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Some agroforestry potential for two tree legumes in the dense rainforests of Côte d'Ivoire: Characteristics of seed germination

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The Ivorian forest area has been declining because of his abuse. To reduce the negative impact of forest loss on natural resources, various reforestation projects are undertaken. The species used in these programs are usually rapidly growing exotic legumes. Unfortunately, these plants are very poorly adapted to the prevailing conditions and targets are rarely achieved. Hence, replacing them with native species should be considered. In order to meet this requirement, it would be necessary to select some taxa from the local flora with the same characteristics (such as high germination rate, rapid growth, etc.) and this study follows this pathway with research into the morphological characteristics and seed germination of two legumes (*Dialium guineense and Distemonanthus benthamianus*) and the survival rate of seedlings from germination. For this, fruits and seeds of these two species were collected, observed, described and put into germination. The results give 43.33% germination capacity among *D. guineense* and 67.77% in *D. benthamianus* when seeds do not undergo treatment. These rates can be improved by applying their specific treatments. A rate of 85% is obtained after scarification of the *D. guineense* seed. The rate of *D. benthamianus* increases to more than 88% after soaking in water. The different survival rates are estimated at over 80%. These plants may be used instead of exotics.

Key words: Legumes, germination rate, survival rate, seeds, young Ivory Coast plants.

INTRODUCTION

Ivory Coast gets most of its foreign currency from agriculture and the exploitation of wood resources, but faces the rapid loss of its forest cover. Where there were 16 million hectares of forest in 1960, the size dropped to 10,000 million hectares in year 2006 and is currently less than 2 million hectares (Anonymous, 2006), resulting in soil depletion and the loss of plant species, among others (Ake-Assi, 1988). Consequently, arable land and timber resources are becoming increasingly scarce and land degradation and deforestation are major concern for the State. In its search for solutions, Ivory Coast has developed reforestation and agroforestry programs that use generally multiple exotic species whose essential features are rapid growth and the recoverability of soil fertility (Oszwald, 2005).

Many studies have demonstrated that the species of the *Leguminoseae* family are fast growing and have, in addition, the ability to protect, restore and enhance

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soil fertility, due to symbiotic bacteria. The pioneer species most commonly used are trees and shrubs of the genus *Acacia* (Konate, 2007).

Two species are mainly used in Ivory Coast: *Acacia mangium* and *Acacia auriculaeformis*. Studies on these species do not yet predict the externalities that could impact upon and cause a hazard by their long-term presence, especially on biodiversity, ecology and the environment. Therefore, the use of local materials, as an alternative to exotic materials currently employed in the majority of reforestation projects in Côte d'Ivoire is necessary. Studies on their domestication are underway and they concern in particular the characteristics, growth and development of their seeds. It is in this context that the present work was undertaken, in relation to the morphological and physiological characterisation of the seeds of two species of socioeconomic interest, and which are commonly found in the forests of Southern Ivory Coast, namely, two *Caesalpinoideae* trees: *Dialium guineense* and *Distemonanthus benthamianus*.

MATERIALS AND METHODS

Location of the site

The study was carried out in the Abidjan region of Southern Côte d'Ivoire between latitudes 5°00' et 5°30' N and longitudes 3°50' et 4°10'W (Figure 1). The climate is Guinean, which is characterised by two dry seasons and two rainy seasons. The original vegetation was dense moist evergreen forest (Aubreville, 1959), but is now down to a fallow mosaic of all ages covered with herbaceous type vegetation with few primary or secondary forests such as the Banco and Anguédédou.

Plant material

The work focused on fruits and seeds of two species of common legumes in Ivorian forests, *D. guineense*, a food and medicinal plant, and *D. benthamianus*, a large multipurpose tree used for medicines, carpentry, etc. *D. guineense* is a species that is currently threatened due to its mode of exploitation, whereby trees are usually slaughtered during the picking of their edible fruits. *D. benthamianus* has a tendency to disappear because of its misuse and the destruction of its habitat to make way for crops.

Methodological approach

Harvesting technique for fruits and seeds

Phenological localisation and plotting: Prior to the harvest of fruits and seeds, parent plants were previously located via a roaming inventory and their phenology studied. Localisation was undertaken by making regular readings by browsing the study area. Whenever either of the two species was identified, we noted its geographical references using a global positioning system (GPS). Direct observation of individuals permitted the noting and monitoring of their phenology. In the fruiting state, fruit or seed were harvested following a methodology which will be described in the next section.

Harvest of fruits and grains: The harvesting technique for fruits and seeds varies according to species. With *D. benthamianus*, mature pods are harvested directly from around the seeds after their fall. These are dried domestic fruits. The extraction of seed from its papery pods necessitates the use of scissors. In *D. guineense*, fruit is harvested directly from the trees. These are also domestic pods, being leathery and whose opening is possible only after strong pressure achieved with a hammer. The seeds are surrounded by an orange mealy pulp which is extracted from the pods before use.

Morphological characterisation of fruits and grains

The colour, shape and measurements of fruits and seeds were made by using a simple methodology (direct observations, measurements and weights) that can be repeated over time, and allow a smooth realisation of observations. Some phenotypic characteristics were observed using the naked eye (colour, geometry, etc.). The measured height and diameter of the bodies were made by using a calliper. The images were made by using digital photography equipment.

Treatment and sowing of seeds

Previously harvested seeds were sorted to eliminate waste and other non-viable seeds. The seeds that were clean in appearance and that would be used were stored in bags or conservation packets. For each species, the seeds were divided into three lots. The first was sown without pre-treatment. The seeds of the second batch were scarified before sowing. Those of the third batch were soaked in tap water for 24 h. Seedlings were cultivated in black bags with holes pierced into the sides in their basal part. They were 18 cm in height and 10 cm in diameter. The experimental design was a Fisher block with 3 treatments and 3 repetitions. Each treatment consisted of 30 seeds sown in individual bags. 30 bags full of black earth were arranged into square plots. This procedure was repeated three times for each treatment and for each species.

Germination behaviour of seeds

This was a study of the germination behaviour of seeds of both species during a trial of three months in duration with germination monitored daily. We conducted a daily count of the number of emerging seedlings. The data collected during these tests focused on germination, survival and germination periods.

Germination rate: The germination rate is the percentage of germinated seeds in relation to the number of seeds sown.

Germination time: The germination time is the time taken by a seed planted in earth to appear above the ground. It corresponds for this work and for each species following treatment, to the average time of seed germination during the period of three months of observation. It is obtained by the following formula:

$$\mathbf{Dlev(j)} = \sum \mathbf{tlév_n} / \mathbf{n}$$

Where Dlev = average time of seed germination, expressed in days; n = total number of seeds raised; TLEV = germination time of the seed n.

Survival rate of young plants: The survival rate is the ratio between the percentage of resulting seedlings having survived after

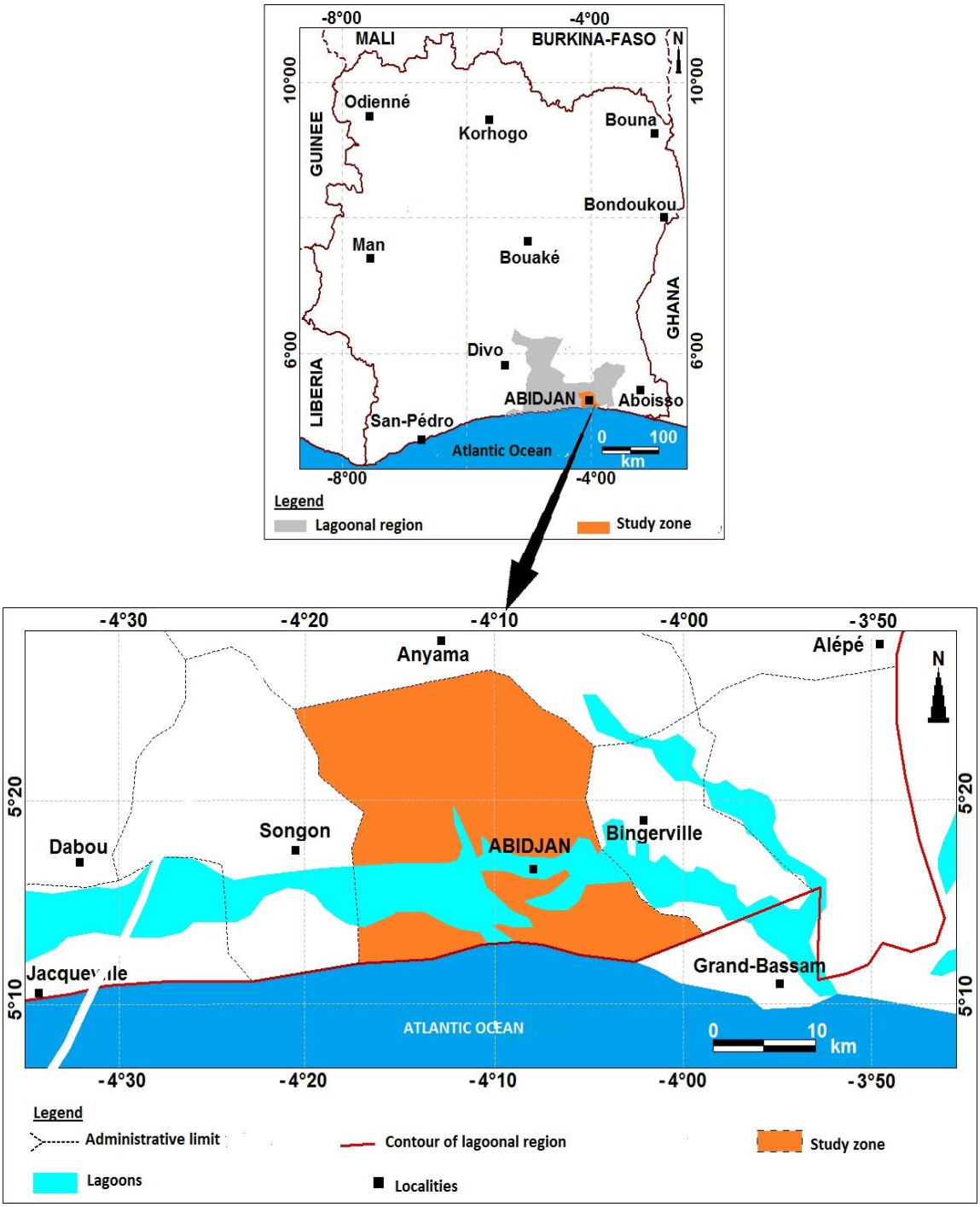

Figure 1. Geographical location of the study area.

3 months of observation and the total number of germinated seeds. It is calculated from the following formula:

$$\text{Tsurv (pc)} = \frac{S}{N} \times 100$$

S = Number of surviving plants. **N** = number of germinated seeds.

Statistical analysis of data

The analysis of variance (ANOVA) was used for exploitation of the data. The test used to compare the mean was the Dunnett test (compared to control).The analysis of variance ANOVA was used for data mining. The test used to compare the mean is the Dunnett test (procedure for comparing each experimental mean with the control mean). The average rates monitored with scarred and hardened treatments were compared to those obtained with the

Figure 2. Seeds of *Dialium guineense*.

Figure 3. Fruits and seeds of *Distemonanthus benthamianus*.

control. Treatment was different from the control when P (the associated probability) was less than 5%. The software which was used to analyse the results was XLSTAT 7.5.3 software.

RESULTS AND DISCUSSION

Morphological characteristics of seeds and fruits

Seeds and fruits of *D. guineense*

The fruits of this species are black, slightly flattened, globular, velvety domestic pods, containing a seed; however, some fruits can contain two seeds. They measure an average of 1.3 to 3.2 cm in length and 0.9 to 2.9 cm in width. The seeds are flattened and lenticular in shape with a small hollow in their centre. They are surrounded by an orange coloured mealy pulp which is sweet and tangy in flavour and edible. They are brown in colour and measure 0.8 cm in average length with a width of 0.5 to 0.7 cm, and with an average mass of 0.21 g (Figure 2).

Fruits and seeds of D. benthamianus

The fruits are domestic pods which are straw coloured, flat and papery when dry and contain from 1 to 5 seeds. They are between 8 and 12 cm in length and 2.8 to 3.5 cm in width. The seeds are oblong and elliptical in shape, and brown in colour. They weigh 0.061 g on average. They are from 0.7 to 1 cm in length and from 0.3 to 0.4 cm in width (Figure 3).

Germination behaviour

Germination period

The seeds of *D. benthamianus* germinate faster than those of *D. guineense* (Table 1). In both species, the time taken to germinate depends on the treatment method. Scarified seeds germinate faster than those of the other two lots.

Germination rate

***Dialium guineense*:** There was a significant difference between the rates of germination of treated batches compared with the controls (Figure 4). The comparison of means (t-test) showed no significant difference between the germination rate in scarified samples and those obtained with the soaked seeds. However, germination was better in scarified seeds.

***Distemonanthus benthamianus*:** The soaked *D. benthamianus* seeds had the best germination rate (88.90%). There is no significant difference between the average rates of germination of control seeds and scarified seeds. However, scarified seeds germinate less well than control seeds (Figure 5).

Developing seedlings from germination: Survival rate *D. guineense*

Table 2 presents the main results of the observations on the seedling survival rate after germination. After analysing these results, it transpires that there is no

Table 1. Average germination period according to species and treatments.

Species	Germination rate (in days)		
	Control (Te)	Soaked (T)	Scarified (S)
Dialium guineense	22,5	22,5	12,5
Distemonanthus benthamianus	11,5	9	6,5

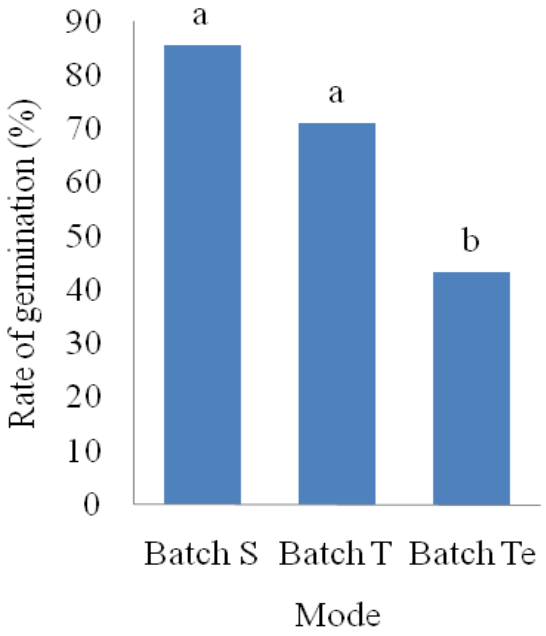

Figure 4. Consolidation of seed batches based on germination.

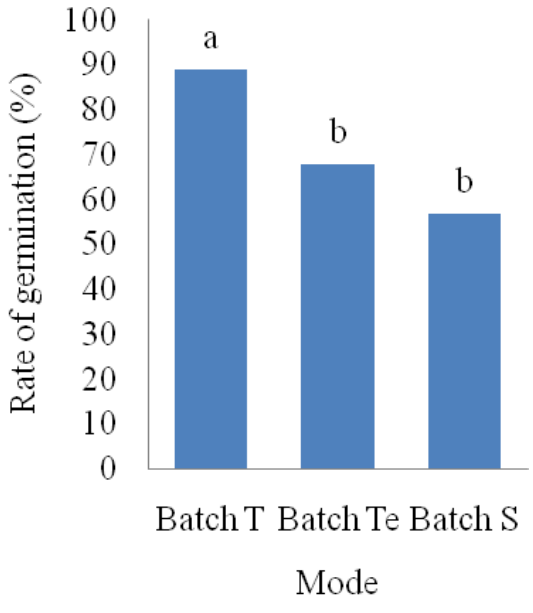

Figure 5. Consolidation of seed batches based on germination.

significant difference between the seedling survival rate of the soaked seeds and the scarified seeds. The survival rates among these are higher than those of control groups with a very significant difference.

D. benthamianus

The plants derived from soaked seeds have the best survival rates. There is no significant difference between the survival rates of scarified seeds and the survival rates of control seeds (Table 3).

DISCUSSION

Seed germination depends on the ecological characteristics of the species (Baskin and Baskin, 1998; Fenner and Thompson, 2006; Finch-Savage and Leubner-Metzger, 2006). De La Mensbruge (1966) classified species according to their germination rate, characterised as very fast when the appearance of the first emergence is obtained within two weeks after planting. Fast or medium germination is attributed to species whose emergence is between two and four weeks and is slow when it is obtained after 30 days of planting. On this basis, *D. guineense* seeds with a delay of about 22.5 days have an average speed of germination when immersed or when not receiving specific treatments. Scarification accelerates the speed, which stabilises at 12.5 days. In contrast, *D. benthamianus* is a species with rapid germination. Indeed, its germination is effective within the first two weeks after planting, with a better result when the seeds are scarified. In both cases, generally the treatment of seeds, especially scarification, accelerates the germination speed. The germination rate is considered high if it is greater than 85%, reduced when between 60 and 75%, and low if it is less than or equal to 50% (De La Mensbruge, 1966; De Koning, 1983). The results demonstrate that untreated seeds have a low germination rate in both species. It is low in *D. guineense* (43.33%) and reduced in *D. benthamianus* (67.77%). This low germination rate is common in legumes (De La Mensbruge, 1966). Similar results have been obtained with other seed species such as *Acacia spirborbis* in a study conducted in New Caledonia by Bailly (1986). For this author, this is due to the presence of a seed coat,

Table 2. Consolidation of seed batches based on survival rates.

Mode	Mean (Rate of survival in %-age)	Combinations
Batch S	85.56	A
Batch T	70.00	A
Batch Te	43.33	B

Table 3. Consolidation of seed batches based on survival rates.

Mode	Mean (Rate of survival in %-age)	Combinations
Batch T	88.889	A
Batch Te	57.778	B
Batch S	53.333	B

which is impermeable to water around the embryo. The behaviour of these species differs depending on their seed treatment conditions.

In *D. bentaniamus*, soaking improves the germination rate but scarification lowers it. In *D. guineense* germination is stronger when the seeds are scarified. The dormancy-breaking treatments have shown positive results for both species. By analysing the germination behaviour of *D. guineense* seeds with 85.55% rate of germination of scarified seed, scarification is the pre-treatment which boosted the germination rate in this species. Mechanical scarification has been successfully used to lift the seed coat dormancy of species such as *Albizia falcataria* and *Albizia lebbeck* in India (Wunder, 1966). The Mimosoideae such as *Acacia fail-fail*, *A. lebbeck*, and *Samanea saman*, have hard seeds that germinate very quickly after scarification of the seed coat (Bailly 1986). According to Kisou et al. (1983), scarification improves the seed germination rate of *Leucaena leucocephala*. Our results have shown that in *D. guineense*, species with a lignified and leathery integument, scarification improved the germination rate. This is consistent with the observations of Konate (2007), which note that the seeds with a thick, hard integumentary shell require prior scarification in order to facilitate germination. Ewedje and Tandjièkpon (2011) confirm our results with respect to ensuring that the seeds of this species should be scarified to promote germination. According to De La Mensbruge (1966), species that have good water permeability and gas exchange will germinate quickly. With a germination period reduced to 10 days, the scarified seeds of our study seem to confirm these results since scarification allows the seed to be in direct contact, or at least in part, with water and air. These results (98 seeds germinated in 9 days) were obtained by Assongba et al. (2013) in the same species. With respect to *D. benthamianus*, treatment by soaking in water at room temperature has a positive influence on the germination rate.

Thus, the best germination rate obtained (that is, 88.89%) in this case is from seeds soaked in water. Our results are consistent with those of Owusu et al. (2012), which reported a 90% germination rate in the same species in Guinea. Those authors note that soaking the seeds in water for 24 h encourages germination. In the Forest Seed Handling Guide (Kisou et al., 1983; Cousins et al., 2014), it is reported that the seed coats of some seeds are not fully permeable, hence, under these condition; the soaking of seeds in water at room temperature for 24 h promotes germination. The soaking treatment not only helps to soften the hard seed coat, but possibly leaches out inhibitory substances it could contain. The improved germination is promoted by soaking this species with its hard seed coat in cold water indicates that the hard seed coat was softened by water which has leached out any chemical inhibitors. It is noteworthy that the scarification reduced the germination time to 5 days with a low rate of germination. This poor rate was due to a deterioration of seeds that have been destroyed by pathogenic microorganisms or macroorganisms that have easier access to the seed cotyledons they house.

Conclusion

The present study on the characterisation of the behaviour of germinal seeds of *D. guineense* and *D. benthamianus*, two tree species of natural forests in Southern Ivory Coast was undertaken in preparation for their possible use in various recovery programs for the restoration of highly degraded forest cover. It is clear from our investigation that the seeds of these two species are subject to integumentary inhibition and in order to negate it and obtain a rapid germination, treatments are needed. Mechanical scarification proved better for *D. guineense* seeds. As for the *D. benthamianus* seeds, it is the process of soaking in water at room temperature that

suits them. The seedlings of these species are perfectly resistant in the environment. These results are good sign for their perfect adaptation for use as a reforestation species or improvement of fallow areas. In order to confirm this assertion, work on other aspects of their biology and ecology should be promoted, focussing on, among other things, on seedling growth rate, ability to adapt to various soil types, and more.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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