***Original Research Article***

**Germinative qualities and dynamics of juvenile growth of *Pterocarpus erinaceus* Poir. (Fabaceae) in a semi-controlled environment in the north of Côte d'Ivoire**

**Abstract**

**Aims:** The aim of the study is to help improve the conditions for domesticating the species in the Sudan region.

**Study design:** The experimental design adopted for this study consisted of randomised blocks with 4 replications. Pterocarpus erinaceus seed was the primary factor, while abiotic factors (light intensity, sowing depth and soil type) served as secondary factors.

**Place and Duration of Study:** The work was carried out in Kouto, in the north of Côte d'Ivoire, over a period of 26 months, under natural conditions.

**Methodology:** For this purpose, the fruits harvested and subjected to three pre-germination treatments (untreated whole fruits, shelled fruits and fruits soaked in water) were germinated under the effect of three abiotic factors (intensity of sunlight, sowing depth and soil type). The germination parameters and the growth kinetics of the plants (height and diameter of the crown) were evaluated.

**Results:** The results show that the hulled fruit seeds have the best latency times (4.4 ± 1.67 days) and germination rate (77 ± 11.27%) in shaded areas. The seeds must be sown to a maximum depth of 2 cm to obtain good germination performance. The height growth of the seedlings (21.28 ± 6.72 cm) was relatively higher than that of the strains (20.23 ± 7.59 cm) in shaded conditions.

**Conclusion:** Reproduction by strains is therefore an alternative to fruit conservation and a complementary technique to nursery production for the reforestation of the species.

**Keywords***: Domestication, germination performance, growth kinetics, Pterocarpus erinaceus, Côte d’Ivoire*

1. **INTRODUCTION**

*Pterocarpus erinaceus* Poir. (Fabaceae), commonly called Ven or Senegal Rosewood, is a spontaneous species of economic and ethnobotanical interest, endemic to the Guinean-Sudanian and Sudano-Sahelian zones of Africa (Ouédraogo et al. 2006; Segla et al. 2015). It is a species of timber widespread from Senegal to the Central African Republic. The natural niche of the species is mainly found in West Africa where the species occupies almost 17.48% of the total area of this geographical area (Adjonou et al. 2020). The species is exploited in Africa for a whole range of non-wood products including food for human consumption, fodder for animals (Petit and Mallet 2001), medicinal products and raw materials for handicrafts (tannins, dyes, sap, resin, etc.). In the field of pharmacopoeia, the bark, leaves and roots are used to treat several ailments including malaria, and childhood fever (Segla et al. 2015; Ouedraogo et al. 2011). In handicrafts, wood is used for the manufacture of balafons, handles of agricultural tools etc. (Rabiou et al. 2015). Also, the leaves of the species are used as fodder for livestock (Silué et al. 2014). These technological qualities make the species one of the best timbers in West Africa, very appreciated for cabinetmaking, heavy carpentry, and exterior carpentry (Segla et al. 2015; Ouedraogo et al. 2011). Given the ecosystem goods and services that *P. erinaceus* provides to local populations, it is under strong anthropogenic pressure that threatens its natural populations. The overexploitation of the wood of ven has led to its inscription on the list of threatened species since 2018 (UICN 2018).

In Côte d'Ivoire, its illegal harvesting and marketing have been remarkable during the period of political instability in the Sudanese sector where logging is prohibited. The country comes in third position among the West African countries where the exploitation of pine wood has increased in recent decades (CITES 2017). Faced with this situation, which threatens the species with extinction, its exploitation in all its forms was prohibited in 2013 by Decree n° 2013-508 of July 25, 2013 (MINEF 2013). However, anthropogenic pressures (extensive agriculture, overgrazing, bushfires) and the effects of climate change appear today as factors aggravating threats to the species at the national level.

Unfortunately, although it is a utilitarian plant and its state of conservation is worrying in Côte d'Ivoire, *P. erinaceus* is relegated to a marginal place in reforestation campaigns. To overcome this situation and give it a silvicultural importance, it is necessary to know its reproductive potentialities to find appropriate strategies for conservation and sustainable management of its resources. Also, the scientific work carried out on the spread of the species in Côte d'Ivoire is fragmentary (Bamba et al. 2018). In such a context, the capitalization of information relating to the artificial regeneration of the species should constitute a solution for the domestication of the plant. It is with this in mind that this study was carried out to contribute to the improvement of the domestication conditions of *P. erinaceus* in Côte d'Ivoire. Specifically, the study aims to determine the effect of different abiotic factors on the development and juvenile growth of *P. erinaceus* in a controlled environment.

1. **MATERIALS AND METHODS**

**2.1 Study area**

Rangers Agent Cantonment of Waters and Forests of the Kouto Department, located in the Bagoué region in North-Western Côte d'Ivoire (Fig. 1). The climate is of the Sudanese type, marked by two contrasting seasons: a long dry season of 7 months (November to May) and a short rainy season of 5 months (June to October). The average annual temperature is 26.7°C. In this area, rainfall is irregular with an average annual rainfall of 1300 mm/year (Cort and Kenji 2001). The vegetation is characterized by savannas (wooded and shrubby) and open forests in which islands of gallery forests remain (Kouamé et al. 2010).



**Fig. 1. Geographical location of the study area**



**2.2 Materials**

The study material is composed of the biological material and the technical material. The biological material consists of seeds (fruits and seeds) and stumps of *P. erinaceus* (Fig. 2). The stumps are portions (15-20 cm) of plants whose aerial part was removed above the first buds (Silué et al. 2017) and taken from a nursery made one year rather. The technical equipment consists of the equipment usually used by the nurseryman (polyethylene plastic film bags, watering can, graduated ruler, vernier caliper, potting soil, etc.).

**Fig. 2. Overview of the *Pterocarpus erinaceus* plant material used: (a) seeds; (b) stumps.**



**2.3 Sampling and data collection**

**2.3.1 Harvesting fruits**

The fruit used for all the experimental trials was harvested in village plots in the department of Kouto. The pods were collected from eight (08) seedbeds identified according to the four cardinal points for their high productivity and seed quality. The collected pods were mixed and sampled. Part of this sample was dehulled, resulting in two (2) batches: one batch of pods and one batch of seeds. The stumps were taken from plants produced in the nursery a year earlier.

**2.3.2 Pre-germinative seed treatments**

The fruits harvested in the field were divided into three seed batches corresponding to the three pregermination treatments used in the germination trial: treatment 1 (T1) for whole pods without prior treatment (Control); treatment 2 (T2) for whole pods soaked in warm water for 48 hours; treatment 3 (T3) for seeds from pod hulling.

**2.3.3 Experimental set-up**

The experimental set-up consisted of a series of blocks, the number of which varied according to the factors studied, made up of 100 bags of nursery stock corresponding to the different treatments applied during the trials. Each block is subdivided into four (4) sub-blocks (or replicates) of 25 bags each, corresponding to the experimental unit (Fig. 3). The experimental trials were carried out under the effect of three abiotic factors. These were sun intensity, sowing depth and soil type (Silué et al. 2017). The intensity of sunshine was characterised by a set-up consisting of two environments: a sunny or open environment and a shady environment provided by a canopy made up of a screen heavily covered with oil palm leaves Silué et al. (2021). The influence of sowing depth on germination parameters was demonstrated by sowing at different depths: 1 cm; 2 cm; 3 cm; 4 cm; 5 cm; 7 cm and 9 cm. To study the variation in soil type on seed germination qualities, trials were carried out on sandy, clayey and gravelly soils, corresponding to the main soils encountered in the study area (Silué et al. 2017; Silué et al. 2021).

**Fig. 3. Diagram of the unitary experimental system for sowing *Pterocarpus erinaceus* seeds**



**2.3.4 Data collection**

The germination trials were carried out over 26 weeks under natural conditions. Germinated seeds were counted every day for 15 days, and healthy ungerminated seeds were counted at the end of the experiment, in order to evaluate and express the germination parameters. A seed is considered to have germinated when the stem appears above the substrate, which corresponds to emergence.

The study of the growth of *Pterocarpus erinaceus* plants consisted in measuring the height between the collar and the terminal bud and the diameter at the collar of 15 individuals of plants resulting from seed germination and 15 individuals of plants resulting from stumps, taken at random from batches of 100 individuals of each category of plant material, following the work of Silué et al. (2021). Measurements were taken monthly for five months, in shaded and sunny conditions.

**2.4. Expression and statistical analysis of data**

The comparison focused on the following parameters:

* the Latency Time (LT) which represents the time taken to observe the first germination;
* Germination Rate (GR), which represents the percentage of germinated seeds at the end of the trial;
* Germination Energy (GE), is the percentage of seeds (by number) that germinate up to the moment of maximum germination, generally corresponding to the 24 hours when the greatest number of germinations occur (Willan 1992; Bationo 1994).
* the Crop Value (CV), which is the expression of the combination of the germination rate and the purity rate, which is the sum of germinated seeds and those likely to germinate divided by 100 (Cuisance 1978; Toure 2001).
* Growth speed (GS) in plant height, which is the proportion of maximum growth per unit of time over a given period (Silué et al. 2017).

The data were processed using an Excel spreadsheet and XLSTAT version 2014 and R 3.2 software. Data on germination parameters, plant height and collar diameter were subjected to Student's t-test and Mann-Whitney test for significance of means. For the study on the effect of variation in sowing depth, where several parameters with qualitative and quantitative characteristics were taken into account, Multiple Factor Analysis (MFA) was used.

1. **RESULTS AND DISCUSSION**

**3.1 Results**

**3.1.1 Effect of sunshine intensity on seed germination qualities**

For the lag time, the seeds on a shaded medium recorded the lowest average value of 4.4 ± 1.67 days (Table 1). The highest value was obtained with untreated pods on shaded media (9 ± 0.71 days). The differences between the mean values are significant (P ˂ .001). For germination rate, the highest mean value was obtained with seeds on shaded media (77 ± 11.27%). The lowest value was observed in the pods treated in a sunny environment, with 52.2 ± 3.35%. The differences between the mean germination rate values are significant (P ˂ .001). For germination energy, the highest mean value was obtained with seeds in a shaded environment (39.13 ± 24.55%). The lowest mean value for this parameter, 25 ± 7.38%, was obtained with untreated pods in a shaded environment. The differences between the mean values were not significant (P = .29). In terms of cultural value, the seeds in the shaded area recorded the highest rate (68.23 ± 6.42%). The lowest rate was recorded for untreated pods in sunny conditions (31.54 ± 4.69%). The differences between the mean values of the crop value are highly significant (P ˂ .001).

**3.1.2 Effect of soil type on seed germination quality**

Table 2 shows the cultivation results obtained on the different soils. The clay soil recorded the species' shortest germination time (8.6 ± 0.55 days). The differences between the mean values are significant (P = .02). In terms of germination rate, the sandy soil recorded the highest germination rate, 55.6 ± 7.02%. The gravelly soil had the lowest germination rate (53.2 ± 4.87%). The differences between the mean values were insignificant (P = .86). In terms of germination energy, the gravelly soil recorded the highest mean value, 31.31 ± 3.81%, while the sandy soil recorded the lowest value (24.4 ± 2.9%). The differences between the mean values are significant (P = .02). In terms of crop value, the sandy soil produced the best mean value, at 31.31 ± 7.92%. The gravelly soil produced the lowest value, 4.95 ± 1.31 (P < .001).

Table 1. Mean values of the main germination parameters for different types of *Pterocarpus erinaceus seed in shaded and sunny environments*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Types of treatments | LT (days) | GR (%) | GE (%) | CV (%) |
| Seeds in shaded areas (T3) | 4,4 ± 1,67a | 77 ± 11,27a | 39,13 ± 24,55a | 68,23 ± 6,42a |
| Seeds in sunny conditions (T3) | 8 ± 2cb | 61,8 ± 8,55b | 35,8 ± 8,04a | 32,99 ± 10,26b |
| Treated pods in shaded area (T2) | 7 ± 0,71b | 59 ± 7,17bc | 28,8 ± 9,09a | 38,06 ± 10,84b |
| Treated pods in sunny conditions (T2) | 7,8 ± 0,45cb | 52,2 ± 3,35c | 39 ± 7,97a | 32,63 ± 2,21b |
| Untreated pods in shaded areas (T1) | 9 ± 0,71c | 54,2 ± 7,2bc | 25 ± 7,38a | 31,99 ± 10,26b |
| Untreated pods in sunny conditions (T1) | 8,6 ± 0,55c | 56,80 ± 1,64bc | 27,6 ± 1,14a | 31,54 ± 4,69b |
| Statistique du test | *p ˂ 0,000* | *p ˂ 0,0001* | *p = 0,29* | *p ˂ 0,0001* |

LT = Latency time; GR = Germination rate; GE = Germinative energy; CV = Crop value

NB: in each column, there are no significant differences between the averages followed by the same letter at the threshold of α = .05

Table 2. Average values of the main germination parameters of *Pterocarpus erinaceus* seeds *by soil type*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameters | Sandy soil | Clay soil | Gravelly soil | Test statistics |
| TL (day) | 10,6 ± 0,55a | 8,6 ± 0,55b | 9,1 ± 0,89ab | *χ² = 9,63 ; p = 0,002* |
| TG (%) | 55,6 ± 7,02a | 53,2 ± 8,98a | 53,2 ± 4,87a | *F = 3,77 ; p = 0,86* |
| EG (%) | 24,4 ± 2,96a | 25,4 ± 3,04a | 31 ± 3,81b | *F = 3,77 ; p = 0,02* |
| VC (%) | 31,31 ± 7,92a | 28,95 ± 9,42a | 28,49 ± 5,10a | *F = 3,77 ; p = 0,83* |

TL = Latency time; TG = Germination rate; EG = Germinative energy; VC = Crop value

NB: on each line, there are no significant differences between the averages followed by the same letter at the threshold of α = .05

**3.1.3 Effect of sowing depth on seed germination quality**

Fig. 4 shows the factorial map of the Multiple Factor Analysis relating to the influence of sowing depth on the germination parameters of *Pterocarpus erinaceus* seeds. Examination of the first factorial plane of the variables reveals an axis 1 that describes, on the positive side, sowing depths P1 and P2. On the negative side, we have seeding depths P3 and P4. According to this axis, these two groups of depths are distinct in terms of germination parameters. Axis 2 describes, on the positive side, depths P2 and P9 and, on the negative side, depths P1, P3, P5 and P7. According to this axis, the two groups of depths are distinct based on germination parameters. Latency time and germination energy had a significant effect on depth distribution, with P < .001 and P = .01 respectively.

The factorial map shows three groups. The first group is P4, the second is P3 and the third is P1 and P2. The variables' correlation circle (Fig. 5) shows strong relationships between crop value, germination energy and germination rate. All these variables are negatively correlated with the lag time.

The mean values of the germination parameters for each group are given in Table 3. Germination time was higher, 20.6 ± 0.55 days for group G1. It was reduced to less than a third for group G3, which recorded the best delay (6.5 ± 0.53 days). For the germination rate, group G3 recorded the highest value, 68.2 ± 10.03%. Outside this group, the rates were very low, with values as low as 4.2 ± 0.84% in group G1. Concerning germination energy, the maximum average value for this parameter was 36.4 ± 5.98% in group G3. As for cultivation value, G3 stood out with an average value of 49.51 ± 13.74%. The value of this parameter is very low for the other groups.

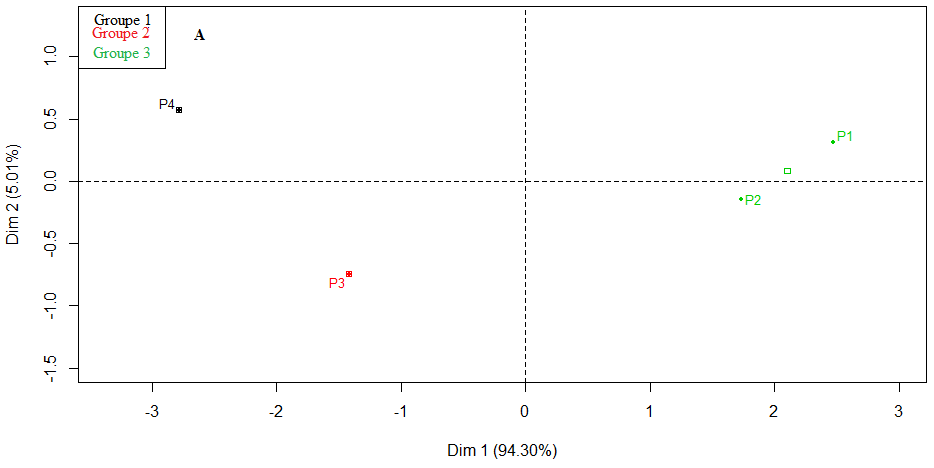
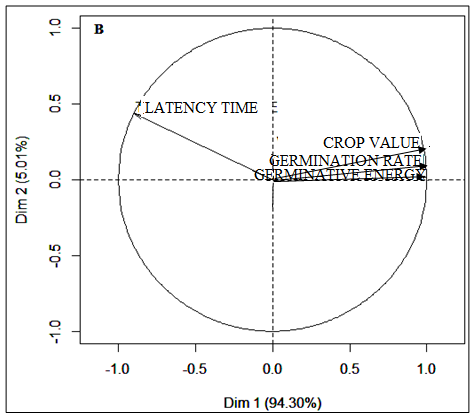


Fig. 4. Factor map of the effect of sowing depths on germination parameters of *Pterocarpus erinaceus* seeds

**Fig. 5. Correlation circle between germination parameters of *Pterocarpus erinaceus* seeds**



**3.1.4 Effect of sunshine intensity on the growth of seedlings germinating from seeds and stumps**

Table 4 summarises the evolution of the parameters of the growth dynamics of the two types of *Pterocarpus erinaceus* plant material. From the first month of the trial, the shaded environment induced a relatively higher growth in height of the seedlings, 9.02 ± 1.69 cm, than the sunny environment, 6.41 ± 2.91 cm. The differences between the mean values are significant (P < .001). After five months of growth (Figure 6), the results were the same, with values of 21.28 ± 6.72 cm in the shaded environment, compared with 14.93 ± 5.46 cm in the sunny environment (P = .01). The results are similar for the average seedling growth rate.

The stumps grew to 6.41 ± 2.91 cm in the shade and only 4.69 ± 1.46 cm in the sun (p = 0.004). By the 5th month of growth (Fig. 6), plants grown in the shade had reached a height of 20.23 ± 7.69 cm, compared with 13.36 ± 2.3 cm for those grown in the sun (P = .04). The average shoot growth rate was 3.13 ± 1.55 cm/month in the shade, compared with 1.76 ± 0.52 cm/month in the sun (P = .03).

The comparative analysis of the vertical growth of the two types of plant material shows that plants grown from seeds do not grow significantly more than plants grown from stumps in a shaded environment (P = .72) and in a sunny environment (P = .38).

For growth in diameter, the sunny environment induced better growth in seedlings (0.34 ± 0.06 cm) compared with the shady environment (0.3 ± 0.07 cm), over the five-month observation period (P = .12). The results were identical for plants grown from stumps, with values of 0.35 ± 0.08 cm for the sunny environment and 0.34 ± 0.13 cm for the shady environment (P = .77).

A comparative study of the growth in diameter of the two types of seedlings (Fig. 7) shows that the shoots from the stumps grow relatively faster, without any significant effect than the seedlings from germination of the seeds, in the shaded environment (P = .44) and in the sunny environment (P = .61).

Table 4. Mean values for growth parameters of Khaya senegalensis plant types as a function of environment (shaded, sunny)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Growth parameters | Origin of seedlings | Shaded area | Sunny environment | Test statistics |
| Mean initial total height (cm) | Seeds | 9,02 ± 1,69 | 6,21 ± 0,82 | t = 5,54 ; P ˂ .001 |
| Stumps | 6,41 ± 2,91 | 4,69 ± 1,46 | U = 82,5 ; P = .16 |
| Final average total height (cm) | Seeds | 21,28 ± 6,72 | 14,93 ± 5,46 | U = 97 ; P = .02 |
| Stumps | 20,23 ± 7,59 | 13,36 ± 2,3 | t = 1,02 ; P = .31 |
| Average height growth rate (cm/month) | Seeds | 2,45 ± 1,36 | 1,74 ± 1,04 | t = 2,39 ; P = .02 |
| Stumps | 2,7 ± 1,91 | 1,73 ± 0,5 | U= 80 ; P = .03 |
| Average collar diameter (cm) | Seeds | 0,3 ± 0,07 | 0,34 ± 0,06 | U= 61 ; P = .12 |
| Stumps | 0,34 ± 0,13 | 0,35 ± 0,08 | t = 0,3 ; P = .77 |

**Fig. 6. View of 5-month-old *Pterocarpus erinaceus* seedlings: (a) sunny environment; (b) shady environment.**



**Fig. 7. Growth in diameter of *Pterocarpus erinaceus* plants as a function of the environment**



**3.2 Discussion**

The results of this study showed that, overall, *Pterocarpus erinaceus* seeds take longer to germinate in a sunny environment than in a shady one. In the case of shelled seeds, the effect of shade reduced germination time by almost half. Kouamé (2009), studying the effect of elephant droppings on the germination of seeds of forest species, obtained similar results. It could be argued that sunlight, which reduces substrate humidity, slows down the metabolic reactions of the embryo and hence the rapid emergence of the radicle in this species. Seed germination is also prolific in shaded conditions, with a high germination rate of 77%, particularly with seeds. However, all the germination rates obtained were above 50%. These rates are higher than those obtained by Bationo (1995) and Touré (2001). These differences in results may be linked to the type of substrate used for the trials, the storage time of the seeds and probably the health status of the fruits of the species (Touré 2001; Niang-Diop et al. 2010).

For germination energy, a parameter that provides information on the survival and mortality of seedlings after the germination stage, the values remain below 50%, although the shaded environment has a better influence on this parameter. Touré (2001) obtained a rate of 41 p.c. with seeds of the species in Burkina Faso. Hulled seeds, sown in a shaded environment, are therefore the treatment that offers the germination potential to facilitate and encourage the production of seedlings in the nursery.

Concerning the cultural value of the seeds, an expression used by certain authors to determine the quality of a batch of seeds, the highest values are obtained in a shaded environment, with an average relatively higher than 50% for the seeds. This rate shows that a smaller quantity of seed should be used in a shaded environment than in an open environment, to ensure that the seed is not too light (Cuissance 1978; Touré 2001).

The results of germination trials on the three soil types show that the effect of soil type is not very significant on the germination parameters of *P. erinaceus*. The germination rates were identical on the different soils, although the gravelly soil significantly reduced the latency time. These fluctuations in results from one soil to another show that the effect of soil type has little influence on the germinative qualities of *P.* *erinaceus* seeds and that the differences observed are due to the sanitary state of the seeds mentioned by Touré (2001). This factor is at the origin of low germination rates (< 50 %) and crop value.

The results of germination trials at different depths show that sowing depth significantly affects germination parameters. There is a sharp drop in germination parameter values from a depth of 3 cm. In *P. erinaceus*, which germinates epigeously, there is no tolerance threshold for sowing depth. The germination capacity of the seeds depends on the mechanical strength and thickness of the top layer of soil through which the seed stalk has to grow (Gerard 1980). Our results corroborate those of Bowers and Hayden (1972) on bean germination trials.

In terms of the growth kinetics of the various *Pterocarpus erinaceus* seedlings, the shaded environment resulted in better growth in height over the five months of observation. High light intensities would therefore be detrimental to the development of young *P. erinaceus* plants. Kouadio et al. (2008) also reported the beneficial effect of a shaded environment on the height growth of seedlings produced in a nursery. This strong growth in shaded plants is thought to be due to the phenomenon of wilting (Prat 2008; Vitre 2012). According to these authors, light inhibits the action of auxin and slows stem growth, resulting in shorter plants in plots exposed to the sun. However, this initial growth of *P. erinaceus* plants is lower than that of certain forest species such as *Carapa procera* (53.3 cm) and *Quercus suber* (59.33 cm), obtained respectively by Sanogo et al. (2013) and El Boukhari et al. (2013). This initially slow growth of *P. erinaceus* could be linked to the development of the root system (hypertrophy of the root pivot), which reflects the tendency of seedlings to favour root growth to the detriment of above-ground growth in the early stages of development (Bationo et al. 2010).

Regarding growth in diameter, the plants, whatever their origin, develop better in a sunny environment. Kouadio et al. (2013) obtained different results with *Guibourtia ehie*. These differences in results are in line with the conclusions of M'sadak et al. (2013), who state that crown diameter is a variable that integrates the morphological response to environmental factors.

Furthermore, in the same environment, no significant effect of the nature of the plant material on plant growth dynamics was noted. This can be explained by the fact that stumps, derived from plants that are about a year old, have stored nutrient reserves that ensure the rapid recovery and growth of regrowth (Silué et al. 2021). The multiplication through stumps would therefore constitute an alternative to the conservation of *P. erinaceus* fruits.

1. **CONCLUSION**

This study assessed the effect of some abiotic factors on the germination and growth of *Pterocarpus erinaceus*. This study is therefore a source of additional information for the domestication of the species. Under the experimental conditions, which were very similar to those in the natural environment, the seeds produced good germination qualities in a shaded environment.

The study revealed that pod hulling is the treatment that offers the best germination capacity. The different types of soil used in the trials, corresponding to the main soils encountered in the study area, produced similar germination potential. In addition, analysis of the effect of seed sowing depth showed that germination potential was better for seeds sown no more than 2 cm deep. For monitoring growth kinetics, the shaded environment offered the best growth potential and produced vigorous plants. Under the conditions of the trial, juvenile growth of *P. erinaceus* was better with stumps. The production of seedlings from this plant material would therefore provide a solution to the problem of conserving the fruits of this species in natural conditions.

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