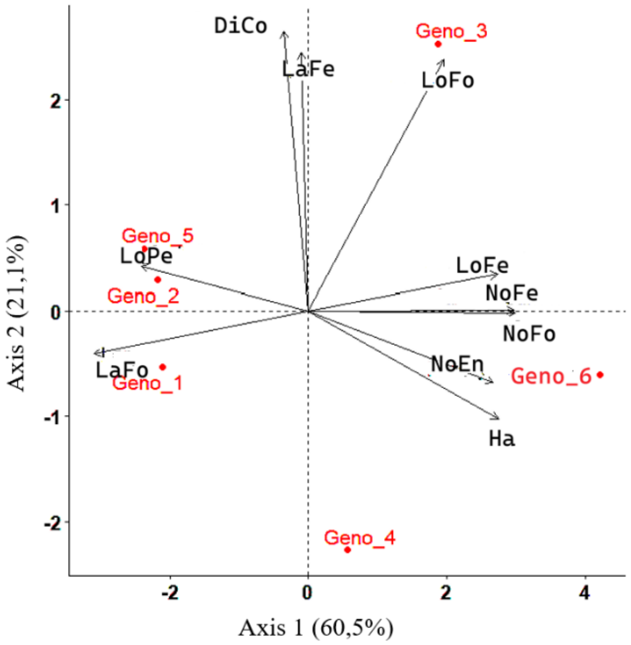

Figure 1. *Projection of the genotypes on the first two axes revealed by PCA.*

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; LaFe: Leaf width; LoPe: Petiole length; NoFo: Number of leaf tiers (nodes); LoFo: Leaflet length; LaFo: Leaflet width

3.2.2. Adjustment of Genotype Classification Using Hierarchical Cluster Analysis

In order to group genotypes into homogeneous clusters based on their morphological similarity, Hierarchical Cluster Analysis (HCA) was applied. The dendrogram obtained using the UPGMA method (Unweighted Pair-Group Method with Arithmetic Mean) revealed three main genotype groups (Figure 2). These groups became clearly distinguishable at a Euclidean distance of 20 units.

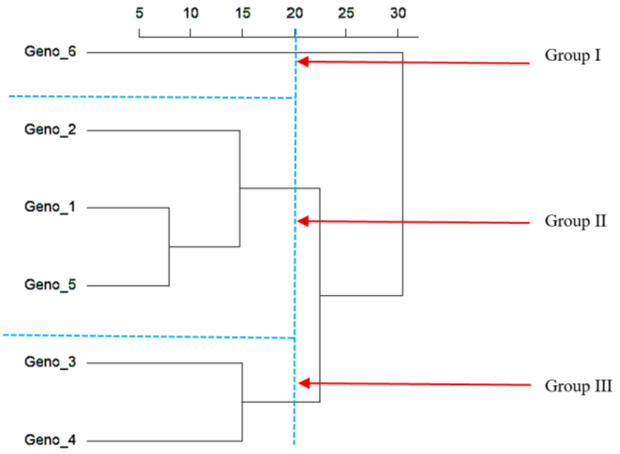

Figure 2. *UPGMA dendrogram showing the clustering of six Khaya senegalensis genotypes based on Euclidean distances.*

Geno_1: Genotype 1; Geno_2: Genotype 2; Geno_3: Genotype 3; Geno_4; Genotype 4; Geno_5: Genotype 5; Geno_6: Genotype 6.

Examination of the data indicated that the clusters differed based on seven of the analyzed traits (Table 5), which allowed partial discrimination among genotypes. The distribution of the six genotypes among the clusters is presented in Table 5 and can be summarized as follows:

1) Group I consisted of three genotypes (Genotypes 1, 2 and 5). Individuals in this group exhibited low plant height (38.34), a low number of leaf tiers (12.08), a low number of leaves (22.53), short leaf length (11.24), a moderate number of internodes (21.46), wide leaflets (7.33), and a large collar diameter (20.98).
2) Group II comprised two genotypes (Genotypes 3 and 4). Individuals in this group were characterized by moderate plant height (38.34), a moderate number of leaf tiers (18.59), a low number of leaves (25.48), long leaves (22.12), a moderate number of internodes (23.02), wide leaflets (5.67), and a large collar diameter (20.22).
3) Group III included a single genotype (Genotype 6). Individuals in this group were distinguished by greater plant height (64.62), a high number of leaf tiers (22.51), a high number of leaves (30.96), long leaves (23.00), a relatively high number of internodes (29.82), narrow leaflets (4.56), and a large collar diameter (18.19).

Table 5. *Main characteristics of the different groups formed by hierarchical cluster analysis.*

Traits Groups	**Ha**	**NoFo**	**NoFe**	**LoFe**	**NoEn**	**LaFo**	**DiCo**
Group I	38.34 ± 4.71^{b}	12.08 ± 2.39^{b}	22.53 ± 1.07^{b}	11.24 ± 3.80^{a}	21.46 ± 1.24^{b}	7.33 ± 0.09^{a}	20.98 ± 3.10^{a}
Group II	45.83 ± 2.98^{ab}	18.59 ± 2.09^{ab}	25.48 ± 1.24^{ab}	22.12 ± 2.62^{a}	23.02 ± 0.31^{b}	5.67 ± 0.73^{b}	20.22 ± 8.06^{a}
Group III	64.62 ± 22.82^{ab}	22.51 ± 12.58^{a}	30.95 ± 7.58^{a}	22.99 ± 9.95^{a}	29.82 ± 7.68^{a}	20.55 ± 4.84^{b}	18.19 ± 10.36^{a}
F	14.58	9.63	21.18	7.85	24.58	18.79	0.10
p	0.03	0.05	0.02	0.06	0.01	0.02	0.90

For each trait, values sharing the same letter are not significantly different.
Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; NoFo: Number of leaf tiers (nodes); LaFo: Leaflet width.

3.2.3. Selection of Discriminant Traits Using Discriminant Factor Analysis

Principal Component Analysis and Hierarchical Cluster Analysis (HCA) resulted in the identification of three diversity groups. Subsequently, Discriminant Factor Analysis (DFA) was applied to the seven selected variables in order to identify a subset of traits providing sufficient discriminatory power among the previously defined groups. Based on Wilks' lambda test, four traits were identified as the most discriminant descriptors (Table 6). Ranked in order of importance, these traits were:

(i) plant height
(ii) leaflet width
(iii) number of leaves
(iv) number of internodes

Table 6. *Discriminant analysis based on seven analyzed traits.*

Traits	***F***	***p***
Ha	14.58	0.028
LaFo	18.79	0.02
NoFe	21.17	0.02
NoEn	24.58	0.01

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; LaFo: Leaflet width.

3.2.4. Comparison of *Khaya senegalensis* Genotypes

Significant differences were observed among the six *K. senegalensis* genotypes for all measured parameters ($p < 0.001$) (Table 7).

Genotype 6 consistently exhibited superior growth performance, showing the highest values for plant height, number of fertile nodes, number of entered nodes, and number of flowers. In contrast, Genotype 2 generally recorded the lowest values for most growth traits. Collar diameter varied significantly among genotypes, with Genotypes 1 and 5 showing the largest diameters, whereas Genotypes 3 and 4 presented comparatively lower values. Leaf-related traits (leaf length, leaf width, petiole length, and foliar characteristics) also differed significantly. Genotypes 3 and 6 generally displayed higher leaf dimension values, while Genotypes 1 and 5 tended to show smaller measurements.

Overall, the results highlight substantial phenotypic variability among the evaluated genotypes, indicating important genetic differences in growth and morphological traits within *K. senegalensis*.

Table 7. Comparative analysis of Khaya senegalensis genotypes based on the measured growth and morphological parameters.

Parameters	Genotype 1	Genotype 2	Genotype 3	Genotype 4	Genotype 5	Genotype 6	*p*
Ha	42,96±13,94^{a}	33,54±10,81^{b}	43,72±13,08^{a}	47,93±19,05^{a}	38,5±16,59^{b}	64,62±22,82^{c}	< 0,001
NoFe	22,65±5,16^{bc}	21,4±4,55^{c}	26,36±20,41^{b}	24,6±8,24^{bc}	23,53±6,35^{bc}	30,95±7,58^{a}	< 0,001
NoEn	21,82±5,19^{a}	20,07±4,86^{b}	22,79±5,82^{a}	23,25±6,43^{a}	22,5±6,27^{a}	29,82±7,68^{c}	< 0,001
DiCo	22,22±5,66^{a}	17,44±8,24^{b}	13,56±5,55^{c}	14,52±10,71^{d}	23,26±6,34^{a}	18,19±10,36^{b}	< 0,001
LoFe	8,94±2,39^{a}	15,63±8,96^{b}	23,98±12,89^{c}	20,27±8,72^{d}	9,14±2,71^{a}	22,99±9,95^{c}	< 0,001
LaFe	8,94±2,39^{ab}	15,63±8,96^{c}	23,98±12,89^{c}	20,27±8,72^{a}	9,14±2,71^{cd}	22,99±9,95^{bd}	< 0,001
LoPe	31,93±7,54^{a}	22,67±10,94^{b}	16,64±10,98^{c}	13,64±9,27^{d}	29,14±6,95^{e}	16,37±11,24^{c}	< 0,001
NoFo	14,51±8,09^{ab}	11,99±4,91^{a}	20,06±9,32^{c}	17,11±8,02^{b}	9,73±5,9^{d}	22,5±12,58^{c}	< 0,001
LoFo	7,22±3,31^{c}	6,97±3,18^{c}	10,58±4,35^{a}	6,29±2,76^{c}	7,4±3,11^{c}	8,99±3,98^{b}	< 0,001
LaFo	18,32±7,57^{ab}	23,4±11,88^{c}	22,81±4,98^{c}	18,12±4,66^{a}	21,52±5,33^{cd}	20,55±4,84^{bd}	< 0,001

Ha: Height; NoFe: Number of leaves; NoEn: Number of internodes; DiCo: Collar diameter; LoFe: Leaf length; LaFe: Leaf width; LoPe: Petiole length; NoFo: Number of leaf tiers (nodes); LoFo: Leaflet length; LaFo: Leaflet width

4. Discussion

Understanding intra-specific variability is fundamental for the sustainable management and genetic improvement of tropical forest tree species. In the present study, progenies from six mother trees of *Khaya senegalensis* were evaluated under nursery conditions in Côte d'Ivoire to assess growth performance and morphological differentiation. The significant variation observed among genotypes across all measured traits confirms the presence of substantial phenotypic diversity, which likely reflects underlying genetic differentiation [13-16].

Morphological traits such as plant height, number of leaves, number of internodes, petiole length, leaflet width, and collar diameter proved effective in distinguishing among genotypes. These findings are consistent with studies demonstrating the relevance of agro-morphological descriptors in identifying phenotypic divergence within tree populations [17-19]. In forest tree species, early growth traits are often considered proxies for vigor and adaptive potential, particularly at the nursery stage where environmental variation is relatively controlled [20]. The observed differentiation therefore suggests the presence of exploitable genetic variation that could be harnessed in breeding or domestication programs.

Principal Component Analysis (PCA) revealed strong positive correlations among plant height, number of internodes, number of leaves, foliar tier number, and leaf length. This coordinated variation reflects the integrative nature of growth processes in woody species. According to functional growth theory, height increment in young trees is closely associated with photosynthetic capacity, which in turn depends on leaf area development and canopy architecture. Increased leaf number and size enhance light interception and carbon assimilation, thereby promoting apical growth [21]. The present results support this theoretical framework and suggest that these traits form a functional growth complex rather than acting independently.

Collar diameter also showed significant variation among genotypes and was positively associated with overall vigor. In forest trees, basal diameter is widely regarded as an indicator of structural robustness and biomass allocation strategies [22]. Reis et al. [23] demonstrated that increases in collar diameter in *Khaya senegalensis* are associated with enhanced height growth and crown expansion, whereas restricted diameter growth may favor mechanical stability through increased stem thickening. Such allometric relationships reflect resource allocation trade-offs, a central concept in plant ecological strategy theory. Our findings therefore suggest that genotypic differences in diameter may represent divergent growth strategies rather than mere size variation.

Cluster analysis further revealed a clear genetic structuring of the six genotypes into three distinct groups. Notably, Geno_6 formed a separate cluster, indicating marked divergence from the remaining genotypes. From a conservation genetics perspective, such divergence may reflect the presence of rare or unique alleles, making this genotype particularly valuable for maintaining evolutionary potential [20]. The existence of differentiated genetic pools within a relatively small sampling frame is consistent with patterns reported in other tropical tree species, where restricted gene flow, local adaptation, or historical demographic processes contribute to genetic structuring [18, 19].

The identification of genetically divergent genotypes has direct implications for silvicultural planning. Incorporating genetically distinct individuals into seed production systems can enhance adaptive capacity and reduce the risks associated with genetic uniformity. Given the ecological and economic importance of *K. senegalensis* [24], particularly for timber production and reforestation initiatives, preserving such diversity is critical for long-term sustainability.

Discriminant factor analysis indicated that only four traits (plant height, leaflet width, number of leaves, and number of internodes) significantly contributed to genotype differentiation. The fact that not all morphological traits were discriminant highlights the importance of identifying stable and heritable descriptors when assessing intra-specific variability [25]. While some studies have identified leaf number as the sole discriminating trait [17], our results suggest a more complex pattern of trait interaction. Differences between studies may reflect environmental modulation of phenotypic expression, as growth traits such as height and collar diameter are known to be sensitive to climatic and edaphic conditions [17, 18]. This aligns with the broader understanding that phenotypic variation in forest trees results from both genetic control and genotype–environment interactions [17, 18].

Importantly, the discriminant role of leaflet width and number of internodes suggests that these traits may be less environmentally plastic and more strongly genetically determined. Stable morphological traits are often reliable indicators of genetic differentiation, particularly when supported by molecular evidence [24]. Therefore, while agro-morphological analyses provide valuable preliminary insights, integrating molecular markers would allow more precise quantification of genetic structure and heritability.

The significant variability observed among the six *Khaya senegalensis* genotypes suggests the presence of substantial genetic diversity influencing growth and morphological performance [26, 27]. The superior performance of Genotype 6 across several growth parameters indicates a potentially higher adaptive capacity and vigor under the studied conditions [28, 29].

Similarly, the marked differences in leaf morphology and collar diameter among genotypes reflect variations in structural development that may influence photosynthetic efficiency and overall plant productivity [28, 30]. These findings provide a strong basis for further discussion regarding genotype selection, genetic improvement strategies, and the potential use of high-performing genotypes in breeding or reforestation programs [27, 29].

The observed phenotypic differences may also reflect genotype–environment interactions that warrant deeper investigation [26, 30].

Overall, the results demonstrate substantial intra-specific variability in *Khaya senegalensis*, with clear implications for conservation, domestication, and breeding strategies. From a silvicultural standpoint, early selection based on growth-related traits such as height, internode number, and leaflet width could enhance productivity in nursery and plantation systems. However, sustainable management should prioritize not only high-performing genotypes but also the preservation of genetically divergent individuals to maintain adaptive resilience under changing environmental conditions [13-16, 23, 25].

5. Conclusion

This study compared growth and development among six progenies of *Khaya senegalensis* in Côte d'Ivoire, identifying plant height, leaflet length, number of fertile nodes, and number of internodes as the most discriminant traits for genotype differentiation. Genotype 6 demonstrated superior growth and adaptability, making it a priority for reforestation, genetic improvement, and conservation initiatives.

These findings confirm the influence of progeny on individual performance and highlight the value of integrating molecular analyses, ecological assessments, and economic evaluations. Future research should therefore combine quantitative genetic approaches, multi-site trials, and molecular analyses to disentangle genetic effects from environmental influences and to estimate heritability and genetic gain. Such integrated strategies will be essential for developing evidence-based improvement programmes for *K. senegalensis* in West Africa, supporting the selection of well-adapted genotypes, promoting sustainable utilization, and enhancing both in situ and ex situ conservation to contribute to forest restoration and resilience.

Abbreviations

ANOVA	Analysis of Variance
CNRA	National Center for Agronomic Research (Centre National de Recherche Agronomique)

DFA	Discriminant Factor Analysis
DiCo	Collar Diameter
F	Fisher's Test Statistic
Ha	Height
HCA	Hierarchical Cluster Analysis
K. senegalensis	Khaya Senegalensis
LaFe	Leaf Width
LaFo	Leaflet Width
LSD	Least Significant Difference
LoFe	Leaf Length
LoFo	Leaflet Length
LoPe	Petiole Length
m	Meter
MANOVA	Multivariate Analysis of Variance
NoEn	Number of Internodes
NoFe	Number of Leaves
NoFo	Number of Leaf Tiers (Nodes)
p	P-value
PCA	Principal Component Analysis
UPGMA	Unweighted Pair-Group Method with Arithmetic Mean

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Conflicts of Interest

The authors declare no conflicts of interest.

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