Germination and growth of *Faidherbia albida* (Del.) A. Chev. under different proportions of potting soil and different water regimes

ABSTRACT

Faidherbia albida is an economically important forest tree species mostly used in agroforestry systems. The species is heavily threatened with livestock feed, and studies about its regeneration are scares. The aim of this study is to contribute to the knowledge of the species *F. albida* production techniques, specifically by investigating the best pre-treatments for lifting the dormancy of seeds and the best suited substrate and water regime to the growth the growth and development of seedlings. An experimental study as regards germination of seeds in the laboratory, and assessment of growth parameters through irrigation regime and type of substrate in nursery was carried out. A split-plot experimental design was used for seed germination rates i.e. five pre-treatments (98 % acid, 75 %, 50 %, 10 % and H_2O) with four repetitions each. Afterwards, the 98% and 75% acid concentrations were used for the remaining study. A randomized complete block design with three blocks and nine plots was established in a nursery to assess the growth variables. The highest germination rates were noted with sulfuric acid doses of 98% and 75% with respective rates of 100% and 43.75%. Significant differences in growth parameters were observed among treatments, and the treatment that consisted of 100% potting soil and watering once every two days showed the best growth for all assessed growth parameters (height, number of leaves and number of spines) except for root length. This study supports that suitable pre-treatment is needed to lift seeds dormancy in *F. albida*, as well as suitable substrate and water regime are required for seedlings growth and development.

Keywords: *Faidherbia albida*, regeneration, seedlings, sulfuric acid, soil, water regime,

- **Introduction**

Agroforestry parks can be defined as agrarian landscapes where mature trees are scattered across cultivated fields or recent fallow land (Boffa, 2000). According to Bonkoungou et al., (1994), this is a land-use system in which perennial woody plants are deliberately maintained in association with crops and/or livestock in a dispersed spatial arrangement where ecological and/or economic interactions must exist between the different components of the system. To combat increasing desertification, Sahelian governments have set up national reforestation programmes. These reforestation programmes are generally limited by the limited availability of quality seeds. (Samaké et al., 2011)

Agroforestry parks are deteriorating under the combined influence of various biophysical, socio-economic and political factors (Samaké et al., 2011). In addition to the effects of climate change, there are the effects of declining soil fertility, natural and/or provoked bush fires, pests and population growth, all of which contribute to the degradation of agroforestry parks. Cissé (1995) attests that continuous cultivation is detrimental to the development of young seedlings, despite regular inputs of manure and compost.

Futhermore, Tougiani et al. (2021) reported that *F. albida* has come under increasing pressure in recent years, and this is mainly due to dieback, in most cases leading to tree mortality. Similar attacks leading to mortality or dieback of young and old *F. albida* in the 1990s were reported by Thomson (1994). Tree dieback can be defined as the expression of the immediate effects of acute stress (Jurskis, 2005). Tree dieback in rural areas could be linked to factors such as global climate change, overuse of pesticides and fertilizers, heavy metals in soils, pathogens and habitat fragmentation (Close & Davidson, 2004; Sapsford et al., 2017). These factors have direct effects on the survival of symbiotic microorganisms (mycorrhizae), which play an important role in the life of trees.

Aging stands also hinder the sustainability of agroforestry parks, as not all trees and shrubs in the parks produce enough quality seeds to ensure natural regeneration (Samaké et al., 2011). The aim of this study is therefore to contribute to our knowledge of *Faidherbia albida* production techniques. We investigated the best pre-treatments for lifting the dormancy of seeds and the best suited substrate and irrigation regime to the growth and development of young seedlings.

- **Materials and methods**

- **Study area**

The present study was conducted at the Pratical Application Farm of the Department of Agroforestry Assane Seck university of Ziguinchor in Ziguinchor (16°16’37.3” W, 12°32’ 57.2” N), Senegal (Figure 1). The farm covers an area of around 1.3 ha and is located in the Castor district of Ziguinchor characterized by a South Sudanese coastal climate with an annual mean rainfall that ranged between 1300 and 1500 mm (Camara et al., 2023). The Relative humidity influenced by the Harmattan is low in January, February, and March (Ndiaye and Sambou, 2022).

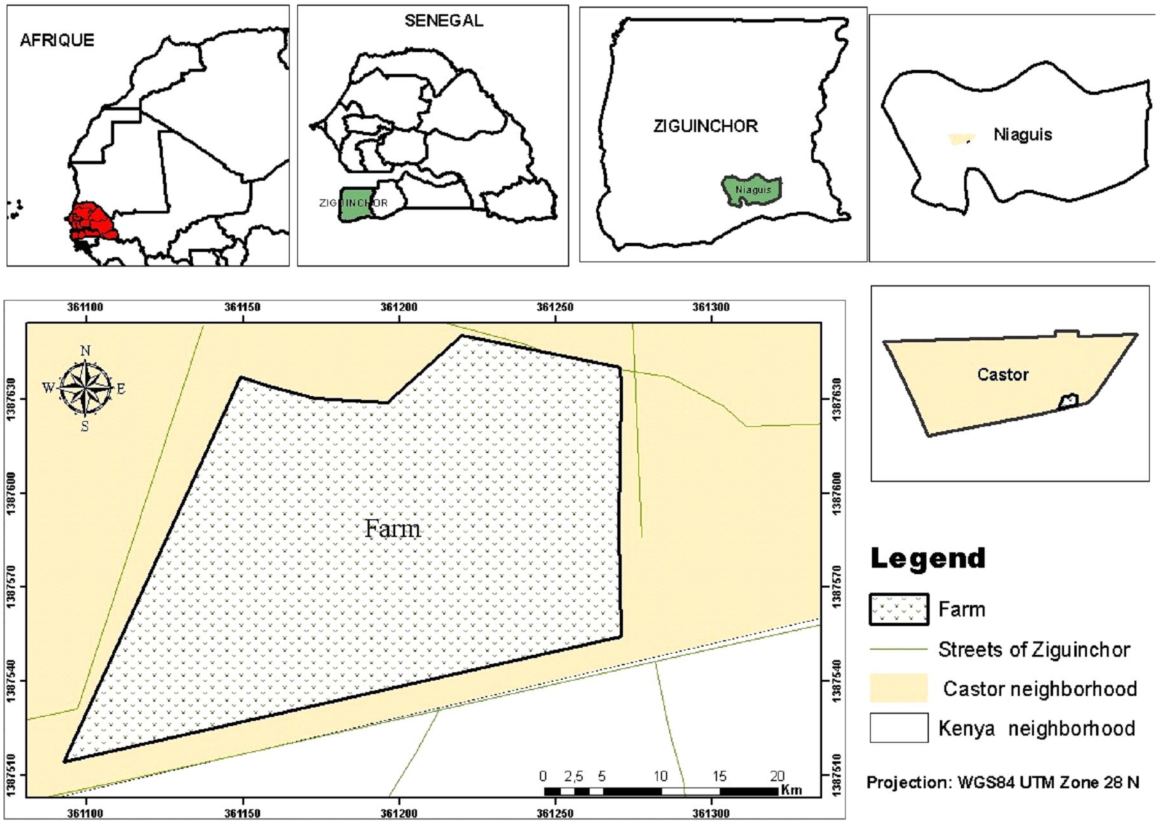

Figure 1. Location of the study area (Source: base geao.gouv.sn.2020).

- **Study species**

Faidherbia albida, originally known as *Acacia albida* is a leguminous trees species that belongs to the Fabaceae family and Mimosoideae subfamily (APGIII, 2009). It is widely distributed in arid and semi-arid regions of Africa (Danthu et al., 2002; Mokgolodi et al., 2011; Tougiani et al., 2021). The species is generally found in cultivated areas in West Africa, while in Southern and East Africa it is one of the natural species from the banks of ponds and watercourses (Dembele, 1994). In normal conditions, *F. albida* can reach over 30 m in height and 1.5 m in diameter at breast height. The trunk is unique with up to 2 m in diameter, and the bark is brown to dull grey or whitish, rough, and more or less corky, scaly and cracked. The young shoots are ashy to whitish, and the crown is rounded and spreading, with branches often drooping on adult trees. The leaves are compound and bipinnate. The species is distinguished by its reversed phenological rhythm, losing its leaves at the beginning of the raining season and remaining leafy in the dry season (Dembele, 1994; Tougiani et al., 2021). The reversed phenology is favorable to the association of F. albida with annual crops, which benefit from sunshine during their full growth in the rainy season (Dembele, 1994; Roupsard, 1997; Roupsard et al., 1998; Tougiani et al., 2021).

Faidherbia albida is an excellent agroforestry trees species through its impact on improving soil carbon and soil fertility, increasing the activity of symbiotic micro-organisms and improving crop yields and nutritional values (Danthu et al., 2002; Gnankambary et al., 2009; Takimoto et al., 2008). Thanks to its deep root system in dune soils, competition for surface water and nutrient resources between this species and surrounding crops is very limited (Roupsard, 1997; Roupsard et al., 1996, 1998).

With regards to seeds, Ibrahim et al., (1997) identified three ecotypes of *F. albida* in Africa ie the Sahelian ecotype, the South Africa ecotype and the ecotype that straddles the two zones, particularly in Ethiopia (Tougiani et al., 2021).

- **Experimental design and germination test**

<u>Germination test</u>

The germination test was first performed at the Laboratory of Agroforestry and Ecology (LAFE) at the Assane Seck University of Ziguinchor. Seeds from *F. albida* trees were manually removed from their pods (manual hulling) and then subjected to two types of treatments. The first treatment consisted of pre-treating the seeds with sulphuric acid in different proportions (10%, 50%, 75% et 98%) in glass jars for 10 minutes, and the second consisted of soaking them in water for 24 hours before placing them in petri dishes (4 seeds per dish) with cotton wool soaked in water to determine which treatment gave the best germination rate. Seeds treated with acid were rinsed thoroughly with water.

Figure 2. Experimental design for dormancy breakage tests

Site preparation

The experimental site was first cleared before collecting mango potting soil (t) and sand. The collected substrates were sieved using onion bags and mixed in different proportions (1/3t, 2/3t and 100%t). This mixture was used to repot the small polyethylene sheaths and placed in the experimental plot.

Experimental design

The experimental trial was realized over an area of $8m^2$. The experiment was a randomized block design with two factors: substrate and watering frequency. The main factor, substrate, was divided into three modalities: 100% potting soil, 2/3 potting soil ± 1/3 sand, and 1/3 potting soil ±2/3 sand. The second factor, watering frequency, was also defined in three different modalities: daily watering, 2-day watering and 3-day watering. The experimental design consisted of three blocks divided into 3 sub-blocks, corresponding to a replication represented by three proportions of substrates. There are 9 treatments (3t*1fj ; 3t*2fj ; 3t*3fj ; 2t*1fj ; 2t*2fj ; 2t*3fj ; 1t*1fj ; 1t*2fj et 1t*3fj), and each treatment contains 90 sheaths.

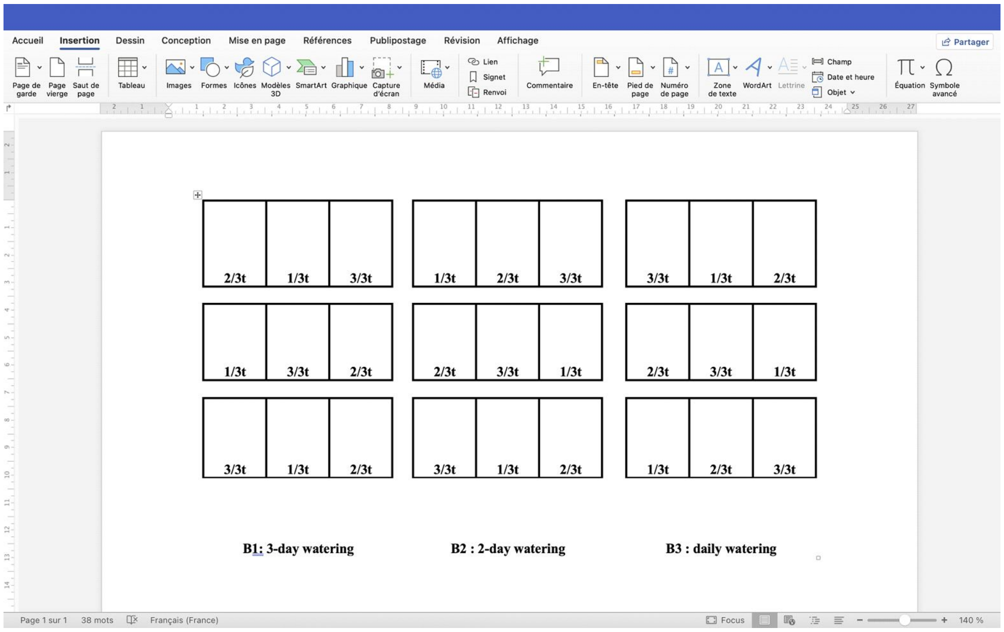

Figure 3. The experimental design

<u>Caption</u> :

3/3t :100% potting soil

2/3t : 2/3 potting soil ±1/3 sand

1/3t : 1/3 potting soil ±2/3 sand

B1 : block1=, 1f3j : 3-day watering

B2 : block 2 =1f2j : 2-day watering

B3 : block 3= 1fj : daily watering

Table 1. Watering status

	Daily watering	2-day watering	3-day watering
100% potting soil	**T0** (3t*1fj)	**T1** (3t*1f2j)	**T2** (3t*1f3j)

2/3 potting soil ±1/3 sand	**T3** (2t*1fj)	**T4** (2t*1f2j)	**T5** (2t*1f3j)
1/3 potting soil ±2/3 sand	**T6** (1t*1fj)	**T7** (1t*1f2j)	**T8** (1t*1f3j)

Growth trial

In December 12th 2020, sowing was carried out with three batches of seeds, i.e. two batches treated with 98% and 75% sulphuric acid and one batch treated with warm water. Each sheath contained 4 seeds, and each block contained 90 sheaths grouped into three small blocks with substrate (100% mango potting soil, 2/3 potting soil ±1/3 sand, and 1/3 potting soil ±2/3 sand). The watering was done with watering cans. After 5 days of watering, water stress was applied and distributed as follows: block 3 was watered daily, block 2 was watered every two days and block 3 was watered every three days. From day 45th, dendrometric parameters (diameter at the collar, height, number of leaves and number of thorns) were assessed every 15 days using a caliper and a ruler. In addition, leaves and thorns were counted manually. After carrying out three assessments, five sheaths in each sub-block were sacrificed for the measurement of the roots and the aerial part.

- **Statistical analysis**

Data were subjected to two-way analysis of variance (ANOVA) using XLSTAT software. The means of the measured variables were compared using the Fisher test at the 5% probability level. Results are considered significant when $P \leq 0.05$ and highly significant when $P < 0.001$.

3. Results

3.1. Germination rate

Germination tests in the laboratory started for all treatments, i.e. with sulfuric acid (98%, 75%, 50% and 10%) and lukewarm water, and lasted 7 days. The highest germination rates were noted with sulfuric acid doses of 98% and 75% with respective rates of 100% and 43.75%. As for the germination speed, seeds with 98% sulfuric acid dose recorded a germination rate of 80% and 100% on the first and fourth day respectively, while all remained treatments did not reach a germination rate of 50% during the seven days of germination tests (Figure 4).

Figure 4. Germination rate as a function of days.

3.2. Effect of treatments on growth parameters of *Faidherbia albida* (leaves, spines, height and collar diameter)

Number of leaves

The different treatments displayed highly significant differences in number of leaves ($p \leq 0.0001$). The highest number of leaves was observed with the treatments T1 (33.30 ± 11.95) and T4 (32.48 ± 10.22). The lowest number of leaves was noted with the treatments T2 (19.58 ± 9.67) and T8 (19.01 ± 8.21) (Figure 5).

Figure 5. Number of leaves according to treatments

Number of spines

Analysis of variance for the number of spines was significantly different ($p < 0.001$) among the different treatments. Germination rate was highest in treatment T1 (43,05 ± 16,13) and least in treatments T8 (25,38 ± 9.98) and T2 (24,4 ± 10.97). However, there was no significant difference among the treatments T0 (36,8 ± 13.38), T3 (34,61 ± 18,24), T6 (34,05 ± 19,46), and T5 (31,86 ± 12,58) (Figure 6).

Figure 6. Changes in number of spines as a function of treatment

Height

The analysis of variance showed significant differences among treatment ($p \leq 0.0001$) in height of plants (Figure 7). The greatest height of the plants was displayed with the treatment T1 (13.3 ± 3.17cm). The lowest heights were noted in the plants of the treatments T3 (10.91 ± 3.82cm) and T8 (10.82 ± 3.59cm). There was no difference among the observed heights of the plants with T4, T0, T5, T2, T7 and T6 treatments.

Figure 7 Evolution of plant height among treatments

Collar diameter

Figure 8 represents the evolution of the collar diameter among the treatments. The analysis of variance showed collar diameter was significantly different (p=0.001) among treatments. The treatment T1 had the largest collar diameter (3.18±0.44cm), while treatments T8 and T2 recorded the smallest collar diameter with values (1.63±0.54cm) and (1.54±0.46cm) respectively. No significant differences were observed for collar diameters of the plants among the treatments T4, T0, T3, T6, T5 and T7.

Figure 8. Evolution of collar diameter among treatments

Root length

Root length was significantly different (p = 0.04) among the different treatments (Figure 9). Root length was longest with treatment T5 (40.22 ± 13.74cm), followed by T2 (37.07 ± 11.72cm), T6 (31.44 ± 9.75cm), T8 (31.64 ± 8.84cm), and T0 (30.24 ± 10.08cm) (Figure 9). The lowest root length of plants was noted with T0 (30.24 ± 8.43cm).

Figure 9. Evolution of root length among treatments

- **Discussion**

The aim of this study was to contribute knowledge on *Faidherbia albida* production techniques. Results showed that treatment with sulfuric acid or lukewarm water is necessary to obtain faster germination of *F. albida* seeds. Seeds treated with sulfuric acid 98% (100%) give the best germination rate compared to other treatments, i.e. 75% (43.75%), 50% (31.25%), 10% (18.75%) sulfuric acid doses, and lukewarm water (37.5%). These results corroborate the work of CTFT (1988) et Iroko et al., (2021), who highlighted the importance of sulfuric acid pre-treatment in the germination of *F. albida* seeds, as well as studies carried out on leguminous (Aliero, 2004; Aref et al., 2011; CTFT, 1988; Fredrick et al., 2017; Mojeremane, W. Makgobota et al., 2020; Sy et al., 2001). Indeed, the CTFT (1988) showed that *F. albida* seeds treated with sulfuric acid for 5 minutes develop a germination rate ranging from 32 to 92%. Iroko et al., (2021), demonstrated that pretreatment of *F. albida* seeds with sulfuric acid (H2SO4 concentration) for 15 minutes gave the best results in terms of germination value. These results could be due to the rapid dissolution of the seed coat, which allowed rapid penetration of water into the seeds. Chuyong & Acidri (2015), also Fredrick et al., (2017) showed that nicked pre-sowing treatment of *Faidherbia albida* seeds had the highest cumulative germination percentages. Leguminous seeds from dry areas are generally hard (Baskin & Baskin, 2004; Garba et al., 2020; Teketay, 1996). They have integuments that are impermeable to water and oxygen inducing integumentary inhibition (Werker, 1981). This dormancy allows long-term seed conservation but needs to be lifted before sowing, otherwise germination will be very erratic (Cavanaght, 1987). Acid scarification of seeds is an effective method for breaking dormancy and improving germination of seeds with hard, impermeable seed coats (Botsheleng et al., 2014; Likoswe et al., 2008; Mcdonald & Omoruyi, 2003).

Sulfuric acid disrupts the seed coat by allowing the water access and triggering germination (Amusa, 2011; Mojeremane, W. Makgobota et al., 2020; Nikoleave, 1977) by its ability to remove the waxy layer or hard matter from the seed coat (Agbogidi et al., 2007; Bhattacharya & Saha, 1990). In addition, sulfuric acid stimulates the biochemical and physiological activities necessary for germination (Akinyele & Ibeh, 2020). The lower germination rate obtained by soaking in sulfuric acid at lower concentrations could be explained by the fact that the seed coat has not been softened sufficiently to allow water and oxygen to pass through (Aduradola and Badru, 2004).

The lower germination rate observed with seeds soaked in lukewarm water could be explained by the impact of the soaking time. Immersion of *Faidherbia albida* seeds in boiled water for between 30 and 180 seconds yielded significantly higher final germination percentage (Akpalu et al 2019).The later affects the germinative capacity of certain seeds whose rate of tegumental impermeability varies according to the internal and external physiological state of the embryo (Rakoto et al., 2022). The harder a seed is, the more resistant it is to the effects of dormancy-breaking factors; the softer the seed, the less resistant it is to the environmental conditions that affect germination.

One characteristic of plants in semi-arid environments such as the Sahelian savannah is that they have a high degree of temporal and spatial variation in growth variables, which in turn depends on the variability of the environment, particularly soil moisture (Abdelrahman and Krzywinski, 2008). In the morphological development of young *F. albida* seedlings in a nursery, significant differences in growth parameters were observed among treatments. Treatment that consisted of 100% potting soil and watering once every two days showed the best growth for all the parameters monitored (height, number of leaves and number of spines) except for root length. This growth can be explained by the abundance of nutrients at the substrate level (100% potting soil). These results are like the findings of Le Bouler et al., (2012), who showed that the substrate alone determines the physiological quality of the plant. However, Diémé et al., (2019) showed that the relative growth speed (RGS) of young Sahelian tree species including *F. albida*, increases soil water and nutrients inputs increase.

Root length was greater in the 2t1f3j treatment. This difference in root length may be due not only to the porosity of the substrate (2t), made up of a mixture of potting soil and sand, which provides good air and water circulation, essential for root development; but also to the close watering frequency (1f2d) with relatively high humidity, which induces permanent humidity at the root level and which results in a slowdown in root elongation at the 3t1f2d level. Excess water reduces the density of long new roots than new short roots (Levy, 1981). Alternatively, when plants are watered once every three days, they tend to develop a mechanism for absorbing water, which results in the elongation of the roots of plants that received the 2t1f3j treatment.

In sum, this study confirms the findings of Diémé et al., (2019), who showed that *F. albida* and *Acacia tortilis* have great plasticity at the level of functional traits, which enables them to adapt to variations in water resources and soil nutrients.

- **Conclusion**

This study highlighted the fact that treating *F. albida* seeds with sulfuric acid is more effective than treating them with water in breaking dormancy. Monitoring of growth parameters highlighted the importance of substrate and water content in the development of young plants. It showed that 100% potting soil and watering once every two days is the best treatment for the development of seedlings at the beginning of their growth in the nursery. Watering should be spaced out to encourage root elongation.

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