Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com

Biodiversity

Approaches of Artificial Regeneration of *K. anthotheca (Welw.)* C.DC in the Forest Massif of the South-West of Central African Republic

Bruce Deguene[1, 3*], Gorgon Igor Touckia[1, 2], Olga Diane Yongo[2], Jean Joël Loumeto[3]

[1]Institut Supérieur de Développement Rural (ISDR), Université de Bangui, BP: 1053, M'Baïki, Central African Republic
[2]Laboratoire de Biodiversité Végétale et Fongique, Faculté des Sciences, Université de Bangui, BP 908, Central African Republic
[3]Laboratoire de Biodiversité, de Gestion des Ecosystèmes et de l'Environnement, Faculté des Sciences et Techniques, Université Marien Ngouabi, BP: 69, Brazzaville, Congo

DOI: 10.36347/sajb.2021.v09i11.006 | **Received:** 08.10.2021 | **Accepted:** 13.11.2021 | **Published:** 24.11.2021

***Corresponding author:** Bruce Deguene

Abstract **Original Research Article**

In southwestern Central African Republic, natural stands of *K. anthotheca* are difficult to regenerate due to numerous pressures related to industrial exploitation and ethnobotanical uses. In order to identify the best approach for artificial regeneration of this species, two reproduction methods (seed sowing and cuttings) were evaluated. In particular, the effects of seed pre-treatment on germination and seedling growth as well as the effect of the type of cuttings on bud recovery and seedling growth of *K. anthotheca* were tested. Repeated measures Analysis of Variance (ANNOVA) was performed using XLSAT 2008 software. From the results obtained, the control seeds of *K. anthotheca* were significantly more successful (64.44±7.33%) compared to the pre-treated seeds (F= 2.261 and p= 0.001). Seedlings from control seeds grew faster than from pre-treated seeds with a highly significant difference (F=10.690 and p=0.000). The wild type cuttings were more successful (55.33±7.39%) than the cuttings from the seeds (11.92±0.75%) with a highly significant difference (p=0.0001). All seedlings from basal cuttings died after budding. Overall, the control seeds of *K. anthotheca* had the highest success rate (64.44±7.33%) followed by the wild type cuttings (55.33±7.39%). Artificial regeneration of *K. anthotheca* could be done by sowing the seeds without pre-treatment and cutting the wildings. However, further investigations on the survival of seedlings in the field is needed to determine the most viable option for planting.

Keywords: CAR, forest massif, *K. anthotheca*, reproduction strategies, artificial regeneration.

INTRODUCTION

For decades, foresters, researchers and planners in different African countries in general and those of the Congo Basin in particular have been aware of the progressive reduction of natural populations of many timber-producing species that also have socio-economic interests for rural populations (Daïnou K *et al.*, 2021). To face this challenge, they have tested various methods of planting local tree species. These trials have sometimes been simply motivated by curiosity, or the desire to domesticate a tree deemed interesting in order to have it closer to home and to be able to cultivate it as one pleases, in quality as well as in quantity. At other times, the trials have been motivated by a real need to help prevent the rarefaction of a given species in its natural environment.

The planting of a tree species by the population and industrial forestry operators of many countries of the Congo Basin has most often been linked to their interest in it, but also and above all to the control of its biological cycle, the ease of obtaining positive results in relation to limited means. However, many people tend to think that planting trees from the dense forests of Africa sometimes leads to mixed or even mediocre results. This situation has led to the adoption and popularization of plantations of exotic species (*Tectonia grandis*, *Gmelina arborea*, *Eucalyptus spp.*, etc.) at the expense of local forest species (Daïnou K *et al.*, 2021).

Also, it should be added that natural regeneration of many forest species depends on the availability and viability of seeds, environmental soil conditions and the ability of some species to shoot, lay down or suckle (Kozlowski J et *al*, 2002). For multiple-use forest species such as *K. anthotheca*, which are subject to various pressures, natural regeneration alone cannot ensure their preservation in their natural state to meet the demands of a growing population for forest products and services. The vagaries of climate, anthropic pressures linked to numerous ethnobotanical uses as well as the loss of seeds and juveniles are the major barriers to the establishment of juveniles for natural regeneration (Guariguata M.R, 2000).

In southwestern Central African Republic too, natural stands of *K. anthotheca* are regenerating with difficulty due to numerous pressures related to industrial exploitation and ethnobotanical uses. Studies on the ethnobotanical uses of *K. anthotheca* and other rare species in southwestern CAR (Deguene B *et al.*, 2018) have shown, for example, that this species is under increasing pressure because of its food and pharmacopoeia properties. Similarly, the characterization of the natural population has shown the tendency for the regression of individuals of this species in the forest massif of the southwest (Deguene B *et al.*, 2020) of the country. This indicates that it is important to evaluate different breeding strategies that could help prevent the extinction of many species in Congo Basin forests in general and those of the Central African Republic in particular. Specially, it is necessary to explore the ways of artificial regeneration with a particular emphasis on the biology of reproduction, the response of the tree and the genotype to environmental pressures.

So far, to date, the approach most often used to prevent species extinction in its natural environment is the planting of seedlings as an alternative to assist and accelerate the natural regeneration process. In this regard, many studies have been carried out on the germination capacity of seeds and vegetative propagation (Zida D *et al.*, 2007; Ouedraogo A *et al.*, 2006; Zida D *et al.*, 2007b) and on the success rate of planting local species elsewhere in Africa and in the world.

However, in the Central African Republic, few studies have addressed the issue of artificial regeneration of local forest species in general and of *K. anthotheca* in particular notably as far as the different reproduction strategies of this species (sexual through seeds and asexual through cuttings or roots) are concerned, following the types of plant material and different treatments. In the current context where woody resources of economic interest are dwindling, the aim of silviculture is to provide for the socio-economic needs of the population by helping to create conducive conditions for the safeguarding of species of multiple value both in their natural and non-natural environment (Deguene B *et al.*, 2020; Daïnou K *et al.*, 2021). For *K. anthotheca* in CAR, research on artificial regeneration that can help decision-making in restoration programmes and conservation strategies for this species is of primary importance.

This justifies the current study, the objective of which is to contribute to the improvement of knowledge on the methods of artificial regeneration of *K. anthotheca* in the Central African Republic. Specifically, the study aims to: (i) estimate the germination performance of seeds and rooting of *K. anthotheca* cuttings in the nursery according to different types of treatment; and to (ii) evaluate the growth dynamics of *K. anthotheca* seedlings from seedlings and cuttings at the juvenile stage.

1. MATERIALS AND METHODS

1.1. Study site

Geographic location

The study was conducted in the commune of Pissa in the Prefecture of Lobaye in the southwest of CAR (Figure 1). Located about 70 Km from the capital Bangui, this commune extends more precisely between 4°03′ 12″ North latitude and 18°11′40″ East longitude for an area of 910.26 km2. It is home to part of the forest concessions of the IFB companies (PEA 165 and 186) and SCAD (PEA171). Agro-industrial oil palm plantations (Centrapalm in Bossongo and Palmex in Bogbaté) are also located in this commune. With an estimated population of 27,401 inhabitants in 2012, or a density of 30 inhabitants/km2, Pissa is one of the most densely populated communes in CAR. The landscape is a juxtaposition of agricultural areas, fallow land making up the village lands, savannahs but also areas of degraded forest, signs of the passage of logging.

Figure 1: Location of the study area (source: PDRSO, 2019)

Climate and rainfall

The climate of the commune of Pissa is characteristic of the subequatorial type. Rainfall varies between 1500 and 1800 mm per year with an annual thermal amplitude of 2°C. Rainfall is distributed over eight to nine months (March-November) with a short dry season of 2 to 3 months (Boulvert Y, 1986).

Relief, soil and hydrography

The municipality is located in a peneplain; it is therefore not very hilly. This monotony is broken in places by the presence of escarpments, hillocks and hills. The highest elevations are around 500 meters at the village Ndibakan. This peneplain, which slopes slightly to the south, favors poorly drained depressed areas with the existence of two marshy areas: Sangala to the north and Magouga to the south of Pissa. The geological formations in place are essentially ferralitic and kaolinite formations. These materials have been characterized by their low permeability, which determines the nature of the soil.

Two types of soil are found throughout the commune: ferralitic soil and hydro morph soil. The constitution of a ferralitic soil in a humid tropical zone results from the alteration of all the original minerals except quartz and the neoformation of kaolinite. These soils, of reddish color (the color of iron); occupy a good part of the commune. They are favourable for the cultivation of coffee, oil palm, banana, etc. The presence of kaolin does not allow the infiltration of rainwater, hence the formation of hydro morphic soils. These soils are generally poor. Benefiting from a sub-equatorial climate with abundant rainfall, the commune of Pissa has a dense hydrographic network (PDRSO, 2019).

Three rivers (the Léssé, the Mbéko and the Mboma) have a permanent regime while their numerous tributaries dry up in the dry season. The two large depressions have favoured the marshy areas of the Sangala and Magouga. These rivers are rich in fish and fishing activities are developed there. The waters contain a variety of fish species. We note the presence of clarias (Ngoro), tilapias (Kpakara), eels (Nzombo), etc. which are very numerous and highly prized by the population and travelers. We also note the presence of protected species such as hippos and crocodiles. This hydrographic network offers potential for rice and fish farming (Magbé A.S, 1990).

Vegetation

The commune of Pissa has a sub-equatorial climate with dense forest and open forest vegetation planted as result of human activities and savannah areas due to the nature of the hydro morph soil. The savannah is in the foreground near the village while the forest is in the background. In the forest, wood species such as *Pachiloba*, *Bubinga*, *Tali* and some rare *Bossé* are exploited by the IFB forestry company in PEA 186. The hydro morphic soil bears a shrubby savannah vegetation of the type with *Terminalia glauscens*, *Bridelia*, etc. The herbaceous stratum is based on *Imperata cylindricum* (Magbe A.S, 1990).

The trend in recent years related to advanced deforestation linked to illegal traditional cutting of shrub species for economic purposes. The vegetation represents a clear potentiality for the development of the commune (LERSA, 2016).

Wildlife

The destruction of the natural habitat of animals in some places has led to the disappearance of large game near human habitation. The various savannahs and the forest of the commune all shelter a diversified fauna composed of aquatic species (*crocodiles*, *turtles*, *monitor lizards*, *fishes*...), arboreal species (monkeys), mammals, birds and insects.

It turns out that despite the regulation of hunting in the locality, poaching represents a serious threat to the survival of wildlife. Indeed, the proliferation of hunting weapons (especially home-made) and ammunition supplied by traders has led to a scarcity of game in the immediate vicinity of the villages. Certain species such as elephants and buffaloes are on the verge of extinction in the commune (PDRSO, 2019).

1.2 Experimental design, data collection and analysis

Germination and growth test of K. anthotheca

Seeds were collected in two forest concessions (i.e., PEA 186 of the IFB and PEA 192 of the CentraBois Company) following the distribution of *K. anthotheca* in these areas. The term provenance denotes the geographical origin from which the seeds were collected. The batches are noted according to the date of collection, the order number, the name of the commune and the official number of the forest concession. Trees with a clean bole, a well-developed crown and abundant mature and dry fruit were selected and favoured for seed collection.

The germination test was carried out in anursery at the Pissa site. The seeds of *K. anthotheca* were first subjected to three different types of treatments before sowing, namely:

i. First batch (G0): without pre-treatment ;
ii. Second batch (G1): soaked in ordinary water for one day (24 h);
iii. Third batch (G2): soaked in hot water until cool.

The substrate is made up of forest soil from the site filled in 8 cm wide and 15 cm long polythene bags.

The objective of the work is to test the effect of pre-treatment on the germination of *K. anthotheca* through a Fisher randomized block design (Figure 2). This set-up consists of three treatments arranged in a block and repeated twice. Thirsty (30) seeds per treatment type and per replication (n = 90 for the three replications per treatment type) were sown. The experimental units were then placed under shade to reduce evaporation.

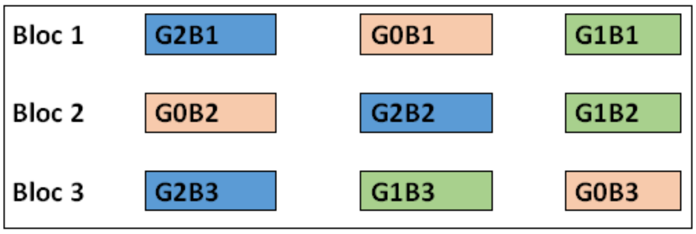

Figure 2: Experimental set-up for germination and growth testing of *K. anthotheca*

With B1 = block 1; B2 = block 2 and B3 = block 3

Cutting test of K. anthotheca

The effect of types of cuttings (seedlings and wildings) was also tested without pre-treatment. The first type (B1) is composed of cuttings taken from the lower branches of adult trees (seed trees) in good health. These are basal or proximal cuttings of about 12 to 15 mm in diameter and 25 to 30 cm in length. The second type of cuttings (B2) come from young wildings that have reached at least 1.30 m in height and cut at about 20 cm above the crown. The cuttings from the wildings are also cut into 25-30 cm segments. Both types of primed cuttings were kept in a humid place to ensure protection from heat. They were sown obliquely on boards (substrate) consisting of the forest soil from the experiment site. To avoid early rotting of the cuttings, the aerial end of each one is cut at an angle and protected by a plastic sheet to prevent rainwater or watering from infiltrating the tissue.

The set up for the cutting test is also Fisher's Complete Random Block (Figure 3) with only one factor namely the type of cuttings and 3 replications as follows:

- For basal cuttings (B1): 30 cuttings x 3 replicates (90 cuttings);
- For cuttings from wildings (B2): 30 cuttings x 3 replicates (i.e. 90 cuttings).

The system in place is shown in the diagram below:

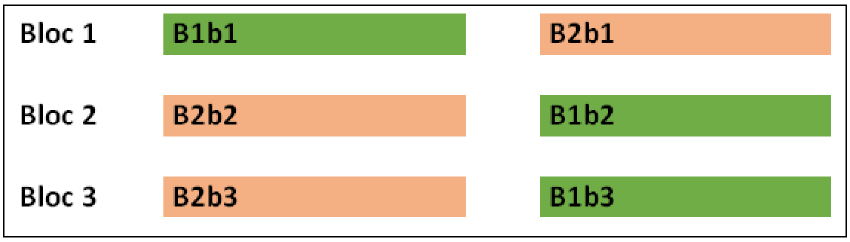

Figure 3: Experimental device for testing cuttings of *K. anthotheca*
Where b1 = block 1; b2 = block 2 and b3 = block 3

Data collection

During the experiment, data was collected in the following way:

(i) As for the germination test, the number of germinated seeds is noted every two days during one month, i.e. a total of 15 measurements;
(ii) For the cutting test, the number of budded stems was also noted every two (2) days for one month, i.e. 15 measurements.
(iii) For growth monitoring, the height was measured with a tape measure each week and the number of leaves of 10 seedlings per sub-plot from cuttings or germination of K. anthotheca seeds was noted each week for three (03) months, i.e. twelve (12) repeated measurements in total.

Data processing and analysis

The data collected made it possible to determine the average germination rate according to the types of pretreatment. This rate represents the germination power, i.e. the average percentage of seeds that germinated after semi (Daïnou and *al.*, 2021). Following the same approach, the average rate of bud recovery in the case of cuttings test was also determined. Repeated measurements were also used to establish germination and bud recovery curves over a one-month period.

Analyses of variance (ANOVA) was performed using XLSTAT 2019.4.2.63677 with a significance level of 5%. This allowed us to determine the effect of the pretreatments on seed germination and the effect of the cutting type on the rate of bud recovery on the one hand, and to compare the seed germination rates with the bud recovery rates on the other hand.

Furthermore, the effect of pretreatments on the growth of seedlings, and the effect of the cutting type on the growth of shoots from stem cuttings, as well as the growth performance of seedlings from seeds and shoots from cuttings on the same types of substrate were subjected to an analysis of variance (ANOVA) using XLSTAT2019.4.2.63677 software at the threshold of 5% also. The repeated measures analysis of variance model was used, the repeated measures factor being the time factor with twelve levels corresponding to the twelve growth measurement dates (heights and number of leaves).

2. RESULTS

2.1 Germination test

Effect of pre-treatments on seed germination of K. anthotheca

The figure below shows the results of germination tests of *K. anthotheca* seeds following different pre-treatments.

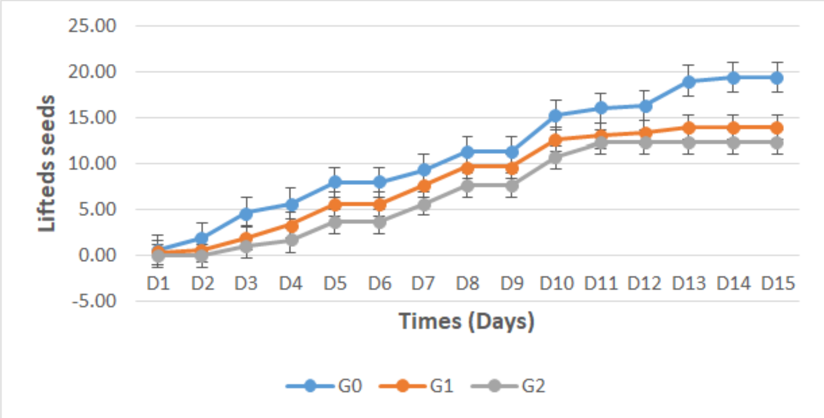

Figure 4: Variation in germination of *K. anthotheca* seeds over time as a function of pretreatment

For the different pre-treatments, the number of seeds that emerged varied between 10 and 29 days after sowing. The first seeds germinated 10 days after sowing. Throughout the test the seeds not having undergone pretreatment presented results higher than the pretreated seeds with a very significant difference (F= 2,261 and p= 0,001). They were followed by the seeds soaked in simple water and in last, those soaked in boiling water. This makes it possible to affirm that pretreatment slows down the speed of rise of seeds.

Average germination rate

The table below shows the average germination rate according to the type of pre-treatment.

Table 1: Average germination rate (%) of *K. anthotheca* seeds following different pre-treatments

Pretreatments	G0	G1	G2	Moyenne
Averages (%)	64,44±7,33	46,67 ±6,67	41,11±12,22	50,74±8,74

The germination rate is less than 50% for seeds soaked in room temperature water and hot water while it reaches 60% for untreated seeds. However, the average reaches 50% for the three types of *K. anthotheca* seeds.

Growth in height of K. anthotheca plants

As with emergence, the growth rate of seedlings in height of *K. anthotheca* seeds varies progressively between 34 and 105 days (Figure 5).

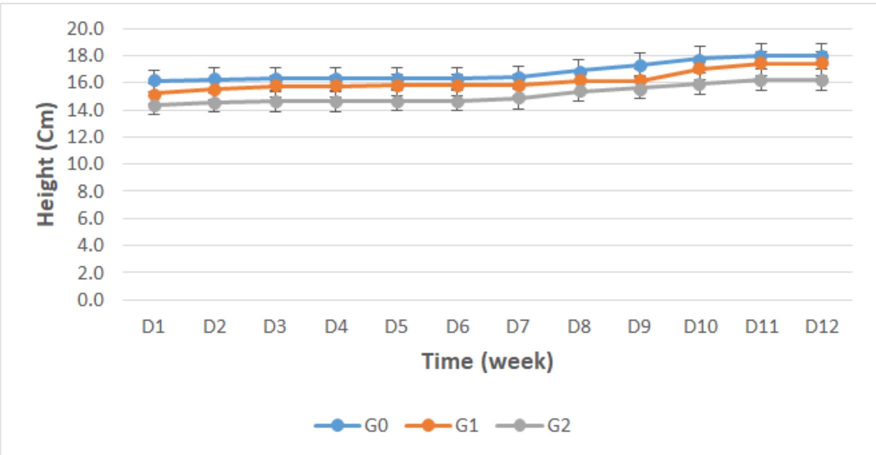

Figure 5: Growth in height of seedlings from three types of *K. anthotheca* seeds

In contrast to emergence, the growth rate of seedlings in height was significantly influenced by the type of pre-treatment (F=10.690 and p=0.000). Seedlings from seeds that did not undergo any pre-treatment (control) grew faster than those soaked in water at room temperature or boiling. Similarly, seedlings from seeds soaked in cold water grew even faster than from seeds soaked in boiling water.

Growth in number of leaves of K. anthotheca plants

Depending on the type of pre-treatment, the growth in number of *K. anthotheca* leaves varies with time (Figure 6).

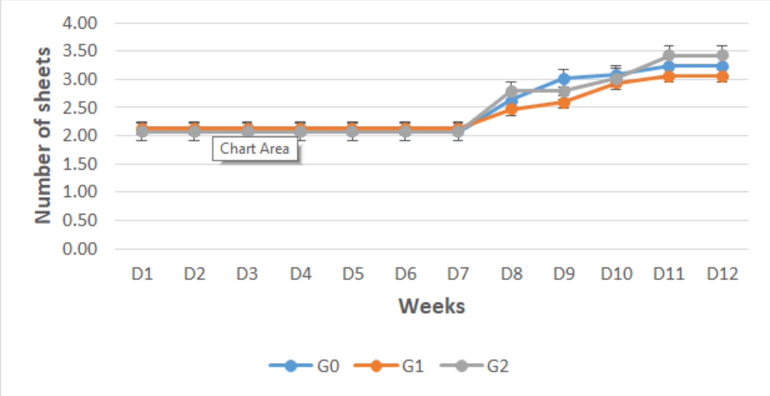

Figure 6: Growth in number of leaves of seedlings from three types of *K. anthotheca* seeds

Between 34 and 75 days, the growth in number of leaves was similar and did not vary significantly (2-3 leaves) regardless of the type of pre-treatment (F=0.072 and p= 0.931). Beyond this period, a very significant variation in the number of leaves is noted according to the type of pre-treatment (F=16.88 and p= 0.0001). In particular, it was noted towards the end of the test that the seedlings resulting from seeds soaked in boiling water present the values of growth in number of leaves highest, followed by the seedlings resulting from not pretreated seeds and in last position the seedlings resulting from seeds soaked in simple water. These results show that the type of pre-treatment has an influence on the growth rate of *K. anthotheca* plants at the juvenile stage. However, the differences observed are not very significant and it is difficult to draw conclusions at this stage.

2.2 Cutting test

Effect of the type of cutting on the recovery of the buds in 30 days

Cuttings from wildings (B2) are clearly more successful than from basal branches of seedlings (B1) with a very significant difference (F=62.072 and p=0.0001).

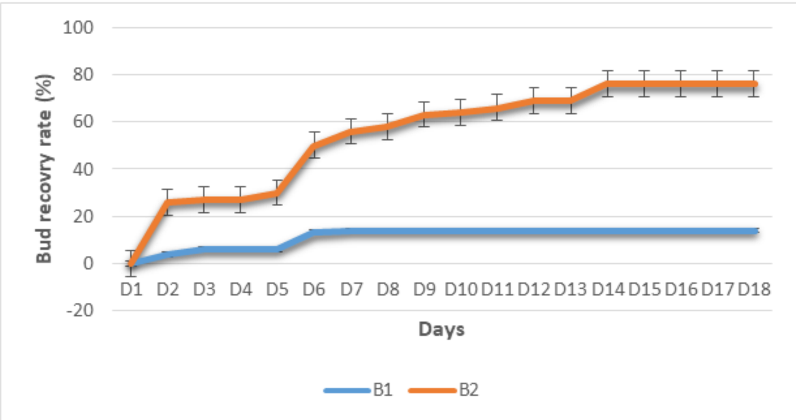

Figure 7: Variation in bud recovery over time according to the type of *K. anthotheca* cuttings

When they restart growth, budding begins thirteen days after planting regardless of the type of cutting. For cuttings from basal branches, the maximum level of budding is reached at day 37 (D5) with a rate of 14% while those from wildings reached the maximum level at day 60 (D13) with a rate of 76%.

Even though the waiting time for the first bud recovery is similar for both types of cuttings (13th day), it is however more intense for the cuttings from wildings (8 on average) and slower for the basal cuttings (1 on average). Automatically, after having reached the maximum value, we observe a flat curve that marks the end of the bud recovery process according to the different types of cuttings.

Bud recovery rate

As indicated above, cuttings from wildings are more successful as shown in Table 2 below.

Table 2: Success rates of the two types of *K. anthotheca* cuttings

Types of cuttings	B1	B2	Average
Averages (%)	11,92±0,75	55,33±7,39	33,62±4,07

The repeated measures analysis of variance performed on the rate of bud regrowth indicated that the types of cuttings have a highly significant effect on the rate of bud regrowth of *K. anthotheca* (Table 3).

Table 3: Results of the analysis of variance of the *K. anthotheca* cutting test

Source	DDL	SC	MC	F	Pr > F
Model	1	3815,511	3815,511	126,143	**< 0,0001**
Error	88	2661,778	30,247		
Corrected total	89	6477,289			

DDL: Degree of freedom; SC: Sum of squares; MC: Mean of squares; F: Fischer statistic and Pr: Probability.

Growth in height of plants from different types of cuttings

The seedlings from the wild-type cuttings showed the best growth rate in height (Figure 8) after budding until three months later. In contrast, all the seedlings taken from seedling branches experienced total mortality (100%) a few weeks after budding.

The results of the analyses of variance performed on the height growth dynamics and number of leaves of *K. anthotheca* seedlings showed that the types of cuttings had a highly significant effect on the height of *K. anthotheca* seedlings (F= 63.968 and p= 0.0001).

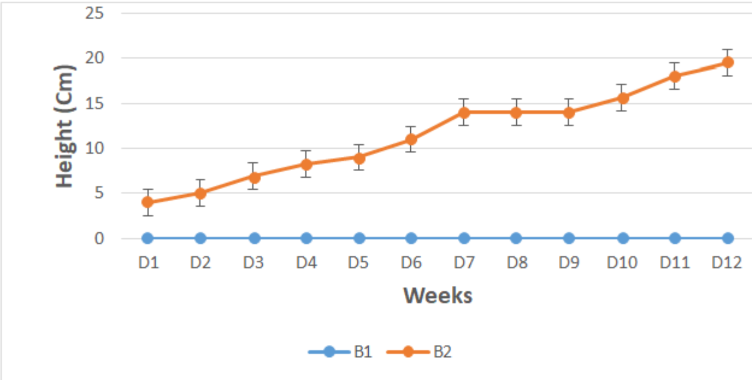

Figure 8: Variation in height growth over time of seedlings from two types of *K. anthotheca* cuttings

The shoots from the cuttings of the wildings have an average height of 11.6 cm while the average number of leaves is 6.6 in three (3) months of follow-up. After a phase of continuous increase in the height of the seedlings, a phase of stagnation of the growth noted towards the end of the second month and which spreads out for over two weeks.

After this period, the growth resumes its course. This observation is the same for the growth in number of leaves of *K. anthotheca* shoots coming from wild cuttings.

Growth in number of leaves of plants from K. anthotheca cuttings

The number of leaves increases continuously and rapidly from the first to the seventh week after bud resumes growth and then stabilizes for a period of two weeks. The analysis of variance clearly shows that the growth rate in number of leaves varies very significantly according to the type of cutting (F= 74.576 and p=0.0001).

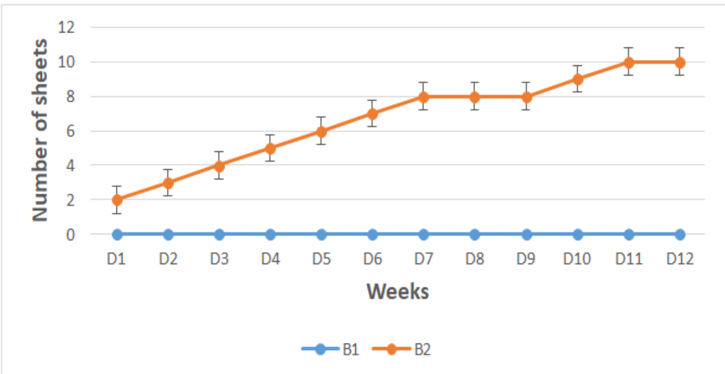

Figure 9: variation over time in the number of leaves of seedlings from two types of cuttings of *K. anthotheca*

The first leaves (two to three) appear on the first branch blanks nineteen (19) days after cutting (Figure 9). Overall, budding is at its peak and the first leaves appear between one and three months. This corresponds to the full rainy season in the southwestern forest zone (July to September). After that (September-October), growth stagnates.

Comparison of seed germination rates to bud recovery rates

Figure 10 compares the five types of plant material, including germination rates of pre-treated seeds to bud recovery rates of cuttings.

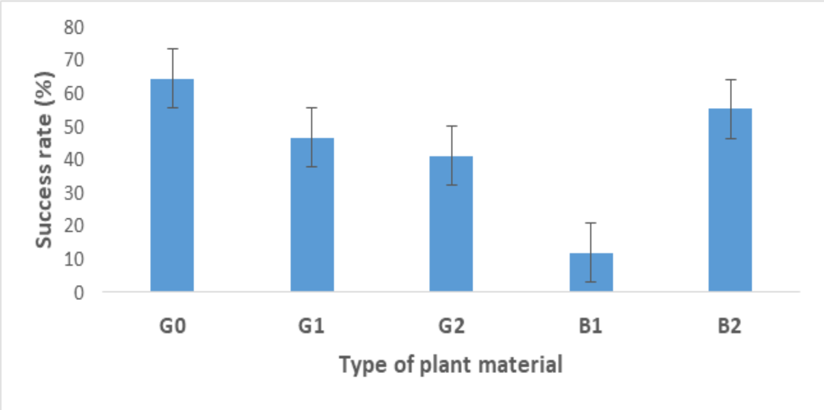

Figure 10: Comparison of seed emergence and budding rates of *K. anthotheca*

The success rate varied significantly with the type of plant material used (F= 51.840 and p= 0.0001). Unsoaked *K. anthotheca* seeds had the highest success rates (64.44±7.33%). They were followed by the cuttings from wild type (55.33±7.39%). Seeds soaked in plain water had success rates (46.67±6.67%) which were not significantly different from that of seeds soaked in boiling water (41.11±12.22%). Finally, cuttings from basal bases had the lowest recovery rates (11.92±0.75%).

Height growth of seedlings from seeds and cuttings of K. anthotheca

Figure 11 compares the growth of seedlings from seeds with the growth of young shoots from the buds of basal cuttings and wildings.

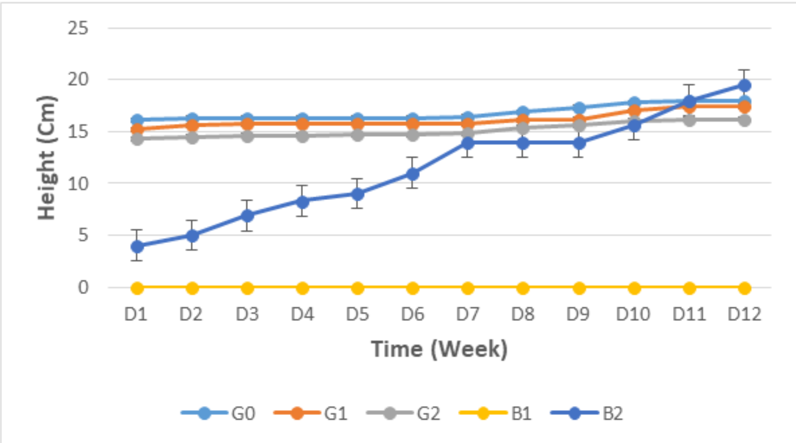

Figure 11: Growth in height of plants according to type of plant material

G0= non-pretreated seeds; G1= seeds soaked in plain water; G2= seeds soaked in boiling water until cooled; B1: cuttings from basal branches; B2: cuttings from wildings of *K. anthotheca*.

Between 30 and 75 days, shoots from cuttings showed lower heights than those from seed regardless of the type of pretreatment. After this period, this difference was reduced and from 100 days, the shoots from wildings show relatively higher heights than those from seedlings regardless of the type of pre-treatment. The results of the analysis of variance show that there is a highly significant difference between the type of plant material and the height growth of seedlings from either seed or budding (F= 105.957 and p= 0.0001).

Growth in number of leaves of shoots from seeds and cuttings

Figure 12 shows the growth in number of leaves of seedlings from seeds and shoots from buds of wild-type cuttings (all plants from basal cuttings having died).

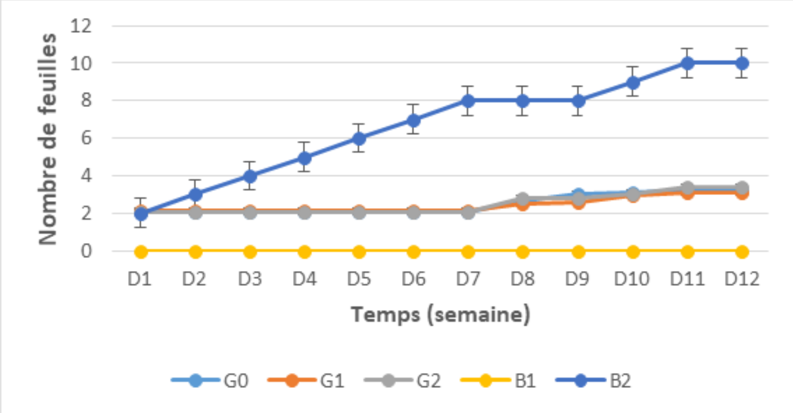

Figure 12: Growth in number of leaves of plants according to the type of plant material

Between 35 and 75 days, the number of leaves of the shoots from wildings cuttings increases steadily with success rates far above those of the shoots from seeds whose number of leaves hardly varies. After 75 days, the growth in number of leaves of the plants from wildings stagnates for a period of two weeks, while the shoots from seeds increase progressively over the same period. After 90 days, the growth in number of leaves resumed for the plants from wildings cuttings and also continued for the shoots from seeds with very significant differences between these two types of plant material (F=43.971 and p= 0.0001). From 105 days, the beginning of stagnation in the growth in number of leaves of the plants is noted resulting from the cuttings of wildlings whereas that of the shoots resulting from seeds continues.

3. DISCUSSION

In the present study, the modes of sexual reproduction by seed sowing and asexual reproduction by cuttings were tested for artificial regeneration of *K. anthotheca*. The results showed that the seeds of *K. anthotheca* have good germination ability. They do not require any special pre-treatment. The pre-treatment methods tested probably induced losses in seed viability, with varying effects depending on the method. The soaking in boiling water until cooling is the method, which affects the most the viability of seeds with losses of about 20 % compared to the not pre-treated seeds. The pretreatment by soaking in simple water during 24 hours also affects the viability of seeds but with losses of about 15% compared to the not pretreated seeds. The non-treatment of seeds made it possible to obtain a suitable germination rate (60% and more). Some authors state that germination rates of fresh healthy seeds are around 85%, but it decreases rapidly under natural conditions (Mensbruge G, 1966; Mittal R.K *et al.*, 2003). The average germinability of *K. anthotheca* seeds in this study is fair (average germination rate of about 50%) whereas Daïnou K *et al.* (2021) classified this species among the species with a good germinability (between 67-100%). Seed storage conditions, pre-treatments (Mapongmetsem P.M et *al.*, 1999; Rao N.K *et al*., 2006; Gonmadje C.F *et al.*, 2012) and nursery work could explain the results obtained in the present study.

As for germination, seedlings from the different types show relatively low growth rates in height during the first months even if there is a decreasing gradient from unsoaked seeds to seeds soaked in simple or boiling water. Seedlings from seeds soaked in boiling water had a lower height growth although the differences observed seem less significant. These results seem to show that pre-treatments are not needed to stimulate height growth. These possible effects of pretreatment on seedling height growth suggest that pretreatment may negatively influence seedling utilization of seed reserves due to their high fat content. Many authors (Guariguata M.R, 2000; Baraloto C *et al.*, 2005; Bouka D *et al.*, 2019) have also pointed out that the growth of *K. anthotheca* seedlings is slower during the first months which supports the results obtained in the present study. Indeed, the growth and vigour of seedlings depend on the availability of nutrient reserves that the seeds contain (Jaenicke H, 2006; Wightman K.E, 2006; Houehounha R, 2009). Thus, for example, larger or heavier seeds generally generate more vigorous seedlings that grow and are more resistant to environmental hazards (Baraloto C *et al.*, 2005; Bladé C *et al.*, 2008; Du and Huang, 2008; Houehounha R, 2009). Regarding the growth in number of leaves, the results showed on the other hand that seedlings from seeds soaked in boiling water performed better towards the end of the test followed by untreated seeds and those soaked in simple water.

K. anthotheca also reproduces by cuttings (asexual reproduction). The results of the cutting test (artificial vegetative propagation), showed that cuttings from basal and proximal branches of seed trees are unsuitable for reproducing *K. anthotheca*. Shoots from these types of cuttings were not viable as they degenerated very rapidly within 45 days. In contrast, cuttings from wild-type stems survived with success rates of about 55% and consistent growth of young shoots up to eight months after the start of the experiment. In trials in Indonesia, vegetative propagation by cuttings was successfully achieved with a 75% rooting success rate when growth hormone was applied (Dupuy B *et al.*, 1993). This indicates that the results obtained in the present work (without the application of a growth hormone) are very appreciable (Daïnou K *et al.*, 2021; Bellefontaine R, 2005). For the cuttings from the seedlings, it seems that they could not develop roots for their survival, which explains why after a month and a half, all the shoots had degenerated (even if rooting was not directly observed). In contrast, the wild-type cuttings probably developed a good root system, which would explain the survival and growth of the shoots over eight months.

Comparison of seed propagation and propagation by stem cuttings (wildings and seedlings) in terms of success rates suggests that the success rate of non-pretreated seeds is much higher than the success rate of wildings cuttings, which in turn is also higher than the success rate of seeds pretreated with simple or boiling water. Basal cuttings had the lowest success rates. From a growth point of view, shoots from wildings grow much faster than all types of seeds, whether pre-treated or not. All shoots from the re-budding of basal cuttings degenerate.

CONCLUSION

This study has shown that it is possible to preserve *K. anthotheca* in the Southwestern forest massif through artificial regeneration. This can done through sexual multiplication through seeds and through vegetative multiplication through cuttings. The seeds of *K. anthotheca* do not present dormancy problems and the species can be reproduced artificially by sowing mature seeds without prior treatment. For vegetative propagation, encouraging results can be obtained when using cuttings from the stems of wildings. Cuttings ensure rapid development of the vegetative organs, especially the stem, whose bark has been prized by communities for its medicinal properties. Seedlings also have the advantage of a better germination rate. Moreover, the study also showed that, the germinative pre-treatment of seeds, although having a harmful effect on germination, could well stimulate the growth of seedlings. However, it is necessary to investigate this last aspect and the survival of seedlings from each type of plant material in the natural environment and in the face of various hazards in order to choose the most viable option for enrichment or plantation installation programmes.

ACKNOWLEDGEMENTS

The authors would like to thank all those who contributed to the successful completion of this study. Special thanks go to the officials of the Pissa Town Council who allowed this research to conduct at their nursery site. Thanks also to the anonymous readers who gave their valuable time to proofread and help in the translation of this manuscript.

REFERENCES

- Baraloto, C., Goldberg, D. E., & Bonal, D. (2005). Performance tradeoffs among tropical seedlings in contrasting microhabitats. *Ecology*, 86(9), 2461-2472, DOI: 10.1890/04-1956
- Bellefontaine, R. (2005). For many woody plants, sexual reproduction is not the only way: analysis of 875 cases. Introductory text, table and bibliography. Drought 16 (4): 315-317.
- Bellefontaine, R., Petit S., Pain-Orcet, M., Deleporte, P., & Bertault, J. G. (2001). Trees outside the forest. Vers une meilleure prise en compte. FAO Conservation Paper 35. 231 p. Available at http://www.fao.org/docrep/005/Y2328f/y2328fOO. htm#toc .
- Blade, C., & Vallejo, V. R. (2008). Seed mass effects on performance of Pinus halepensis Mill. Seedlings sown after fire. *For Ecol Manag*, 225, 2362-2372.
- Bouka, Dipelet U. G., Doumenge, C., Loumeto, J. J., Florence, J., Gonmadje, C., & McKey, D. (2019). Species confusions detrimental to the sustainable management of forest tree species: the example of African mahogany (Khaya, Meliaceae). *Tropical Woods and Forests*, 339, 17-32. DOI: https://doi.org/10.19182/bft2019.339.a31714 .
- Boulvert, Y. (1986). Carte phytogéographique de la République Centrafricaine à 1/1000000. ORSTOM, Ministère de la Recherche Scientifique et de la Technologie. Explanatory note n°143-Paris.
- Daïnou, K., Tosso, F., Bracke, C., Bourland, N., Forni, É., Hubert, D., Kankolongo, A. M., Loumeto, J. J., Louppe, D., NGomanda, A., NGomin, A., Tchuante, T. V., & Doucet, J. L. (2021). Practical guide to tree plantations in the dense humid forests of Africa. Agronomie Gembloux, Presses Universitaires de Liège, 322p.
- Deguene, B., Touckia, G.I., Semboli, O., & Loumeto, J. J. (2018). Analysis of ethnobotanical uses of rare tree species in forest concessions in southwestern Central African Republic, Life, Earth and Agronomy Science REV. RAMRES - VOL.06 NUM.02. 2018 ** ISSN 2424-7235;
- Deguene, B., Touckia, G. I., Yongo, O. D., & Loumeto, J. J. (2020). Structural characterization of natural stands of khaya anthotheca (Welw.) C.DC in forest concessions in southwestern Central African Republic, *International Journal of Biological and Chemical Sciences*, 14(7), 2491-2505. DOI: https://dx.doi.org/10.4314/ijbcs.v14i7.10
- Du, Y., & Huang, Z. (2008). Effects of seed mass and emergence time on seedling performance in Castanopsis chinensis. *For Ecol Manag*, 255, 2485-2501.
- Dupuy, B. & M'Bla, K. (1993). African mahogany plantations: their silviculture in the Ivorian dense rainforest. Bois et Forêts des Tropiques 236: 25-42.
- Guariguata, M. R. (2000). Seed and seedling ecology of tree species in neotropical secondary

forests: management implications. Ecological Applications, 10(1), by the Ecological Society of America pp. 145-154.
- Gonmadje, C. F., Doumenge, C., & Sunderland, D. (2012). Phytogeographic analysis of Central African forests: the case of the Ngovayang Massif, Cameroon. *Plant Ecology and Evolution*, 145, 152-164.
- Houehounha, R. (2009). Analysis of the ecological and socio-cultural impacts of the exploitation of Daniellia oliveri products on the viability of its stands in Benin. PhD thesis, University of Abomey-Calavi, Benin, 120p.
- Jaenicke, H. (2006). Good Forest Nursery Growing Practices - Practical Guidelines for Research Nurseries. ICRAF Technical Manual 3, Majestic Printing Works, Nairobi, Kenya.
- Kozłowski, J., & Gawelczyk, A. T. (2002). Why species' body size distributions usually skewed to the right? British Ecological Society, 42 Wharf Road, London, N1 7GS, https://doi.org/10.1046/j.1365-2435.2002.00646.x
- LERSA. (2016). Diagnostic des communes forestières de la Lobaye et de la Sangha Mbaéré en République Centrafricaine, Université de Bangui, 169 pages.
- PDRSO. (2019). Local development plan for the commune of Pissa, Lobaye, CAR, 119 pages.
- Magbé, A. S. (1990). La monographie de Pissa. Master's thesis in geography, University of Bangui, 229 pages.
- Makana, J. R. (2004). Fellowship report: How to improve the regeneration of African mahoganies in the northeastern block of the Democratic Republic of Congo. ITTO Tropical Forest Update 14(4), 20-21.
- Mapongmetsem, P. M., Duguma, B., Nkongmeneck, B. A., & Selegny, E. (1999). The effect of various seed pretreatments to improve germination in eight indigenous tree species in the forests of Cameroon. *Annals of Forest Science*, 56(8), 679-684.
- Mensbruge, G. (1966). Germination and seedlings of tree species in the dense humid forest of Côte d'Ivoire. Centre technique forestier tropical, Nogent-sur-Marne, France. 389 p.
- Mittal, R. K., Mathur, S. B., & Thomsen, K. (2003). Fungi of the stocked Khaya anthotheca seeds and their effect on germination. *Journal of Tropical Forest Science*, 15 (4), 539-545.
- Ouedraogo, A., Thiombiano, A., Hahn-Hadjali K., & Guinko, S. (2006). Sexual regeneration of Boswellia dalzielii Hutch, a valuable medicinal tree in Burkina Faso. Bois et Forêts des Tropiques, 289(3), 41-48. Available at http://bft.cirad.fr/cd/BFT 289 41-48.pdf
- Rao, N. K., Hanson J., Dulloo M. E., Ghosh, K, Nowell, D., & Larinde, M. (2006). Manual of seed handling in genebanks. Handbooks for Genebanks No. 8. 163 pages.
- Wightman, K. E. (2006). Good Forest Nursery Growing Practices - Practical Guidelines for Forest Nursery Growing. ICRAF Technical Manual 2. Majestic Printing Works, Nairobi, Kenya.
- Zida, D., Tibagu, M., Sawadogo L., Tiveau D., & üdén, P. C. (2007). Long-term effect of prescribed early tire, grazing and selective tree cutting on seedling population in the sudanian savanna of Burkina Faso. In: Zida D., 2007. Impact of forest management regimes on ligneous regeneration in the sudanian savanna of Burkina Faso. Doctoral thesis. Swedish University of Agricultural Sciences. pp l-25.
- Zida, D., Tigabu, M., Sawadogo, L., & Oden, P. C. (2005). Germination requirements of seeds of four woody species from the Sudanian savanna in Burkina Faso, West Africa. *Seed science and technology*, *33*(3), 581-593.