Regeneration of forest treesresources in tropical zones : a (case of *Khaya sSenegalensis* (Desr.) A. Juss.)

ABSTRACT

Humans use the resources of tropical forests, which contain a wealth of biological diversity, for food, traditional and commercial purposes, including on an international scale. Some species have been exploited for timber production. The aim of this work was to identify the best part of the shoot for the regeneration of Khaya senegalensis in the two seeding sebstrates.The aim of this work is to contribute to the sound management of forest biodiversity in humid tropical Africa in general, and in Central West Côte d'Ivoire in particular, and to the socio-economic development of rural communities through the domestication, valorization and improved agricultural yield of these crops. The aim was to set up a management plan based on the regeneration of forest products, with Khaya senegalensis as the model plant. *Khaya senegalensis* is one of the medicinal and timber wood species on which sustained attention and priority actions must be focused. This is why the main objective of this study is to find out whether *K. senegalensis*, a plant with a high health value, can be regenerated by cuttings. The set-up consisted of 180 bags arranged in a random block of 90 bags for each of the seeding substrates (black soil and red soil). The results showed that aged cuttings had the best viability rates, i.e. 70% and 43.33% for the black earth and red earth substrates respectively. The best recovery percentage was observed for aged cuttings (36.66% and 20%). Of the three types of explants tested, the aged part of the stem proved better than the young, augered parts. In short, old stems and black soil provided the best conditions for the regeneration of *K. senegalensis* by cuttings. However, it would be interesting to improve the recovery rate and rooting of cuttings through the use of vegetative hormones.

Keywords : Khaya sénégalensis; Domestication; Cuttings; Forest biodiversity; Regeneration

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1. INTRODUCTION

Humans have always used the resources of tropical forests, which contain a wealth of biological diversity (Sosef et al.[1]), for food, traditional and commercial purposes, including on an international scale (De Wasseige et al.[2]). Some species have been exploited for timber production (Sawyer [3]). *Khaya senegalensis* falls into this category. However, overexploitation of the species has led to its inclusion on the International Union for Conservation of Nature's red list (Adjahossou et al.[4]) as a species facing a very high risk of extinction in the wild (IUCN [5]). This species produces one of the most prized woods on African continent. It has been marketed under the name Mahogany for around two centuries. *Khaya senegalensis* is one of the medicinal and timber species that require sustained attention and priority action on account of its socio-economic importance (Kantende et al. [6]). It is a multi-purpose species and one of the largest and most majestic trees in the Sudanian region (Eyog [7]). Various organs of the species are used for their medicinal properties (Kolawole et al.[8]). Indeed, *K. senegalensis* is a tropical evergreen tree whose organs are widely used in the treatment of several diseases (Sokpon & Ouinsavi [9], Nikiema & Pasternak [10]; Adomou et al.[11]). The leaf, bark, fruit and root have highly recognized medicinal, food and ornamental values. Oil from the seeds is used in African cooking. Leaves and bark are used to treat stomach ache, diarrhea and constipation. These organs also treat malaria. They are a remedy for jaundice and leprosy. It eliminates intestinal parasites, and is a plant with febrifuge, antibiotic and vermifuge therapeutic properties. In addition to its medicinal importance, its wood is also heavily exploited as timber and service wood, which poses threats to the survival of this species, as it faces abusive exploitation by the rural population (Daïnou et al.[12]). This results in forest degradation and loss of biodiversity. However, to remedy this situation, the domestication of this medicinal species with high therapeutic or nutritional value is worth considering. The general objective of this work is to regenerate *K. senegalensis* by cuttings. Specifically, the aim is to determine the best part of the stem to use as a cutting for good regeneration, and to determine the seeding substrate that conditions the best regeneration of the cuttings.

2. MATERIALS AND METHODS

2.1 Experimental site

The study took place in one of the experimental nurseries of the Université Jean Lorougnon Guédé located in the town of Daloa at 6°53 north latitude and 6°27 west longitude. The town is located in the Haut Sassandra Region in West-Central Côte d'Ivoire. It is around 141 km from Yamoussokro, the political capital, and around 400 Km from Abidjan, the economic capital (Diomandé et al. [13]). Daloa is bordered to the north by the town of Vavoua, to the south by Issia, to the west by Duekoue and to the east by Bouafle. The vegetation, which belongs to the mesophilic sector, is largely made up of dense forest, which has now disappeared to make way for various cash crops (Sangare et al.[14]). The soil is ferralitic and the climate is humid tropical, with one rainy season and two dry seasons (N'guessan et al.[15]). Dry and wet seasons alternate with temperatures ranging from 24.65°C to 27.75°C on average.

2.2 Plant material

The plant material used consists of *Khaya senegalensis* cuttings. These cuttings consist of three parts of the stem. The old part, which corresponds to the old wood directly connected to the root; the growing part, characterized by the part that generally bears the leaves; and the middle part, which corresponds to the intermediate zone between the old wood and the young part.

2.3 Methods

2.3.1 Taking and preparing cuttings

Cuttings were taken from stems with a diameter of between two and three centimetres. Each stem was subdivided into three parts (old, young and middle). A total of 30 cuttings of each type were taken, each 14 cm long.

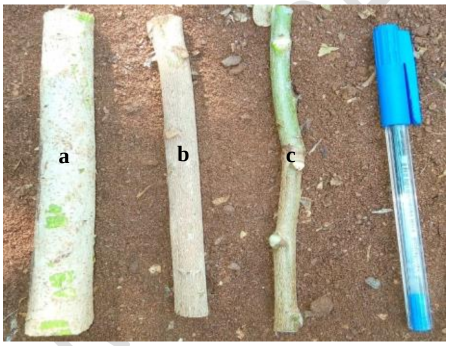

Fig1. Type of cuttings **a** .Older part ; **b** .Middle part ; **c** .Younger part

2.3.2 Seeding substrate

Two substrates commonly used for cuttings were tested. These were red soil taken from the Jean Lorougnon GUEDE University in Daloa, and black soil taken from a former garbage dump.

2.3.3 Experimental design

The trial was conducted in a greenhouse built from the branches of oil palms (Elaeis guineensis), with wires used to connect the branches and a transparent tarpaulin to cover the nursery. The dimensions of the greenhouse are 9.54 m long, 3.3 m wide and 2.9 m high. The set-up comprised 180 bags arranged in a block of 90 bags for each of the seeding substrates. The cuttings were planted at a depth of 5 cm in the substrate. Each substrate received a total of 90 cuttings, i.e. 30 cuttings of each type, including 30 old cuttings, 30 old cuttings and 30 young cuttings. The cuttings are watered every two days and hand weeding is carried out as soon as weeds appear in shaded areas.

2.3.4 Observed parameters

The parameters observed are bud break rate and time, bud height measured every week, bud neck diameter, regeneration and cuttings mortality rate. For this purpose, cuttings having developed a new leafy stem are counted at the end of the experiment, while the mortality rate concerns the proportion of dead cuttings no longer

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capable of developing buds. At the end of the experiment, the total number of each type of dead cuttings was determined according to the substrate. Observations lasted two months from April to June 2021.

2.3.5 Statistical analysis of data

The various parameters collected were subjected to statistical analysis. Two factors (substrates and cuttings) were subjected to an analysis of variance. When a difference was observed for a parameter tested for a given factor. The ANOVA was completed by the small significant difference test (SSDT). This test highlights the best parameter(s) tested. The data collected were analyzed using STATISTICA version 7.1 software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1Bud development and regeneration of cuttings

Cutting regeneration begins with bud formation. The bud formed develops over time into a leafy stem. In the greenhouse, we were able to follow this process. The bud forms on the 7th day after cultivation in the various substrates, and the first leaves of the young stem appear on the 13th day. The leafy stem evolves over time.

Fig2. Bud develoment, **a** : Formation of axillary buds, **b** : Developmment of petioles and appearance of the first leaves on the stem, c : Formation of leaves around the young stem

Table1. Multivariate analysis of significance using Wilk's test

	Test	Value	*F*	dl effect	*P*
ord.origin	Wilk	0.872	12.637	2	0.000
Substrates	Wilk	0.965	3.136	2	0.046
Cuttings	Wilk	0.844	7.594	4	0.000
Substrates*Cuttings	Wilk	0.940	2.701	4	0.031

Table 1 shows the results of the multivariate analysis of two factors studied: substrate (*P=0.046*) and cuttings used (*P<0.001*). This means that the results obtained are significantly influenced by the nature of the substrate and the type of cuttings used. Thus, in this work, results are presented according to substrate and type of cutting.

3.1.2 Mortality and viability of cuttings on different types of substrate

After 40 days' observation, T1 cuttings showed the best viability rates, at 70% and 43.33% respectively on black earth and red earth substrates. T2 cuttings recorded 16.67% and 10% viability in the black and red earth substrates respectively. T3 cuttings recorded 100% mortality, the lowest viability rate in both substrates. No young cuttings survived on either substrate. Finally, on the black earth substrate, the viability rate was 28.87%, compared with a mortality rate of 71.13%. On the red earth substrate, dead cuttings showed a viability rate of 17.7% versus a mortality rate of 82.30%. The red earth substrate thus recorded the highest mortality rate (Table 2~~1~~), while the black earth substrate recorded the highest viability rate.

Table 2. Viability and mortality rates of cuttings according to substrate type

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Substrate	Red earth			Black earth		
Type of cuttings	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Viability (%)	43.33	10	0	70	16.66	0
Mortality (%)	56.66	90	100	30	27	10
Overall viability (%)		17.7			28.887	

T1 Older part ; T2 Middle part ; T3 younger part

3.1.3 Regeneration of cuttings in different types of substrate

Regeneration rates varied in the two substrates ~~from one substrate to another~~. For the two substrates, red earth and black earth, the highest percentage of regeneration was observed in T1 cuttings (20% and 36.66%), followed by T2 cuttings (6.66% and 10%). As for T3 cuttings, we observed a total absence of regeneration (Table 3). Cuttings placed in black soil regenerated at a rate of 23.33%, compared with 13.33% in red soil. This suggests that black soil is a better substrate for regenerating cuttings than red soil.

Table 3. Regeneration rate of cuttings accorging to substrate

Substrates	Regeneration of cuttings		
	T1(%)	**T2(%)**	**T3(%)**
Red earth	20	6.67	0
Black earth	36.67	10	0

T1 : Older part ; T2 : Middle part ; T3 : younger part

3.1.4. Variation in mean stem length and collar diameter

Mean stem length at substrate level ranged from 9 cm (T2) to 19.667 (T1) cm and was significantly different at cuttings level. Neck diameters of cuttings ranged from 0.40 cm (T2) to 0.463 (T1) and were significantly different. No observations were made on T3 cuttings, which did not survive. The nature of the substrate had no influence on the length and diameter at the neck of the cuttings.

Table 4. Average stem length and average collar diameter as a function of substrate

	Stem lenght (cm)			Diameter at collar (cm)		
Cuttings	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Red Eaeth	19.667^{a}±1,461	9.00^{b}±2.53	0^{c}±0.00	0.45^{a}±0.063	0.40^{a}±0.11	0^{b}±0.00
Black Earth	12.272^{a}±1,079	10.333^{a}±2.066	0^{b}±0.00	0.463^{a}±0.046	0.40^{a}±0.089	0^{b}±0.00
F	33.047			0.334		
P	*P< 0.001*			*P< 0.001*		

T1 : Older part ; T2 : Middle part ; T3 : younger part

3.2 Discussion

The highest mortality rate and the lowest viability rate were observed in the red soil substrate, whereas black soil induced the lowest mortality rate and the highest viability rate. Indeed, red earth is a very clayey soil, with the capacity to retain water (Soro[16]). This capacity will lead to excess water. This massive humidity in the substrate will stimulate rotting of the cuttings. This would result in the death of the cuttings. In addition, red soil compacts easily, according to Soro [16], preventing roots from breathing. Thus, this process will lead to root suffocation, which could also promote the death of cuttings.

The high mortality observed in young cuttings could be explained by a loss of water or the infestation of a pathogenic disease in them. Separated from the mother plant, the cutting no longer receives water and mineral salts. For development and growth, the cutting must remain turgid throughout the process. Shortly after harvesting, cells damaged by cutting and handling, and neighbouring cells, dry out and die. A necrotic plaque forms, and the xylem conductor cells become clogged. This protects the wounds against desiccation and various pathogens. After a few days, the parenchymal cells form a scar-like periderm and root buds. This is called calogen (Hartmann et al.[17]). The green cuttings rapidly lose their turgidity, and the necrotic plaque cannot

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form. Cuttings undergo desiccation and are attacked by pathogens, which could explain the high mortality of cuttings in substrates.

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The regeneration of cuttings is not significantly influenced by substrate type, as the results indicate. However, it does influence the mortality rate of Khaya senegalensis cuttings, which have adapted to the physical, chemical and biological conditions of the black earth substrate. This result is in line with the work of Garbaye and Tacon [18] and Mapongmetsem et al. [19]. Indeed, these two authors have shown that black earth is a porous and light substrate. It has good water-holding capacity and at the same time facilitates good circulation of water and oxygen at the base of the cuttings.

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Green cuttings have a low regeneration rate. These have excellent cell division qualities, but fewer nutrient reserves. These portions of stem separated from the mother stem, no longer receiving reserves from elsewhere, dry out, causing the cuttings to die. These results are in line with the work of Traoré [20], who reported that the failure of young *Piliostigma reticulatum* shoots to take cuttings is due to the fact that they do not contain sufficient nutrient reserves to enable eventual emergence. In this work, the old stem of *Khaya senegalensis* was the best part for cuttings (Auneerudy and Pinglo [21]). Taking cuttings from the older part of the *K. senegalensis* stem gave satisfactory results, since by day 60 of the trial, some cuttings had produced root buds and others true roots for shoot survival and development. Thus, the regeneration of old cuttings took place over a long period. As a result, the ability of the cutting to regenerate increases from young to old stems. In fact, older cuttings are able to retain nutrients for bud formation and development over a long period. Embryonic cuttings, on the other hand, are subject to desiccation and death, according to Hartmann et al. [17]. Furthermore, the same authors revealed that higher ambient temperatures can lead to bud break before root initiation, and increase water loss through transpiration. This very often causes cuttings to dry out and die. Cuttings can also develop leafy stems, but without a root system. Similar results have been obtained with stem cuttings of *Guiera senegalensis* in Burkina Faso (Bationo [22]). This author reports that cuttings without a root system are kept alive by accumulated reserves, but gradually wither away as these reserves are depleted.

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In terms of growth parameters, the results showed that the nature of the substrate had no statistical influence on the development of growth parameters. These results corroborate those obtained in tThe work carried out by silué et al.[23]which showed that there was no significant difference in the growth of *Khaya senegalensis* seedlings tested in different soil types. However, analysis of the effect of the two substrates on the regeneration qualities of the cuttings revealed that the black earth substrate induced the best results for growth parameters in Khaya senegalensis. These results are similar to those of Silué et al. [23] and Onana [24], who observed better growth parameter values with *Khaya senegalensis* and *Pericopsis elata* respectively on typicalsubstrates. The experimental period and conditions in which the trials were carried out could also justify the overall results obtained.

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4. Conclusion

The main objective of this study was to determine the potential of *K. sénégalensis*, a plant with a high health value, to be regenerated by cuttings. Following experiments with different types of cuttings (old, mature and young) on different substrates (black earth and red earth), the results showed that the type of substrate did not influence the regeneration rate, but rather the mortality rate. Of the three types of explants tested, the aged part or old part proved to be the better part of the stem than the young and intermediate parts. Although there was no significant difference between the substrate and the growth parameters, the black soil showed the best conditions for viability and regeneration by cuttings of *K. senegalensis*. It would therefore be interesting to improve the regeneration rate and rooting of cuttings through the use of vegetative hormones. In addition, a genotype effect test could be carried out to propose in-vitro culture for recalcitrant genotypes.

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