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Potential germination and initial growth of *Sclerocarya birrea* (A. Rich.) Hochst, in Niger.

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ABSTRACT

Objective: The Marula (*Sclerocarya birrea*) tree is an agroforestry species subjected to various pressures in Niger. A study of potential germination and initial growth of seedlings was conducted in Niamey. The objective of the study was to determine the parameters of seed germination and initial growth of seedlings of this species in order to assess how the findings could help in reforestation in some areas.

Methodology: The parameters studied for the germination test were: latency duration, germination capacity and germination speed. Seedling growth study focused on the thrust leaves and root growth rate.

Results: The results showed that germination capacity of seeds is 68.33% for a germination period of 30 days. Seedling foliage production is characterized by a rapid growth phase in the number of leaves in the first month (5 leaves) and a slight decrease in the appearance of new leaves in the fourth month (17 leaves). Height growth of seedlings, 30.37 ± 7.09 cm, in the first month is greater than the pivot root, 15.52 ± 3.49 cm ($p<0,001$). A steady increase of 1.51 ± 0.10 mm per month was observed in basal diameter reaching an average diameter of 8.97 ± 1.49 mm in the fourth month.

Conclusion and applicability of the results: This study showed that *S. birrea* has good potentialities of sexual reproduction with a relatively short latency and good germination capacity. Also, the introduction of this species in reforestation programs offers a solution of sustainable reforestation of the complex of classified forest of Dan Kada Dodo - Dan Gado.

Keywords*: Sclerocarya birrea,* cores, Germination, initial growth, Niger

RÉSUMÉ

Objectif: Sclerocarya birrea est une espèce agroforestière soumise au Niger à une pression d'exploitation considérable. Une étude des potentialités germinatives et de la croissance initiale des plantules a été conduite à Niamey. L'objectif de l'étude est de préciser les paramètres intervenant dans la germination et la croissance initiale des plantules en vue d'envisager ultérieurement des possibilités de réhabilitation de zones agroforestières.

Méthodologie: Les différents paramètres étudiés pour le test de germination concernent le temps de latence, la durée, la vitesse et la capacité de germination. L'étude de la croissance des plantules a porté sur le rythme de croissance aérienne et racinaire.
Résultats: Les résultats obtenus ont révélé que la capacité germinative des graines est de 68, 33 % pour une durée de germination de 30 jours. La production foliaire des plantules est caractérisée par une phase d'évolution rapide du nombre de feuilles lors du premier mois (5 feuilles) pour atteindre 17 feuilles en moyenne au quatrième mois. La croissance en hauteur des plantules (30,37±7,09 cm) au premier mois est plus importante que celle du pivot racinaire (15,52±3,49 cm) ($p<0,001$). Un accroissement mensuel constant du diamètre au collet de 1,51±0,10 mm est observé pour atteindre un diamètre moyen de 8,97±1,49 mm au 4e mois.
Conclusion et applicabilité des résultats: Cette étude a montré que *S. birrea* présente des bonnes potentialités de reproduction sexuée avec un temps de latence relativement court et une bonne capacité de germination. Aussi, l'introduction de cette espèce dans les programmes de reboisement offre une solution de reforestation durable du complexe des forêts classées de Dan Kada Dodo-Dan Gado.
Mots-clés: *Sclerocarya birrea*, noyaux, Germination, Croissance initiale, Niger

INTRODUCTION

The Sahel region in Sub-saharan Africa is experiencing a gradual degradation of forest ecosystems (Larwanou and Saadou 2005; Kindt *et al.,* 2008; Herrmann et Tappan, 2013). Degradation of vegetation cover, mainly attributed to stressful environmental conditions, land clearing and overgrazing, is now resulting in increasingly negative economic and ecological effects (Bellefontaine *et al*. 2002; Gonzalez *et al*, 2012). The complex of classified forests of Dan Kada Dodo - Dan Gado located in south central Niger is not the spared from this issue. Indeed, a trend of expansion of cultivated areas was reported since 1975 at an average annual rate of 3.80% at the expense of natural forest formations (Abdourhamane *et al.*, 2012). This has resulted in the decrease of density for some woody species with high socio-economic potential such *Balanites aegyptiaca (Desert date), Lannea microcarpa (African grape), Bombax costatum* (Cotton tree) and *Scleorcarya birrea (Marula)*. Marula is not only a species that characterizes the forest complex of Dan Kada Dodo - Dan Gado, but it is also one of the 10 most used forest species in sub-Saharan Africa and is counted among the species that provide large share of income (Muok *et al.* , 2011). Formerly known as *Poupartia birrea* (A. Rich.) Aubrév.*,* the agroforestry species *S. birrea*, is widespread from Senegal to Cameroon to Uganda and to Ethiopia (Arbonnier, 2009). It has a great socio-economic value as all parts of the fruit are edible either raw or cooked. The pulp of fresh fruit is eaten, mostly by children and is an important source of vitamin C for people (Dlamini, 2011). The almonds are rich in protein (28-31 %), oil (56-61 %), magnesium, phosphorus and potassium (Muok *et al.,* 2011). Oil extracted from the seed is used for family consumption or in the cosmetic industry (Murray, 2000). Fruits and bark are used in traditional medicine; trunks and branches to manufacture household items such as mortars and pestles (Muok *et al.,* 2011). These multiple purposes lead to an increased pressure on the populations of the species. Its natural regeneration is very low which suggest an increasing risk of extinction of the species in this forest ecosystem.

Jaouadi *et al.* (2009) indicate that in situations where degradation of vegetation has reached critical level and where natural regeneration cannot, even in the medium term, restore forest cover, the use of rehabilitation technology becomes a necessity. The objective of this study is a better knowledge of the parameters that determine germination and initial growth of *S. birrea* in nursery.

MATERIALS AND METHODS

Study Site: The study was conducted in the nursery of the Faculty of Science and Technology at the University of Niamey (altitude 188 m, 13 ° 30 ' N and 02 ° 05' E) from June to October 2012. The tropical climate of south - Sahelian is characterized by an alternation in of rainy season (June to August) and dry season (September to May). The average annual rainfall of the past five years, registered on the site is 513 mm.

Seed collection: Dioecious species, drupes three to four cm in diameter have a fibrous pulp surrounding a thick core containing from three to four (or five) seeds (Leakey 2005). For this experiment, fruits of *S. birrea* used were harvested at maturity in late May 2012 from 30 seed trees in the complex classified Dan Kada Dodo Dan Gado forests in south-central Niger (between latitudes 13 ° 27' and 13 ° 35' North and longitudes 07 ° 34 ' and 07 ° 43' East). Cores were also collected in the crowns of trees and in the stall of the animals belonging to farmers settled in the forest.

Study of germination: The cores were extracted from the fruit and then sorted to separate healthy seeds from those with defects then washed and dried in the shade for two weeks. The collected cores were subjected to densimetric test tap water to remove the supernatant cores (considered nonviable). All seeds were subsequently mixed. The collection of lots is made using progressive divisions method. It consists of dividing the seeds into two equal parts. One of these selected batches is also divided into two. This procedure is repeated until approximately the number of seed to be tested. Three batches of 60 seeds were used. The germination experiments were conducted from 07 June to 07 November 2012, at an average of 25°C temperature. The cores were sown untreated into rectangular plates containing a substrate composed of three parts of sand to one volume of properly decomposed manure, at the rate of five cores per row spaced 10 cm. These boards were watered every two days. The number of germinated seeds was recorded daily for the 45 first days after sowing. A seed was considered germinated when the two cotyledons emerge. The following parameters were used to express the results of the test (Côme *et al*., 1982):

- Germination time is the time between sowing and the appearance of the first germination
- The speed of germination is the time at which 50 % of the seeds germinated;
- Germination, also called germ or germination capacity, is the proportion of seeds germinated during the period of observation (45 days);

- The duration or timing of germination is the time between the first and last germination during the observation period ;
- The rhythm of leaf appearance.

Study of seedlings growth in the nursery: The study of seedlings growth aim to define the various stages of development and to characterize the speed of morphological changes of the seedling to adapt to environmental conditions. The method applied by Dan Guimbo *et al.* (2011) on the nuts *Neocarya macrophylla* was used. Fifty plastic containers of 1 m in height and 0.6 m in diameter were made and filled with coarse sand up to 70 cm and then a substrate composed of 3/4 sand and 1/4 well decomposed manure to the upper edge. In each container, twelve cores were sown (600 cores in total) without treatment, coated with 3 to 5 cm of substrate and exposed to direct sunlight. Watering is done every two days to maintain the soil in the pots close to field capacity level. After emergence, only six seedlings were maintained in each container after a thinning. Monitoring took place over four months. Indeed, Muok *et al.* (2011) estimated that from three to six months the species could be transplanted. Each month, thirty seedlings of five containers selected at random were collected for measurements in the laboratory (Photo 1) on the height of the aerial part, the pivot length and root collar diameter in using a ruler and an electronic calliper.

Photo 1: Seedlings collected for measurements in the laboratory

Data analysis: The mean values and standard errors of all parameters were calculated. Regression equations were developed to estimate allometric relations between morphological variables of seedlings. For the height growth and pivot root of seedlings, monthly measurements were compared using an analysis of variance ($P < 0.005$). Simple linear regression was used for statistical regression models. These models relate the relationship between height and diameter, height and number of leaves, stem length and number of leaves. Two main tests are used to validate de model of regression:

- The coefficient of determination R^2 gives the percentage of variation explained due to the variation in the explanatory variable;
- Analysis of variance that tests the adequacy of the model as null hypothesis "non-model fit", if the probability associated with this test is less than 0.05, we accept the alternative hypothesis.

RESULTS

Characteristics of germination: *S. birrea* has epigeal germination (Photo 2). Latent period is eight days and less than 14 days, 50% germination rate is obtained. In this test conditions, the germination time is thirty days. The monitoring during 45 days we have not seen any

increase of germination rate. The germination capacity is 68.33% (Table 1).

Tableau 1: Germination characteristics of *S. birrea* in nursery

Latent period (days)	Speed of germination (days)	Duration of germination (Days)	Capacity of germination (%)
8	13	30	68,33

Photo 2: Mode of germination de *S. birrea* (a. Sprouting of a seedling; b. Sprouting of two seedlings from the same nuts)

In this study test conditions, the kinetic analysis shows a first latent phase of 8 days, a second exponential phase between the 9th and 14th day accelerated germination is observed with a germination rate of 55% and finally a third phase characterized by a plateau which extends to the 45th day indicating the stopping of germination after a maximum germination rate of 68.33% (Fig.1).

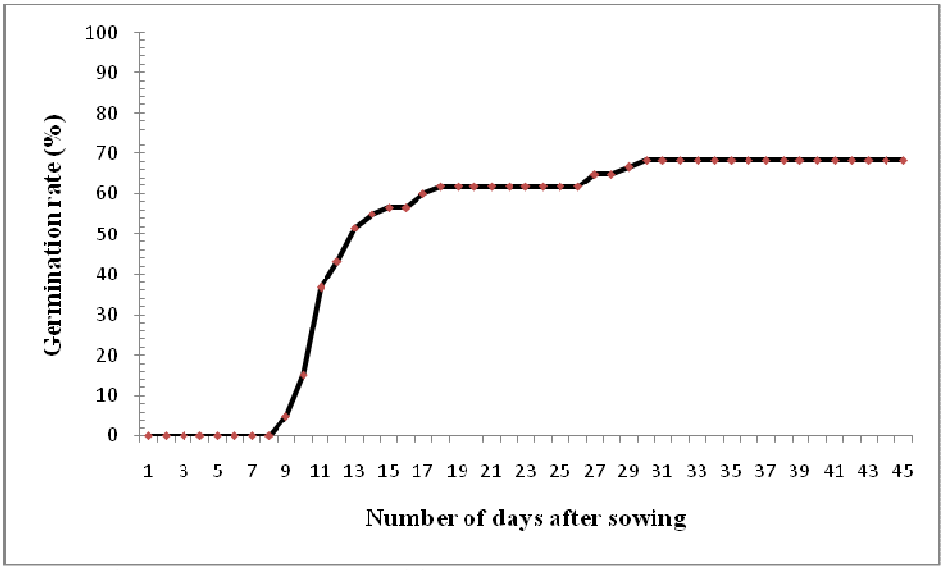

Figure 1: Germination rate evolution of S. *birrea*

Growth rate of seedlings in the nursery: One month after sowing, the mean growth of seedlings (30.37 ± 7.09 cm) is larger than the underground growth of pivot root (15.52 ± 3.49 cm) ($p<0,001$) (Photo 3). In the second month, the mean height is 53.45 ± 9.28 cm, elongation is 23.09 ± 2.19 cm, while a slight increase of the pivot is observed (21.95 ± 5.28 cm). However, a slowdown in growth of air is noted in the third month with an elongation of 1.24 ± 1.09 cm and a slight recovery in the fourth month is 7 ± 1.28 cm while the elongation of the root hub is on average 7.95 ± 1.67 cm during the third and four months (Fig. 2). The results showed a steady monthly increase of 1.57±0.10 mm in basal diameter reaching an average diameter of 8.97±1.49 mm in the fourth month.

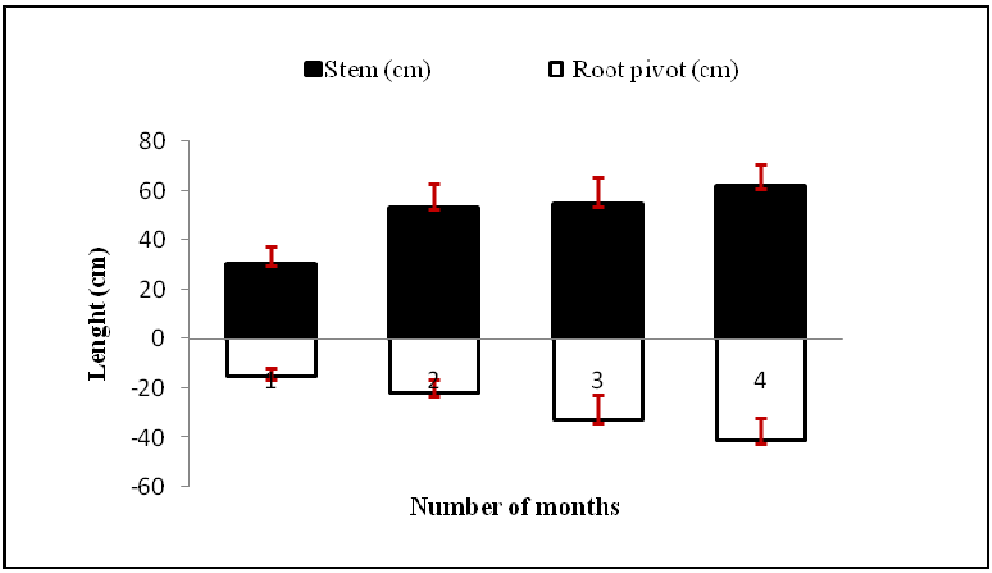

Figure 2: Evolution of the stem growth and root pivots of the seedlings during 4 months of monitoring in the nursery

Photo 3: Arial and root parts of seedlings one month after sowing.

The evolution of the collar diameter over time (Fig.3) shows a gradual increase in the average diameter with respectively 3.45 ± 0.67, 5.96 ± 1.58, 7.31 ± 1.64 mm for 1st, 2nd, 3rd months to 8.97 ± 1.49 mm in the fourth month. As shows on figure 3, a steady monthly increase in the diameter of 1.51 ± 0.10 mm was observed.

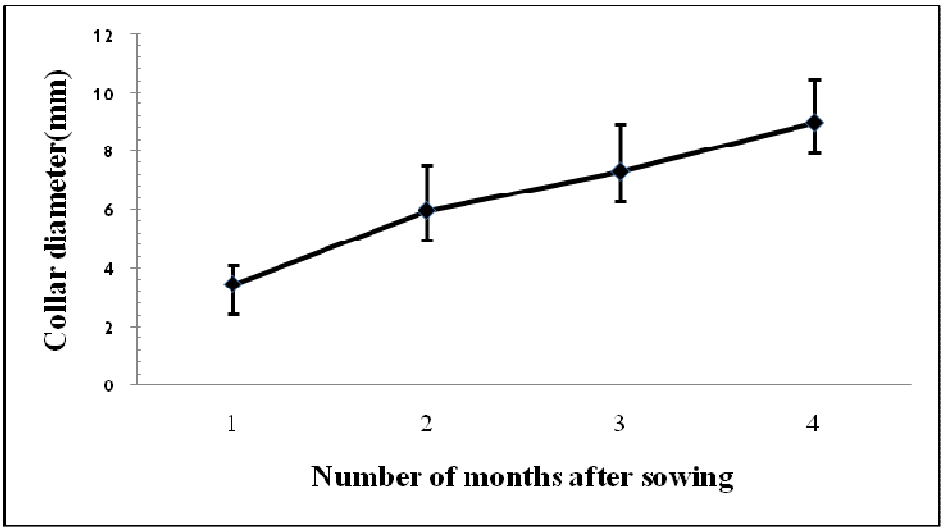

Figure 3: Evolution of seedling diameter over time

Seedling foliage production is characterized by two stages of evolution. From the first month, there is a rapid increase in the number of leaves per shoot; but beyond this period, a slight slowdown was noted in the development of new ones. Seedlings bear on average five leaves after a month. The second and third months this number is respectively 13 and 14 and finally the 17 at the fourth month. The number of leaves varies linearly with the height of the seedlings (Fig. 5) with a very high coefficient of determination (R^2 = 0.81).

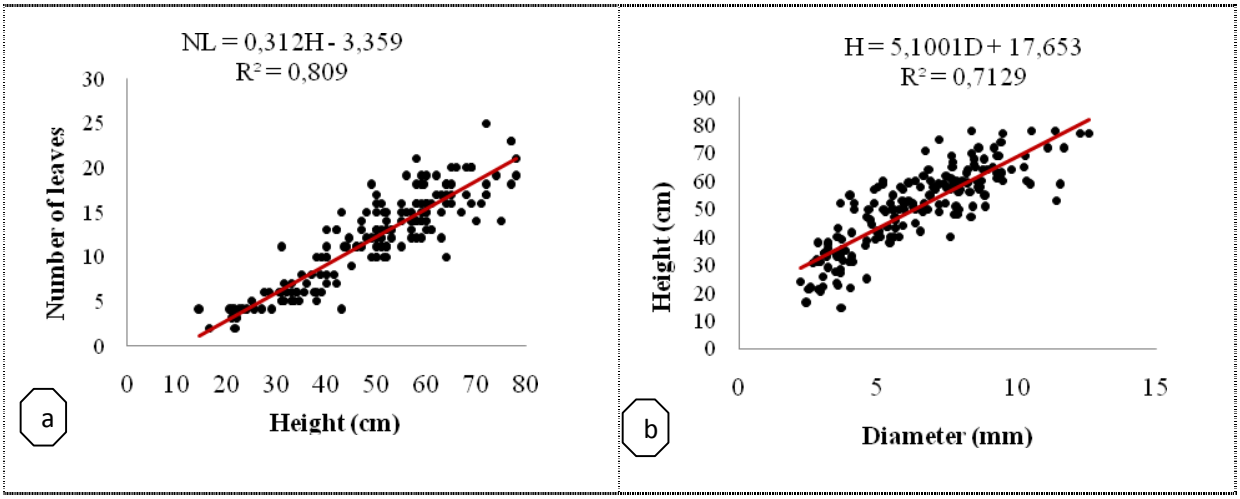

Figure 4: Allometric relationship between growth parameters

The decline reflected the relationship between height and diameter gives a coefficient of determination R^2 = 0.75 between the two parameters. The relationship between growth parameters of seedlings shows that there is a good correlation between the number of leaves and height of seedlings and between height and collar diameter. The adequacy of models tests showed that these models are adequate ($p < .05$). In addition,

the compliance testing of the regression coefficients ($p < 0.05$ for the variable) and ($p < 0.05$ for the variable b) confirms that the equation is actually linear type ($y = ax + b$).

DISCUSSIONS

The study of the germination of *S. birrea* showed good potential for germination of cores recently harvested (3 weeks old now of sowing) without pre-treatment. These results are in line with those of Joker and Erdey (2003) who reported 70% and 85% germination rates respectively after one and two weeks after sowing. Muok *et al*. (2011) reported that a prolonged storage in seed banks (for one or more years) cores of *S. birrea* has a greater effect on seed viability and may increase the capacity of germination. Gamene *et al*. (2005) emphasize that the seeds of S. birrea require a post-maturation period to reach the maximum germination, which was higher with seeds stored for 18 months at 25 ° C. They believe that well-dried seeds can survive after 18 months of storage, even at -18 ° C. Although the cores have lignified envelopes that influence the latency, the time of latency is relatively short. For Roussel (1995), the appropriate treatment is soaking cores in water for 24 to 48 hours. Bationo *et al.* (2000) reported a germination rate of 49 % using the soaking cores in water for 48 hours. The germination rate obtained in this study could be because the experiment was conducted under conditions allowing good imbibition of cores resulting to metabolic reactions that trigger germination. Moreover, the fact that the composite sample is comprised of seed collected in parks animal housing nuclei can play for a good germination rate. Setlalekgomo and Setlalekgomo (2013) also noted enhanced germination capacity of *S. birrea* cores due to the passage through the tract of kudu (*Tragelaphus strepsiceros*). This effect of the ingestion of fruits of *S. birrea* by herbivores on increasing the rate of germination was reported by Helm *et al*. (2011). Actually, cores that are ingested undergo mechanical scarification due to chewing and the peristaltic movements of the stomach on one hand, and a chemical scarification due to digestive juices on the other hand, all resulting in a faster germination and / or better germination as pointed Guèye *et al.* (1999).

Germination time is corroborated with observations by Muok *et al.* (2011). According to the latter germination takes two to four weeks. This relatively long germination can be seen as an adaptation strategy of the species to cope with variability in rainfall (Ouèdraogo *et al.,* 2006). The average duration of germination and good germination ability of *S. birrea,* encourage national seedlings of the species (Bationo *et al.,* 2001). The assessment of the quality of the plants is based on morphological criteria such as height and collar diameter. Behavioural study of seedlings allowed highlighting a good aerial initial growth with an average seedling height exceeding 50 cm in 2 months. The substrate consists of sand and manure appears favourable to the growth of seedlings of *S. birrea*. Benmahioul et al. (2010) reported this beneficial effect of the nature of the substrate on the qualitative aspect of woody plants produced in the nursery. Growth also depends on plant species. Studies conducted by Bationo *et al.* (2010) on four Sudanese woody species in the forest Nazinon in Burkina Faso show a rhythmic aerial growth of these species. The average length of taproot obtained in the first month indicates that it sis deep-rooted, and grows vertically. Yélémou *et al.* (2007) also showed an early development of a taproot system for *Piliostigma reticulatum*. This fast growing taproots in the natural environment allows seedlings to explore the deeper layers of the soil and reduce the constraints of competition, including herbaceous and edaphic drought. However, enlargement of roots was observed from the third and fourth months probably due to storage strategy feeder reserves. The mean diameter obtained in the first month also shows that good growth. Seedlings of this species survive through the accumulation of reserves in their root systems that provide their water and minerals during the difficult times of the year (Alexandre, 1993; Pierre, 2003; Bellefontaine, 2005). The presence of strong and sometimes tuberous root systems has also been reported in other species of the Sahel (Ganaba and Guinko 1995; Bationo *et al*, 2001). This characteristic is seen as a criterion of adaptation of woody species in arid savannah environment where fire and drought severely limit the survival of seedlings. Under these conditions, a vigorous root system would ensure adequate supply of water and nutrients from deeper horizons, and a good strong recovery after fire (Dianda *et al.,* 2010). *S. birrea* is a species that produce very often suckers in the wild (Cuny *et al*, 1997. Harivel *et al*, 2006; Noubissié-Tchiagam *et al*, 2011.), through its carbohydrate reserves stored in the pivot and surface roots. In this respect, it would be interesting to multiply the best clones by inducing suckers (cutting roots) or by

root cuttings (by taking root segments to plant them at the desired location by the farmer (Bellefontaine, 2005; Meunier *et al*., 2006 et 2008; Ky Dembélé *et al*., 2010). The observation sheet shows that *S. birrea* has a rate of occurrence of relatively large leaves. The appearance of successive leaves is an average of two days, which allows them to perform the essential seedling growth photosynthetic reactions. The relationship between the different parts of seedlings, expressed by the coefficients of determination (R^2) show that there is a strong correlation between the number of leaves and the height and diameter. The good correlation between the number of leaves and height shows that their development goes hand in hand. Each stem elongation is the emergence of new leaves where an increase in the aerial part.

CONCLUSION

This study showed that *S. birrea* has good potential for sexual reproduction with a relatively short latent period and a good capacity of germination. Good initial growth of the aerial part and the development of a long pivot root may allow the species to thrive in natural environment in good soil and climatic conditions. The introduction of this species in reforestation programs would represent a sustainable solution for the reforestation of the protected forest complex of Dan Kada - Dodo Dan Gado; particularly in the context of cultivation contract system in place. This would therefore allow a multi-purpose use. However, measures and restoration techniques to undertake are still being defined through studies that take into account the dynamics of development of the species from the previous stock of viable seeds in the soil. This species deserves to be propagated by suckers or root cuttings. In addition, the success of reforestation of the species inevitably requires an understanding of how the species will behave vis-à -Vis environmental conditions after planting.

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