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Original Article

Variability of Seed Germination and Seedling Growth Potential of *Ricinodendron heudelotii* (Euphorbiaceae) at Fine Scale in Southern of Benin

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ABSTRACT

Ricinodendron heudelotii (Euphorbiaceae) is an oilseed plant with high socio-economic value. Unfortunately, the seed's tegumentary dormancy causes low germination and severely limits its large-scale spread. Germination and juvenile growth of eleven provenances from Benin and Central African Republics were tested under four different pre-treatments (control, lime scarification, soaking in water for seven days and scarification followed by soaking in water for three days) in order to provide information for use in the reforestation and improvement of *R. heudelotii*. In a Fischer block with three replicates of ten seeds, the daily and final germination (nine months) was recorded and the cumulative germination rate, average germination time and survival rate were calculated. In addition, total height, diameters at the collar and above the cotyledons, internode length, total number of leaves and seedling internodes were measured quarterly. Germination and growth of juveniles were significantly different between provenances and pre-treatments. The highest germination rate (%) in short duration (d) was recorded with seeds both scarified and soaked for three days in water from Akouho (20%, 42.08 d), CRAPP (36.67%, 18.82 d), Agrimey (33.33%, 18.30 d), Ilikimou (26.67%, 19.94 d) and Woroko (26.67%, 19.25 d) and then lime scarified seeds from Massi (80%, 14.46 d), Itchede (80%, 21.29 d) and Lobaye (60%, 19.11 d). Seedlings from seeds that were scarified and soaked for three days in water showed optimal growth for all traits; Lobaye and CRAPP provenances showed the best height growth (33.22±1.45 and 31.96±1.15 cm) while Massi and Illikimou provenances showed the best growth in collar diameter (1.08±0.06 and 1.11±0.09 cm). Provenances and pre-treatments revealed a discrete variation in germination and growth of *R. heudelotii*. Scarification on the one hand and scarification coupled with soaking into the water for three days on the other hand, are the best pre-treatments to increase seedling production while the best provenances are Lobaye, Massi and Itchede. These provenances are potential seed sources for Forestation Program in Benin.

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INTRODUCTION

Seed germination is a priority in programs for the restoration, conservation and sustainability of forest reserves. Efficient germination, rapid growth and seedling survival are priority characteristics sought in forest restoration (Campos Filho and Sartorelli, 2015). Some seeds have an integumentary dormancy that inhibits germination under normal conditions (Imchen et al., 2015). Therefore, pre-treatments are applied to suppress dormancy and increase the germination rate of these seeds (Debroux et al., 1998). Several authors have shown that mechanical scarification (Ye et al., 2019; Al-Fredan and Ali, 2008), water immersion (Hossain et al., 2018; Marie-Thérèse et al., 2012; Kumar et al., 2007) are pre-treatments that contribute to increasing the germination rate and juvenile growth of seedlings of several useful plant species.

Ricinodendron heudelotii (Baill.), commonly called African wood oil nut tree belongs to the family Euphorbiaceae and is localised from Guinea to Angola (Vivien and Faure, 1985) and Madagascar (Heim et al., 1919). It is a polyvalent species, whose seeds are oleaginous and proteinous (Busson, 1965; Kapseu and Tchiegang, 1995; Tchiegang et al., 2003; Kouame et al., 2015), rich in nutrients and minerals and regularly consumed by local populations (Saki et al., 2005). Leaves and bark have medicinal functions against ovarian cysts (Ngene et al., 2015); obstetric fistulas (Lagou et al., 2016); haemorrhoids (Dibong et al., 2015); kidney problems, injuries and muscle pain (Nole et al., 2016). The leaves also have a purgative effect (N'guessan et al., 2009) and facilitate childbirth in association with *Ehretia cymosa* (N'guessan et al., 2011). The trade of seeds on the European market significantly increases the economy and survival of farmers (Cosyns et al., 2011; Tabuna, 1999) and women (Ayuk et al., 1999). The almond is a potential raw material for agro-food industries (Tchiegang et al., 1997) and makes the species to be the 3rd priority one in West Africa (Leakey and Tomich, 1999), and that should be introduced in agroforestry to meet an ever-increasing demand (FAO, 2016).

In Benin, once considered the most abundant species (77.6%) in the tree stratum of the semi-deciduous Pobè forest (Sokpon, 1995), it is currently rare in open areas. Therefore, the exploitation of *R. heudelotii* has already reached protected areas at the request of the Royal Authority (A. Badou, personal communication, September 2018). Indeed, Guèlèdè masks, mainly made from the wood of *R. heudelotii* (Boko-haya et al., 2017) have now acquired a high market value due to the tourism associated with them since the recognition of Guèlèdè as intangible heritage by UNESCO in 2010.

However, seeds of this species do not germinate without prior treatment (Mapongmetsem et al., 1999) due to their tegumentary dormancy (Djeugap et al., 2014). In view of its multiple uses, the lifting of seed inhibition in the germination process has been discussed by several authors. The suppression of seed coat dormancy was tested by soaking seeds in water (Katende et al., 1995), by lime scarification (Vivien and Faure, 1996) with a germination rate of 40%, or by hammer scarification with a germination rate of 88% (Djeugap et al., 2014). It has been reported that the seed source is also a key factor influencing germination rate and seedling growth (Akaffou et al., 2019; Bischoff et al., 2010; Fredrick et al., 2017; Kheloufi and Mansouri, 2017; Fredrick et al., 2015). Due to the ongoing anthropic pressure in Benin and especially its sharply increasing demand, there is an urgent need to seek sources of seeds with better germination performance. With the aim of valorising this species in Benin in order to exploit its oleaginous potential within the framework of research on species with strong biofuel properties, the present study was conducted. The study aimed at testing the provenances (Benin ones and Central African's) and the different pre-treatments on seed germination rate in order to identify the best ones for germplasm collection for large-scale production. The fundamental question of the study was which pre-treatments and seed provenances offer the best germination rate and juvenile growth of *R. heudelotii*? The objective of this study is to test the influence of various pre-treatments and seed sources on germination and juvenile growth of *R. heudelotii*. This study will provide an information base for the choice of early selection criteria to be taken into account in future *R. heudelotii* seedling production and selection programs.

MATERIAL AND METHODS

Study Environment

The germination test was carried out in the Akassato district (6°30'25.207 "N, 2°20'58.382 "E, 39.01767 m) characterised by a sub-equatorial climate with two dry seasons and two rainy seasons. The long rainy season extends from mid-March to mid-July and the short one from mid-September to mid-November, with an average annual rainfall of 1500 mm and an average temperature of 27 °C. The *R. heudelotii* seeds used to come from two southern Phyto districts (Pobè and Plateau) located in the Guinean climatic zone where the average annual rainfall is 1200 mm and the average temperature is between 25 °C and 29 °C (*Figure 1*). The soils are deep ferritic with low fertility. In addition, exotic seeds from the Central African Republic were collected in the semi-deciduous dense forest of the Lobaye under a Guinean forest-type climate (Aubréville, 1984) with ferritic soils of relatively low fertility (Boulvert, 1996).

Figure 1: Areas of the study in the Benin Republic

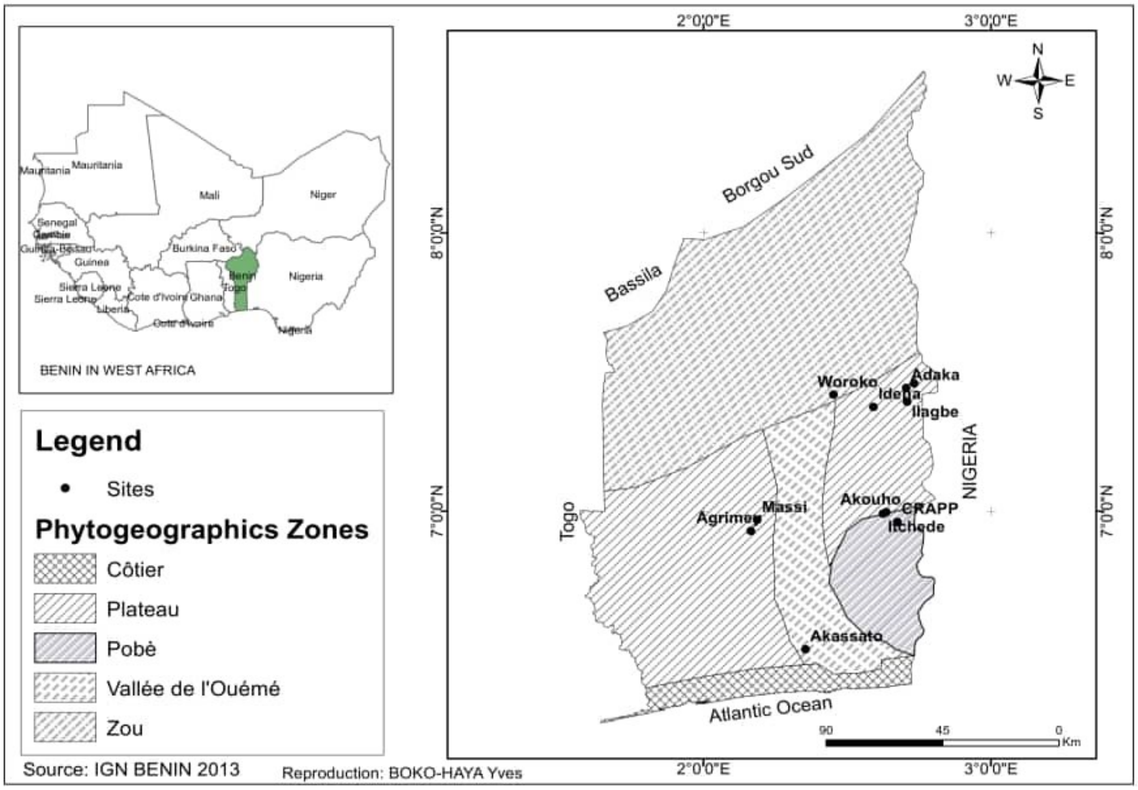
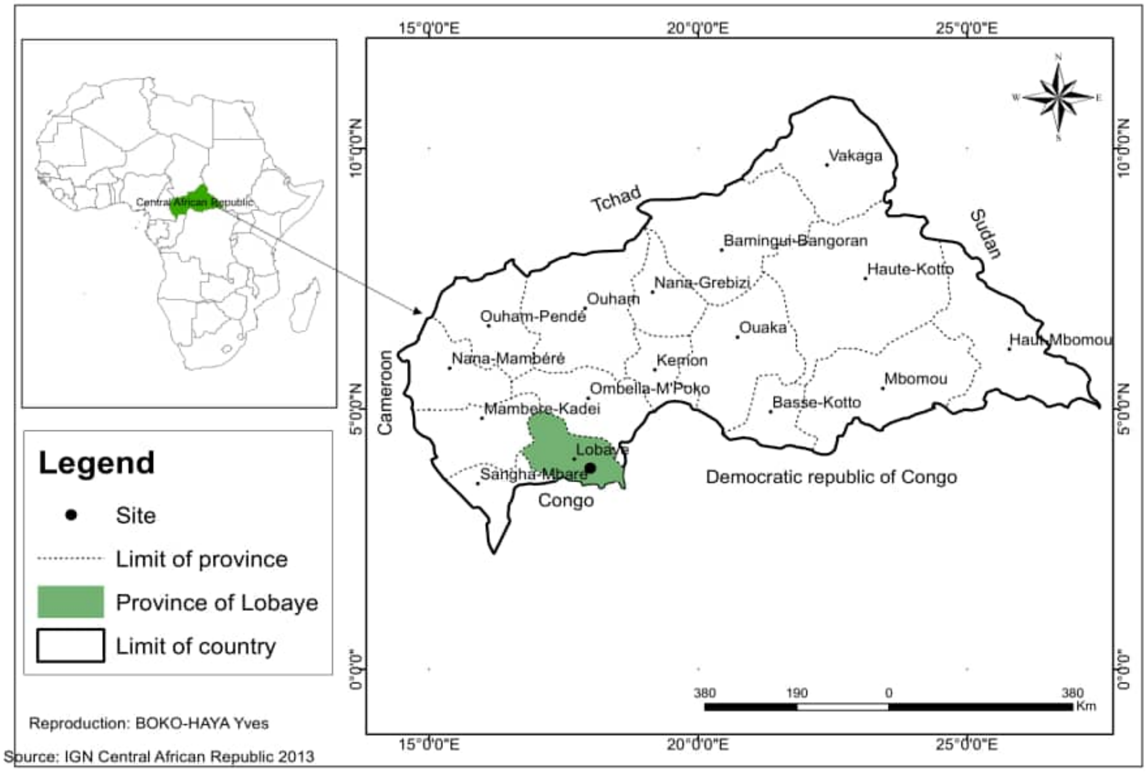


Figure 2: Areas of the study in the Central African Republic



Plant Material and Sampling

The sites sampled were the Akouho and CRAPP (Agricultural Research Centre for Perennial Plants) forests in the commune of Pobè; the Agrimey and Massi sectors of the Lama forest in the commune of Zogbodomey; Adaka, Ilikimou and Woroko sites in the commune of Kétou and the Itchede forest in the commune of Adja-Ouèrè. All these sites are located in the Plateau Phyto district except the CRAPP site located in the Pobè Phyto district (*Figure 1* & *2*). The choice of site was related to habitat and the presence of productive mother trees. Each mother tree provided 200 healthy seeds manually extracted from fruits harvested. In addition, the sample contains a batch of exotic seeds harvested from the Central African Republic in the semi-deciduous dense forest of the Lobaye. All seeds were stored at room temperature in accordance with the seed drying standards set by the International Rules for Seed Testing (ISTA, 2005). Seeds were sorted by removing those with physical cracks or microbial attack.

Experimental Design and Data Collected

Fisher's blocks were used to set up treatments. Two factors were considered: seed pre-treatment and seed provenances. As far as seed pre-treatment is concerned, four levels were considered: T0 (control), T1 (seeds mechanically scarified without damaging the embryo), T2 (seeds soaked into water for 7 days) and T3 (seeds scarified then soaked into water for 3 days). Regarding seed provenances, nine (9) modalities were considered which are: Akouho, CRAPP, Itchede, Woroko, Illikimou, Adaka, Agrimey and Massi in Benin and Lobaye in the Central African Republic. A total of 4 x 9 (36) treatments randomly distributed into 3 blocks were established. Each treatment was repeated three (03) times. Each seed was sown in a polyethene bag (H = 20 cm, D = 12 cm). The pots were watered every three days, in the morning and evening. No fertilisers or plant protection products were used in order to respect the germination conditions in the natural environment of the seeds. The pots were sheltered using palm tree leaves resting on vertical stakes of two (2) meters high.

As far as data collection is concerned, seed germination was recorded as soon as an opening appeared on the soil surface, revealing the cotyledon or stem. Thus, the number of germinated seeds was counted daily for the duration of the trial (273 days). Growth parameters (collar diameter, total height, number of leaves, length of internodes, number of internodes, diameter above the cotyledon) were measured quarterly on each plant up to 9 months age, using a calliper and a graduated ruler.

Data Analysis

Average germination time (Bewley & Black, 1994) and germination rate (Côme D., 1968; Événari M., 1957) were calculated as well as changes in survival rate. Data related to seed germination were submitted to a generalised linear mixed model (binary family) on glmmTMB package (Brooks et al., 2017) to assess the effects of pre-treatments and provenance on the ability of the seed to emerge. Effects of provenance and pre-treatments on growth parameters of *R. heudelotii* were tested using linear mixed models effects on longitudinal data in the nlme package (Pinheiro et al., 2017) excepted the number of internodes and the total number of leaves for which generalised linear mixed model effects were used on the package glmmTMB (Brooks et al., 2017). The modelling process consisted of testing the effects of random factor (block) and duration, using unconditional mean and unconditional growth models, respectively. The effect related to each model was obtained through the inter-class correlation coefficient (ICC). The test structures of the variance-covariance matrix for the residuals of the established models were chosen using the likelihood ratio test (LRT). The best model was selected and allowed to assess the effects of the main factors (models with interaction). Finally, trend curves were constructed for illustration and description purposes.

As far as survival rate and germination time are concerned, binary logistic regression and generalised linear model of Poisson family (negative binomial error) were used to assess the effects of treatments. All statistical analyses were performed using R 3.6.1 (R Core Team, 2019) and $p < 0.05$ was used as a rejection criterion for the null hypothesis.

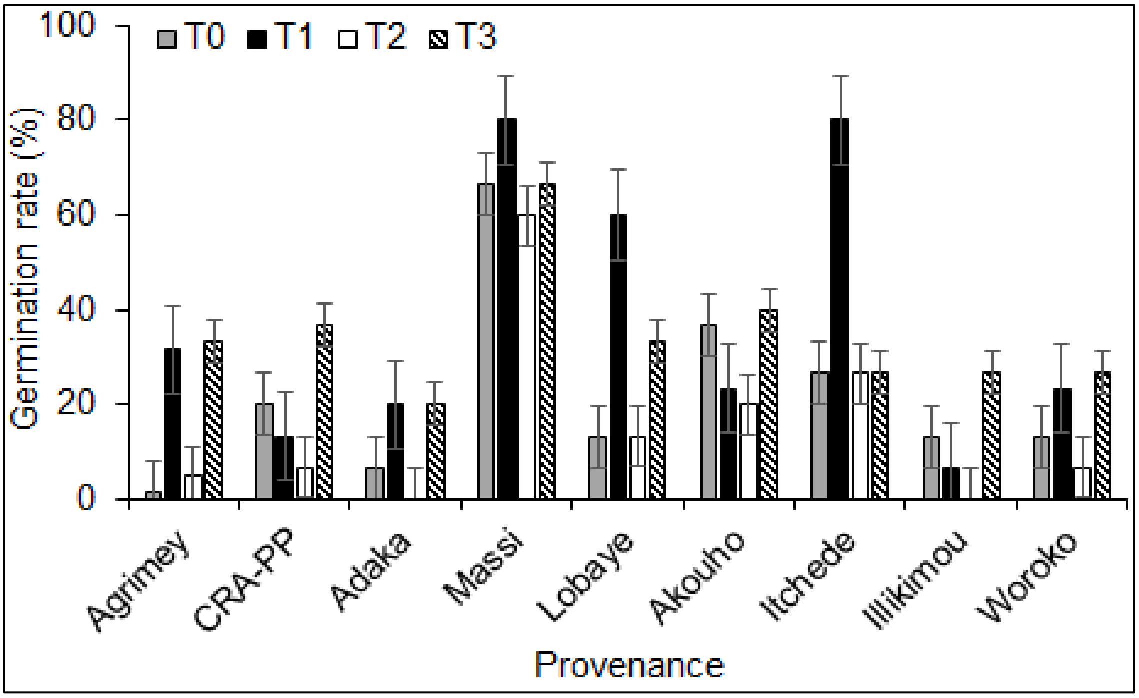
RESULTS

Effect of Seed Provenances and Pre-treatment on Germination Parameters

The results of the binary model showed that the germination rate was significantly affected by the provenance of the seed ($p < 0.05$), the pre-treatment ($p < 0.05$) and the interaction of both of them ($p < 0.05$), suggesting that the dynamics of the seeds were to be germinated according to the pre-treatments differ from one provenance to another.

For all provenances, the germination rate increased to a maximum value with treatments T1 and T3 and then decreased with treatment T2 (see *Figure 3*). However, the treatments with the highest germination rates vary from one provenance to another. For example, for seeds harvested at Lobaye, Massi and Itchede, the highest germination rates were recorded with the T1 treatment (respectively 60%, 80.0% and 80.0% as germination rate values) (see *Figure 3*). While for seeds collected from Ilikimou, Woroko Agrimey, CRAPP and Akouho, the highest germination rate was recorded with T3, the respective values being 26.67%, 26.67%, 33.33%, 36.67% and 40.0%. The Adaka provenance has the highest germination rate (20%) for both T1 and T3 treatments. Only Massi has the highest germination rate for all treatments (T1 = 80%, T2 = 60% and T3 = 66.67%); Massi is therefore the best seed source. With a germination rate of 66.67% for control, Massi suggests that *R. heudelotii* seeds do not need pre-treatments to germinate (see *Figure 3*).

Figure 3: Average germination rate by pre-treatment and seed provenance of *R. heudelotii*



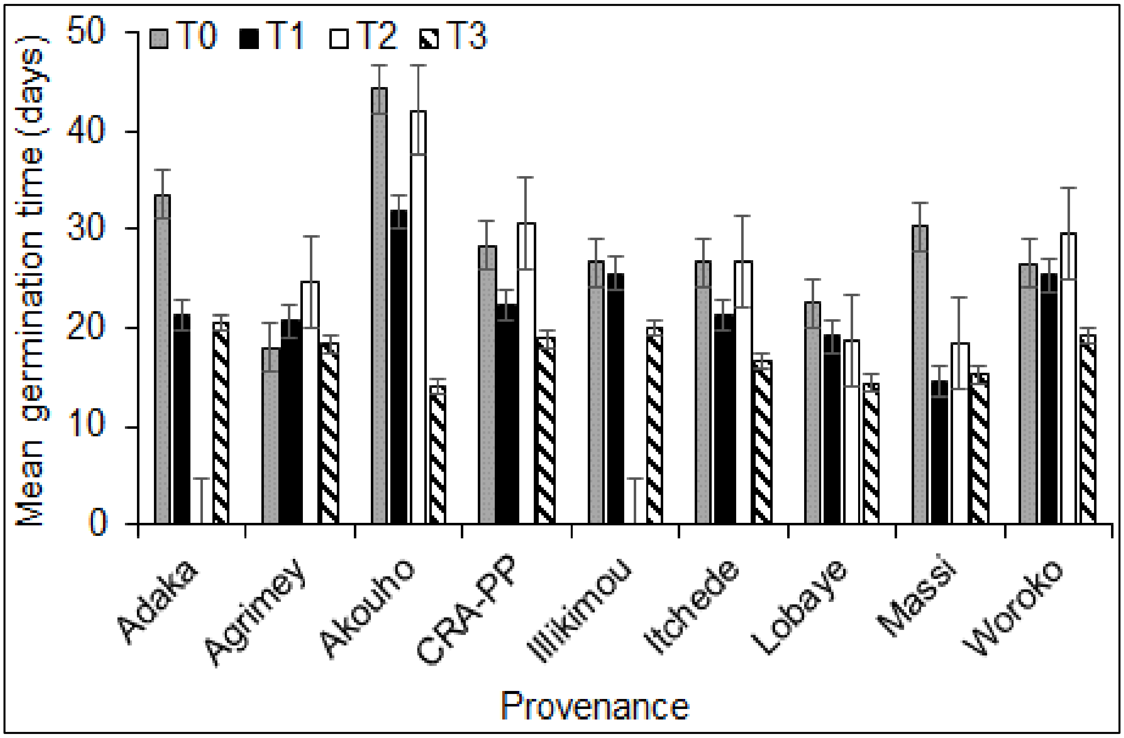
T0: control, T1: mechanically scarified, T2: soak in water for 7 days, T3: Scarify and soak in water for 3 days

In addition, the results of the generalized linear model showed that the mean germination time was significantly affected by provenance (RD = 479.34; $p < 0.001$), pre-treatments (RD = 558.68, $p < 0.001$) and their interactions (RD = 400.22; $p < 0.001$). Seed source and pre-treatments are, therefore, two main factors whose appropriate choices could contribute to reducing the mean seed germination duration in *R. heudelotii*.

For all provenances, the average germination duration was reduced with all treatments (see

Figure 4). The shortest mean germination duration was obtained with T3 for the provenances of Akouho, Lobaye, Massi and Itchede, the respective values being 13.96, 14.4, 15.2 and 16.6 days; i.e., a reduction of one (Itchede, Lobaye), two (Massi) and 3 weeks (Akouho) of the mean germination time compared to the control. Akouho provenance showed a longer average germination duration (44.18 days) compared to the control treatments (see *Figure 4*).

Figure 4: Mean germination duration according to pre-treatment and seed provenance of *R. heudelotii*



With respect to seedling survival, the results of binary logistic regressions indicated that only seed source made a significant difference (p = 0.002). The highest mean survival rate was found in Akouho and Massi, 94% and 93% respectively, while the lowest mean survival rate (69%) came from Itchede. All provenances had a survival rate above 50%; this result means that seeds from Benin and the Central African Republic can be used in reforestation programs with a perfect adaptation of Central African seeds to the climatic and soil conditions of South Benin.

Effect of Seed Sources and Seed Retreatments on Seedling Growth

The result of the linear models (*Table 1*) showed, over time, a significant difference in seedling growth for all agronomic traits for both pre-treatments and provenances. Similarly, time-provenance interaction also had a significant influence on all agronomic characteristics of seedlings. This means that the growth of seedlings over time varies considerably from one provenance to another. This growth dynamic was maintained for all seedlings throughout the experiment. The interaction between time and pre-treatment was significant only for crown diameter; therefore, growth in diameter thickness on cotyledons differed over time for pre-treatments from one provenance to another. In the absence of germination of Adaka and Ilikimou seeds for T2, the interaction between source and pre-treatment was not evaluated.

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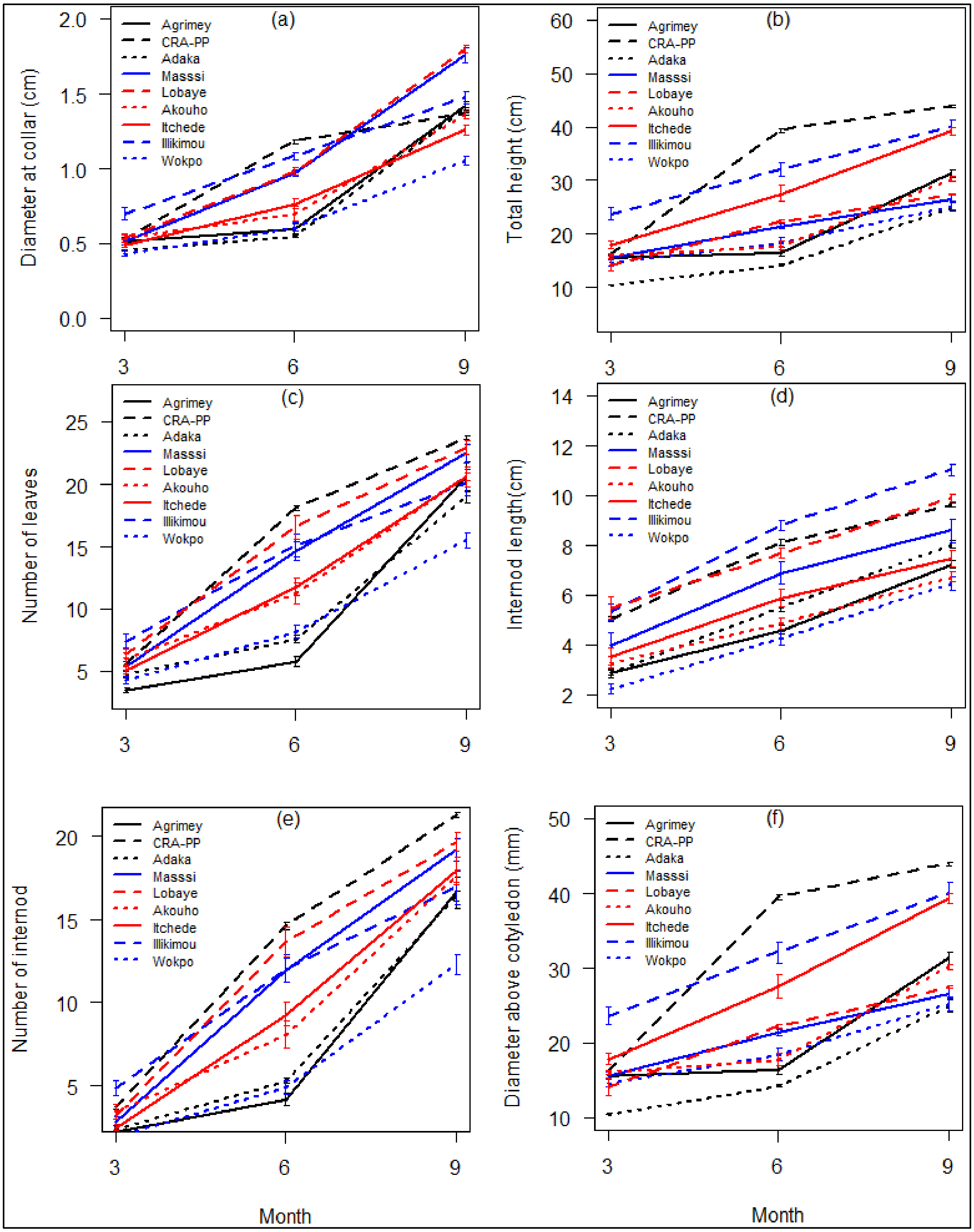
Table 1: Mixed linear and generalised linear model assessing the effect of seed source and pre-treatment on *R. heudelotii* plants (effects results)

Source of variation	Lin	Dac	Dc	Tln	Ni	Th
Duration	2 962.27s	2 431.04s	2 622.51s	2 192.19s	2 361.24s	1 472.09s
Provenances	33.94s	60.55s	51.29s	275.23s	327.39s	108.88s
retreatments	30.36s	07.56s	02.27s	22.59s	21.68s	09.76s
Duration x Provenances	07.25s	16.35s	17.20s	44.59s	42.80s	22.52s
Duration x pre-treatments	1.43ns	03.03s	2.04ns	03.33ns	06.92ns	01.30ns
Block CPI (%)	0.66	0.00	0.00	0.00	0.00	0.00
ICC time (%)	48.26	68.28	71.42	64.838	60.51	45.64
ICC time (%)	48.26	68.28	71.42	64.838	60.51	45.64

The F-value (lmme) / deviation (glmme) of the models are presented in the table (s: significant and ns: not significant at 5%). (Lin: Length of the internode, Dac: Diameter above the cotyledon, Dc: Diameter at the collar, Tln: Total number of leaves, Ni: number of internodes and Th: Total height)

Figure 5 shows the curves describing the evolution of the growth parameters over time. The growth initially dispersed and specific to each provenance tends to become linearised with a rapid increase from the sixth month onwards for all characteristics. The sowings obtained from Itchede and Lobaye seeds (Photo 1) showed the highest values for total height (33.22 ± 1.45 cm and 31.96 ± 1.15 cm), length of internodes (7.59 ± 0.23 cm and 8.39 ± 0.34 cm), number of leaves (15.83 ± 0.91 and 14.22 ± 0.84 cm) and internodes (13.22 ± 0.86 and 11.28 ± 0.79 cm); those obtained with Massi seeds showed the highest values for diameter at the collar (1.08 ± 0.06 cm) and diameter above the cotyledons (0.81 ± 0.05 cm). Adaka seedlings had the lowest values for height (16.58 ± 1.06 cm), diameter above the cotyledons (0.6 ± 0.05 cm), number of leaves (10.47 ± 1.06) and internodes (8.06 ± 1.03).

Figure 5: Trend curve for the variation of growth parameters



a: Diameter at the collar, b: Total height, c: Number of leaves, d: Length of internode, e: Number of internodes, f: Diameter above the cotyledon) as a function of seed source.

Photo 1: Growing plants coming from different provenances

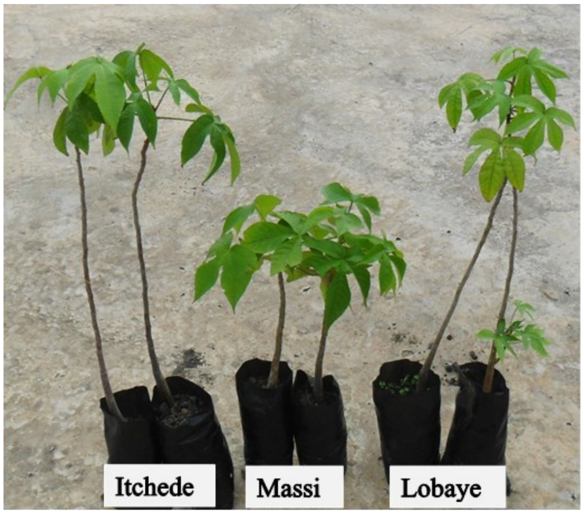


Table 2 shows that pre-treatments made a significant difference in growth parameters. The number of internodes ranged from 9.21 ± 0.52 (T1) to 10.92 ± 0.57 (T3); the length of internodes ranged from 6.11 ± 0.26 cm (T0) to 6.69 ± 0.19 cm (T3); and the total number of leaves ranged from 11.85 ± 0.55 (T1) to 13.73 ± 0.6 (T3); the total height ranged from 23.24 ± 0.91 cm (T0) to 25.9 ± 1.2 cm (T3); the diameter at the collar and above the cotyledon respectively from 0.91 ± 0.04 cm (T2) to 0.95 ± 0.04 cm (T3) and from 0.64 ± 0.03 (T0, T1) to 0.71 ± 0.03 (T3). The T3 treatment showed the maximum values for all agronomic traits except for the total height (25.9 ± 1.2 cm) recorded with T2. On the other hand, the lowest values for the agronomic traits were observed with T0 with the exception of the collar diameter obtained with T2.

Table 2: Descriptive statistics (mean ± standard error) of growth parameters by treatment

	Ni	Lin (cm)	Tln	Dc (cm)	Th (cm)	Dac (cm)
T0	9.89 ± 0.63	6.11 ± 0.26	12.65 ± 0.67	0.93 ± 0.04	23.24 ± 0.91	0.64 ± 0.03
T1	9.21 ± 0.52	6.2 ± 0.2	11.85 ± 0.55	0.92 ± 0.03	24.45 ± 0.78	0.64 ± 0.02
T2	10.27 ± 0.81	5.27 ± 0.31	13.08 ± 0.85	0.91 ± 0.04	25.9 ± 1.2	0.67 ± 0.03
T3	10.92 ± 0.57	6.69 ± 0.19	13.73 ± 0.6	0.95 ± 0.04	24.61 ± 0.77	0.71 ± 0.03

(Lin: length of the internode, Dac: Diameter above the cotyledon, Dc: Diameter at the collar, Tln: Total number of leaves, Ni: Number of internodes and Th: total height)

DISCUSSION

The low germination rate of *R. heudelotii* seeds limits its widespread ability. Applied mechanical scarification (Djeugap et al., 2014; Marie-Thérèse et al., 2012) has increased the germination rate. In the present study, lime scarification, coupled with the soaking of seeds into the water was examined on several geographically distinct provenances to identify the best ones to be used in reforestation and ex-situ introduction programs.

Retreatments and Provenance Revealed a Wide Variation in Germination Parameters

The germination rate and average germination duration showed a significant variation between provenances and the best pre-treatments were scarified seeds and seeds that were both scarified and soaked into water for three days. This inter-provenance variation shows that seeds are heterogeneous between provenances. This heterogeneity would be related to the presence of particular characteristics (Mira et al., 2011; Pérez-García and González-Benito, 2010) of *R. heudelotii* seeds from each provenance. This heterogeneity in seed germination is useful for the survival of wild species under unpredictable environmental conditions. Similar results were obtained by Diouf et al. (2015) between provenances of baobabs (*Adansonia digitata*) with a high variation in seed germination rate, by Moya et al. (2017) with intra- and inter-provenance variation in seed germination capacity of *Nothofagus glauca* and by Mboya et al. (2015) with a significant variation for all germination parameters within provenances in *Faidherbia albida*. The observed variation in germination, due to the specific characteristics of seeds of each provenance, maybe of physiological, physical and/or genetic origin.

Seed dormancy (Pérez-García et al., 2012) with intraspecific variation such as germination (Baskin and Baskin, 2014; Santo et al., 2015) or interpopulation variability due to environmental and/or genetic differences (Cruz et al., 2003; Ginwal et al., 2004) are potential factors that may cause variation in seed germination. Thus, the conditions of the mother plants (Baskin and Baskin, 2014; Roach and Wulff, 1987; Bischoff and Müller-Schärer, 2010) affect seed germination characteristics. The genotype and environment of the mother plant have an impact on the degree of primary seed dormancy (Penfield, 2017) and on seed germination (Keller and Kollmann, 1999).

Recently, abscisic acid (ABA) and gibberellic acid (GA) have been identified as the main hormones that antagonistically regulate seed dormancy and germination (Finkelstein et al., 2008; Lee et al., 2015). High ABA and low GA induce deep seed dormancy, while low ABA and high GA induce early germination. The state (dormancy or germination) of a seed is therefore determined by the concentration of the ABA-GA hormone pair. This state is regulated by molecular mechanisms whose expression is linked to a DNA motif (Shu et al., 2016). Thus, differences in the germination behaviour of seeds from different provenances could be explained by a difference in the blocking of the functioning of the molecular regulators responsible for an increase or decrease in the level of the ABA-GA hormone pair. Some molecular regulators, such as the HONSU protein, act as a negative regulator of seed dormancy by simultaneously inhibiting ABA signalling and activation of GA signalling (Kim et al., 2013); for example, the Abscisic Acid Insensitive 4 (ABI4) gene has been identified as a positive regulator of primary seed dormancy that prevents germination (Kong et al., 2015; Shu et al., 2013).

In addition, seed size variation in *Carpobrotus edulis* (L.) NEBr. (Podda et al., 2018) or seeds in *Rubus sp*. (Choi et al., 2017) also causes variation in germination within provenances. Aref et al. (2011) added that seed coat hardness in Acacia species is a factor affecting germination. In the present study, the significant difference in germination response between provenances of *R. heudelotii* subjected to different pre-treatments suggests that the seed source is a priority in the choice of the best germplasm. Massi is the best source, paradoxically showing that *R. heudelotii* seeds do not need pre-treatment to germinate; which corroborates with the work of Assogbadjo et al. (2011) on baobab. It is, therefore, possible that Massi seeds may have a thin integument that favours easier entry of water to induce rapid germination, as was the case for *Dalbergia odorifera* seeds (Liu et al., 2017). Under the same climatic gradient and in the same Phyto district, optimal germination was obtained with scarified seeds from Itchede against seeds both scarified and soaked for three days in water from Akouho. This difference could be justified by variations in the soil conditions of the mother trees. Similar results were obtained with *Eucalyptus nitens* where, the optimal seed germination temperature for Toolangui and MacAlister provenances under the same latitude was significantly different and corresponded to 28◦C and 18◦C respectively (Humara et al., 2000), in *Eucalyptus ovata*, *Prosopis alba* and *Silene dioica* (Harrison et al., 2014; Venier et al., 2015).

With regard to seedling survival, a significant difference between provenances was observed, in contrast to pre-treatments. This inter-provenance variation in survival rate would be related to a variation in nutrient reserves in seeds from different provenances (Kitajima and Myers, 2008). For example, sucrose is a major source of energy, used during the early stages of germination in *Cicer arietinum* (Arunraj et al., 2020); seedlings from seeds with low sucrose levels will not be able to survive. Mortality is low during the establishment phase of seedlings, meaning that most seeds from all sources had a large amount of available nutrients (Harper, 1977). This low mortality suggests that seedlings of Central African provenance in nurseries are likely to adapt well to the climatic conditions in South Benin.

Differences in Growth between Provenances and between Pre-treatments

This study showed a significant difference in seedling growth for all agronomic traits for both pre-treatments and provenances. Seedling growth was closely related to provenance, which is consistent with seedling growth of *Khaya senegalensis* (Ky-Dembele et al., 2014); *Neolamarckia Cadamba* Miq (Sudrajat et al., 2016) and *Terminalia ivorensis* (Ojo and Ajayi, 2019) where considerable variation was observed within all provenances for all growth traits studied. This result contrasts with that of Moya et al. (2017), where the growth of *N. glauca* seedlings was not related to seed provenance. Significant differences in seedling growth and survival rates were dependent on the availability of reserves (carbohydrates, lipids, storage proteins and other mineral nutrients) stored in the seeds until the plants became established (Kitajima and Myers, 2008). Thus, the variation observed between and within provenances may be related to genetic differences between mother plants. Maternal effects highly influence the early seedling stage of a genotype (Roach and Wulff, 1987). In addition, seedling morphology and cotyledon functions have also affected seedling growth rate (Baraloto and Forget, 2007; Kitajima, 1994).

In the current study, germination tests were carried out ex-situ with the same types of substrate and climate; therefore, the significant differences observed in seedling germination and growth parameters could be of genetic origin, i.e., related to a difference in genotype. Baskin and Baskin (2019) stated that the genotype of an individual depends on its parents. For example, the maternal parent has a significant effect on the germination percentage of *Betula pendula* seeds (Pasonen et al., 2001) while the variation in germination rate of *Iris hexagona* seeds is partly paternal in origin, i.e., it depends on the pollen donor required for oosphere pollination (Van Zandt and Mopper, 2004). However, these differences may also be related to morphometric variables of seeds or seed coat. The observed intra-provenance variation suggests that restoration programs should take into account the provenances of the seeds (Breed et al., 2013); in other words, each provenance requires specific treatment to achieve the expected performance. Variation in germination and growth characteristics within the population will facilitate the selection of populations and individuals most suitable for mass production.

CONCLUSION

This study showed that pre-sprouting treatments are an effective means of lifting the dormancy of *R. heudelotii* seeds. Scarification, on the one hand, and scarification combined with a three-day soaking of the seeds in water, on the other hand, proved to be the best pre-treatments. Seeds of Massi germinate more easily and seedlings have the largest collar diameter while Itchede and Lobaye seedlings have the greatest height and internode length. However, it is necessary to test these results obtained by evaluating the morphometric and molecular aspects of the seeds and to extend the study to all other phytogeographical zones of the countries concerned.

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