

Germination and Viability of *Pericopsis elata* (Harms) V. Meeuwen (Fabaceae) Seedlings Issues of Different Mother Tree Diameters in Forests Production (East - Cameroon)

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Abstract: *Pericopsis elata* (Fabaceae) is a highly commercial species of semi-evergreen wet forests in central and western Africa. Its exploitation began in the second half of the 20th century because of its highly valued wood on the international market. Because of its low potential for natural regeneration, it is now considered an endangered species by IUCN and listed in Appendix II of CITES. No action was taken on the identification of good mother tree to enable good production of seedlings suitable for the management of logged forests of this species. Hence the need for new scientific investigation with a view to obtaining the missing information which would allow an unambiguous decision on the threats to the species. The objective of this study, which was conducted from November 2015 to July 2016, was to determine the diameter classes with the highest seed germination rate and the highest viability of the seedling seedlings at four months after sowing. To determine the germination rate, 100 seeds were tested for each diameter class. After germination, the seedlings were monitored for 120 days at the end of which the viability rate was calculated for each diameter class. Seeds from mother tree of the highest diameter classes [60-70cm], [70-80cm], [80-90cm] and [90-100cm] recorded the best germination rates with respectively 36, 42, 30 and 36%. The simple regression between germination rate and seed diameter classes is significant at the 5% probability threshold. The highest seedling viability rate of 98% is obtained with mother tree the diameter class [70-80cm]. However, it should be noted that the simple regression between plant viability and seed diameter classes have a fairly good relationship.

Keywords: Germination, seed, seedlings, diameter class, mother plant, *Pericopsis elata*

1. Introduction

In most plant species, the seeds vary in their degree of germinability inter and intra individuals and populations. Some of this variation may be of genetic origin, but much of it is known to be phenotypic. That is, it is caused by the local conditions under which the seeds matured. These conditions consist of a combination of the microenvironment experienced by the seed due to its position on the parent plant and the abiotic environment of the plant (Müller et al. 2014). In different plant species, maternal factors, such as the position of the inflorescence on the mother plants or the position of the seeds in the fruit, can markedly influence the germinability of seeds (Gutterman 1994, 1996; Grey and Thomas 1982),

also the age of the mother plant during flower induction (Kigel et al. 1979) or seed maturation (Gutterman 1978). The age of the mother plant can affect the germination parameters of its seeds. Müller et al. (2014), show that there is a positive and significant correlation between age and fertility in *Cistus albidus*. The seed production of *Picea mariana* increased steadily with mother tree age (Viglas et al. 2013). However, Mao et al. (2014) did not identify any relationship between age of mother tree and seed germination. So, the relationship between tree age and seed production remains ambiguous.

Pericopsis elata is a high commercial value timber species, restricted to moist semi-deciduous African

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forests (West and Central Africa). This species is valued for the high quality of its wood, and its exploitation started more than 50 years ago, mainly in Ghana and Côte d'Ivoire (Dickson et al. 2005). *P. elata* is defined as a gregarious species (Boyemba 2011), meaning large numbers of trees generally and naturally occur within spatially restricted areas. Since juvenile and old stems are said to be rare throughout its natural distribution area, the typical population structure of *P. elata* follows a bell-shaped curve in Cameroon (Betti 2007). In Cameroon, flowering starts in March-April (Bourland et al. 2010) and minimum fertile and effective fruiting diameters were 32 and 35cm (Boyemba 2011), respectively. Pieters (1994) stated with certainty that the untouched forest microclimate (close to the ground, with a very low level of light exposure and a high moisture content) is the most favorable for the germination of these species, while the environment created after clear felling is extremely unfavorable. After germination in an untouched forest, he noted a high mortality rate among of young seedlings, especially during the first weeks after germination. Regeneration of *P. elata* is reported as being remarkably rare, despite abundant seed production wherever it is studied in its distribution area (Bourland et al. 2012).

Despite being listed both in CITES Appendix II and on the IUCN Red List, important information on *P. elata* ecology are still lacking (Anglaere 2008). Indeed, too few data are available on phenological patterns and fertility, making it difficult, for example,

to analyze the impact of logging on seed tree populations. The question of what happens to trees as they age has been subject to considerable speculation but few data have been produced on the effects of aging on germination and viability of seedlings. Consequently, more research is needed before a definitive decision can be made to allow harvesting of *P. elata*, in order to ensure that this action does not threaten the species with extinction. Specifics objectives of this study were to:

- determine diameter classes with high seed germination rates of *P. elata*.
- determine diameter classes with high seedling viability rates from *P. elata* seeds at four months after germination.

2. Study area and data collection

2.1. Study area

The fieldwork of this study was carried out in the East Cameroon region, specifically in the forest concession made up of FMU 10.030 and 10.031. This forest concession managed by the Pallisco forestry company straddles the districts of Messok and Abong-Mbang over a total area of 118 052 ha. Geographically it is between 3 ° 01 'and 3 ° 25' north latitude and between 14 ° 05 'and 14 ° 31' east longitude and lies to the east of the departmental road Zoulabot I - Messok and South of the Zoulabot - Medjeuh - Medoum road. It is limited to the East by UFA 10.020 and 10.021 and in the South by UFA 10.029 (Figure 1).

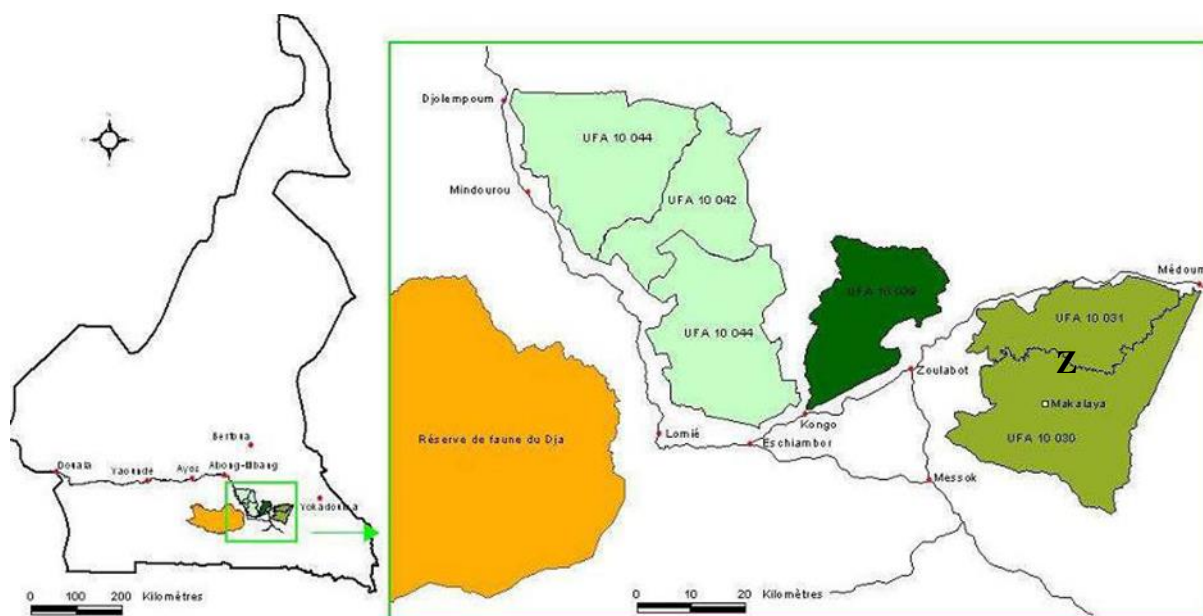


Figure 1: Location of the forest concession made up of FMUs 10.030 and 10.031 (Pallisco FMU Management Plan, 2015) Z: study area

The annual temperature of this zone oscillates around 24 °C and annual rainfall varies between 1550 and 2000 mm with an average altitude of 700 m (Afouba et al., 2011). The predominant floristic composition of this zone is the dense evergreen moist forest with the presence of semi-deciduous formations and whose characteristic dominant species are: *Alstonia boonei*, *Baillonella toxisperma*, *Amphimas ferugiperes*, *Crudia gabonensis* and many other Irvingiaceae (Letouzey, 1968).

2.2. Data collection

Since *P. elata* is an anemochorous species and to avoid attributing the fruit collected on the soil to another nearest tree, we chose isolated mother tree that is, having no neighbors within a radius of 200 m (Boyemba, 2011). The fruiting mother trees with a diameter at breast height greater than 40cm and no external defect were considered as mother plants. An average of six mother plants per class of diameter was selected. These mother plants belonged to 6 classes of diameter of amplitude 10 cm ([40-50cm[, [50-60cm[, [60-70cm[, [70-80cm[, [80-90cm[and [90-100cm[).

The pods were collected around the mother plant during the dispersal period and packed in plastic bags labeled according to a coding that took into account the date of collection, the forest management unit number, geographical coordinates and diameter of the mother plant. After that, the pods were transported to the laboratory of soil microbiology and to the pedagogical nursery of the biotechnological center of the University of Yaounde I for the experiments. Once in the laboratory, the seeds were homogenized and two samples of 100 seeds were randomly selected for seed quality testing (purity and germination).

2.2.1. Seed physical parameters

Purity test

The pure seeds were separated from the impure seeds and weighed. A seed was considered pure if it appeared normal in size, shape and general appearance. On the other hand, the one that was too small, had been partially devoured by the insects, or showed molds, was considered impure. The percentage of pure seeds was calculated according to the following formula:

Purity % = (Weight of "pure" seed / Total weight of original sample) x 100 (FAO, 1980)

Seeds Weight

It is important to know the number of seeds per weight unit, because this number and germinative vigor can be used to calculate the approximate weight

of seed needed to produce a given number of seedlings.

To determine the number of seeds per unit weight, two samples of 100 seeds were randomly taken from the seed lot, and the number of pure and full seeds was then counted and weighed. As in the purity test, the impure seeds were removed. The number of pure seeds per kilogram was calculated by the following formula:

Number of pure seeds per kg = (number of seeds in sample / weight of seeds in sample in g) x 1000 (FAO, 1980).

2.2.2. Germination testing

To determine the percentage of germination, a seed lots were tested according to the diameter classes of the mother plants in a substrate, consisting of 2/3 of soil and 1/3 of sand. This substrate was sifted through a 5 mm mesh screen, mixed and placed in pots. The results of the germination tests are expressed in different ways:

Germination rate = (Number of germinated seeds / Total number of seeds in the sample) x 100

To better appreciate the quality of our seeds, several parameters have been taken into account. Germinative vigor (GV), which is the percentage of seeds that germinate in a sample until the daily germination reaches a maximum; the latent phase or latency duration which represents the time in days which elapses between the seeding and germination of the first seeds of the lot, the cultural value and the rate of germination.

Speed of germination: Number of seedlings emerging daily are counted from day of planting the seeds in the medium till the time germination is complete.

$V_g = G_1/T_1 + G_2/T_2 + \dots + G_n/T_n$ (Scott et al., 1984)

Where G_1 = Number of seeds germinated on the first day

G_2 = Number of seeds germinated on day 2

G_n = Number of germinated seeds on nth day

T_1 = day 1 T_n = day n

2.2.3. Study of seedlings growth in the nursery

After germination, these seedlings were monitored for four months, after which the growth parameters (height and collar diameter) were recorded after every 30 days in order to obtain a general idea of the quality of the plants. The viability rate was calculated after the 120 days by the mathematical formula:

Viability rate = (Number of viable seedlings / Total number of germinated seeds) x 100 (FAO, 1980).

2.3. Data analysis

The data obtained were compiled in Excel 2010 and analyzed using XLSTAT 2014. The mean values and

standard errors of all parameters were calculated. Analysis of the variance (ANOVA) was used to test whether there is a difference between seed lots. Separation of these means was done with the Duncan test at the probability threshold $P < 0.05$.

These models relate the relationship between the germination rate and viability of seedlings with different class diameter of mother plant. The main test used to validate the model of regression, is the coefficient of determination R^2 which gives the percentage of variation explained due to the variation in the explanatory variable.

3. Results

3.1. Determination of germination characteristics by mother tree diameter classes

Table 1 indicates the number of seeds obtained for each diameter class after weighing 10 g and their estimates per kg. The diameter class [50-60 cm[recorded 44 seeds which is significantly higher than that of the other diameter classes ($p \leq 0.05$). Mother plants belonging to the highest diameter classes [70-80cm[, [80-90cm[and [90-100cm[have obtained a significantly low number of seeds, meaning 35 seeds per 10 g.

Table 1: Number of seeds for 10g per mother plants diameter class

Diameter Classes (cm)	[40-50[	[50-60[	[60- 70[	[70- 80[	[80-90[	[90-100[
Mean number of seeds/10g	40,5±0,70b	44±7,07a	39±0b	35,5±0,70c	35±0c	35±2,82c
Estimation /Kg	4050	4400	3900	3500	3500	3500

Means with same letter are not significantly different according to the Duncan test at $p \leq 0.05$

Table 2 summarizes the results obtained with respect to purity, germinative vigor, germination speed, latent period and the corresponding germination rate for each diameter class. The findings of this study clearly show that the percentage of purity of the seeds according to the seed diameter classes is the highest for the mother tree class of diameter [50-60cm[. The classes [70-80cm[and [90-100cm[recorded less significant proportions of pure seeds ($p \leq 0.05$), respectively 42.75% and 47.01%.

From this table, seed belonging to seedlings of the diameter class [80-90cm[recorded a germinative vigor of 29% followed by values obtained in the diameter classes [60-70cm[and [70-80cm[which are respectively 21.7 and 21% ($p \leq 0.05$).

The latency of this germination varies between 8.5 and 12.5 days following the diameter classes. However, seeds from seedlings belonging to the diameter classes [70-80cm[and [80-90cm[germinate faster (8.5 days after sowing) than seeds from the diameter class [50-60cm[(12.5 days after sowing) at $p \leq 0.05$.

Moreover, the germination rate according to the seed diameter classes varies considerably. From the table 3, it can be seen that the diameter class [70-80cm[has a germination rate of 42%. This is significantly higher than the values obtained in the diameter classes [50-60cm[and [40-50cm[, which are respectively 20 and 18% ($p \leq 0.05$).

Table 2: Values of germination parameters by diameter classes

Diameter classes (cm)	% of purity	Germinative Vigor %	Latent period (day)	Germination speed	Germination rate (%)
[40-50[	64,28±3,36b	10,5±0,7d	9,5±0,7bc	1,47±0,24b	18±8.36b
[50-60[	70,41±0,58a	17,5±3,53c	12,5±2,12a	1,21±1,23b	20±10b
[60-70[	54,54±6,42c	21,7±5,33b	9±0bc	4,12±0,14a	36±15.16ab
[70-80[	42,75±7,42d	21±12,72b	8,5±0,7c	2,58±2,54b	42±17.88a
[80-90[	55,76±2,72c	29±8,48a	8,5±0,7c	2,36±1,76b	30±18.7ab
[90-100[	47,01±13,44d	17,5±3,53c	10±2,82b	2,12±2,31b	36±16.73ab

Means with same letter are not significantly different according to the Duncan test at $p \leq 0.05$

The germination rate increases as the diameter of the mother plants grows and as the slope of the regression line is positive. However, the simple linear regression at $p \leq 0.05$ shows that germination rate (explained variable) explain 33% of variation of seed diameter classes (explanatory variable). Therefore we have a fairly good relationship between germination rate and mother plant diameter classes (Figure 2).

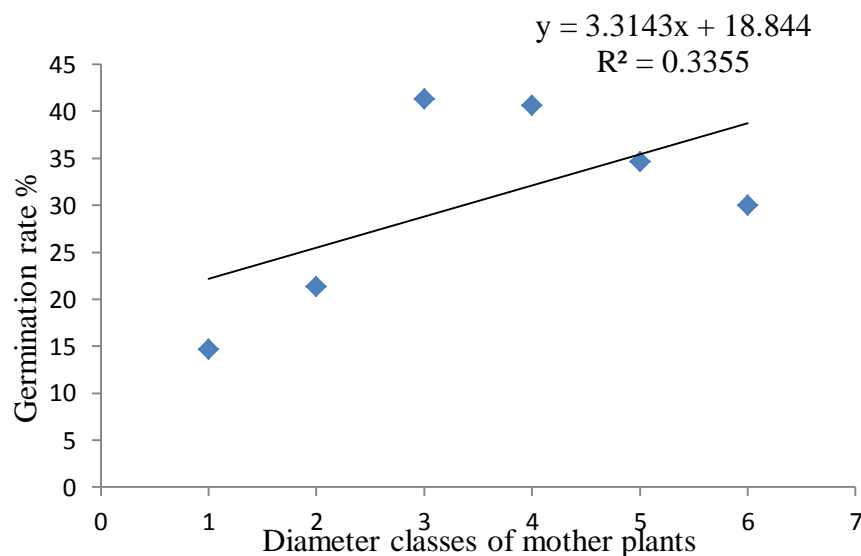


Figure 2. Germination of *P. elata* seeds as a function of diameter classes of mother plants, 1 = [40-50cm[;... 6 = [90-100cm[

3.2. Growth rate of seedlings in the nursery

3.2.1. Growth of stems of seedlings over 4 months in a nursery

The observations indicate that up to 60 days after sowing, the seedlings have significantly the same size (Table 3). At 90 days after sowing, the seedlings of the diameter class [70-80cm[have an important elongation, with height of 31 cm, statistically ($p \leq 0.05$) higher than seedlings of other classes of diameter (about 25 cm). At the end of 120 days after sowing, the diameter class [70-80cm[still have an important elongation along with the diameter classes [50-60cm[and [90-100cm[($p \leq 0.05$).

For each diameter class, between zero and 30 days after sowing, when the seedlings still carry the cotyledons, the diameter at the collar is not significantly different from one class of diameter to the other ($p \leq 0.05$). The evolution of the collar diameter over time shows a gradual increase in the average diameter. At 60 days after sowing seedlings from seed of the class [40-50cm[have a larger collar diameter, which is 2.85 mm, and statistically comparable to seedlings of other classes of diameter ($p \leq 0.05$). At the end of 120 days, seedlings derived from mother plants of the diameter class [40-50cm[had a highest collar diameter, 4.87 mm, comparable to seedlings of all other diameter classes.

Table 3: Growth in height and collar diameter of *P. elata* seedlings as function of mother tree diameter classes

Diameter classes (cm)	30 days		60 days		90 days		120 days	
	height	diameter	height	diameter	height	diameter	height	diameter
[40-50[	12,66 a	2,31a	19,55 a	2,85 a	25,22 b	3,52 a	32,61 ab	4,87 a
[50-60[	12,36 a	2,06 a	18,87 a	2,75 a	25,75 b	3,48 a	34,07 a	4,76 a
[60-70[	11,83 a	2,09 a	18,52 a	2,57 a	24,79 b	3,33 a	32,4 ab	4,65 a
[70-80[	13,53 a	1,98 a	21,25 a	2,58 a	31 a	3,23 a	35,63 a	4,38 a
[80-90[	13,38 a	2,17 a	21,15 a	2,7 a	25,06 b	3,4 a	29,03 c	4,58 a
[90-100[	13,49 a	2,06 a	20,38 a	2,6 a	25,47 b	3,28 a	36,62 a	4,6 a

Means with the same letter in the same column are not significantly different according to the Duncan test at $p \leq 0.05$

Seedling foliage production is continuously increased. From the first month, the number of leaves per shoot was three for all diameter classes; this number double by the second month after sowing for all the seedlings. Four months after sowing, a slight slowdown was noted in the development of new

leaves in mother tree diameter classes except the ones of classes [50-60cm[and [70-80cm[. Seedlings bear on average eleven leaves after four month.

3.2.2. Growth of roots pivots of seedlings over 4 months in a nursery

The results of the analysis of the root growth of the seedlings by diameter class are shown in Table 4. The lengths of 18.74 and 18.70 cm recorded respectively

by the seedlings originating from the seeds belonging to the seedlings of the diameter classes [80-90cm[

and [90-100cm[are significantly greater than those of other diameter classes ($p \leq 0.05$).

Table 4. Root growth of seedlings as function of diameter classes

Diameter classes (cm)	Root length (cm)
[40-50[	17,80±2,38ab
[50-60[	16,32±3,09ab
[60-70[	17,87±3,03ab
[70-80[	15,58±3,37b
[80-90[	18,74±1,44a
[90-100[	18,70±3,06a

Means with the same letter are not significantly different according to the Duncan test at $p \leq 0.05$

3.2.3. Viability of seedlings from *P. elata* seeds at 4 months after sowing

The diameter class [70-80cm[recorded a high seedling viability rate (98%), statistically comparable to that of the lower diameter classes. However, the diameter classes [80-90cm[and [90-100cm[reveal respectively the viability rates of the lowest viability rate seedlings, ie 75 and 83% (Figure 3).

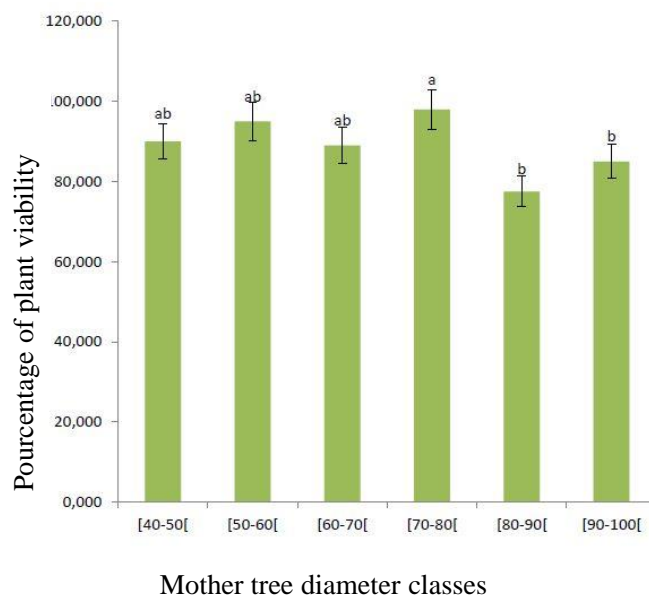


Figure 3: Viability rate (%) of seedlings after 04 months by mother plants diameter classes. The bars (mean ± standard error) bearing the same letters are not significantly different at the 5% probability threshold. The regression line showing the negative relation between mother plants diameter classes and seedling viability rate. The observations made in figure 4 shows that the viability of the seedlings decreases as the mother plants diameter increases.

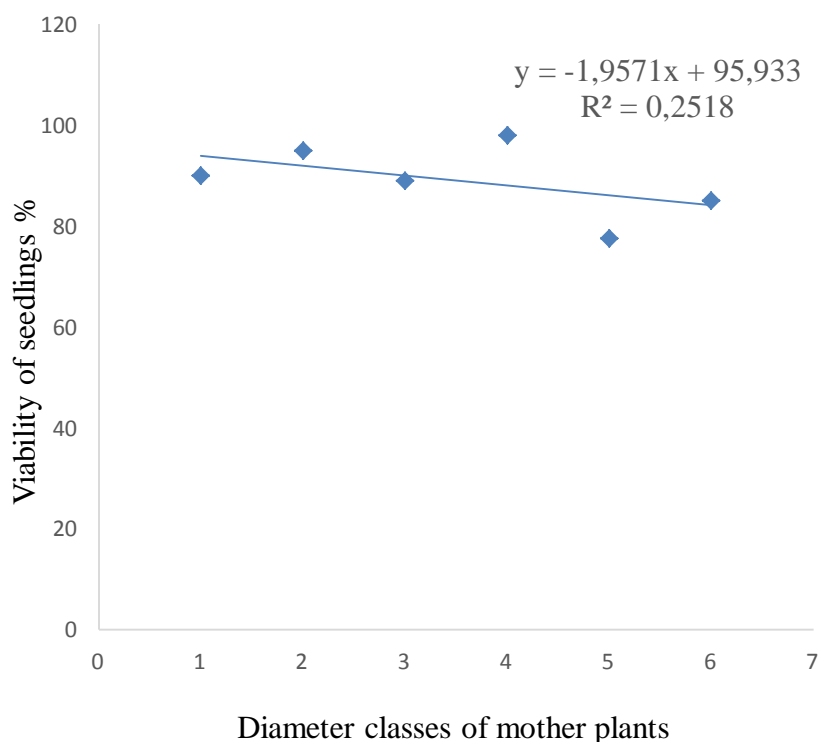


Figure 4: Viability of *P. elata* seedlings according to diameter classes of mother plants, 1 = [40-50cm[;... 6 = [90-100cm[

4. Discussion

Plant regeneration is one of the problems in the ecological field in recent decades. The main regeneration stages of seed plants involve seed production, dispersal, and seedling establishment (Nathan and Müller-Landau 2000). Seed quality and quantity are affected by maternal identity (Cendán et al. 2013; Fabião et al. 2014; Stancic et al. 2014), such as maternal age (Müller et al. 2014) and maternal environment (Ganatsas et al. 2008), which will influence the natural regeneration processes. The number of seeds is estimated at 4400 seeds per kg for seeds from seedlings belonging to the lower diameter classes [40-50cm[, [50-60cm[, [60-70cm[. On the other hand, seedlings belonging to the upper diameter classes ([70-80 cm[, [80-90cm[, [90-100cm]) obtained about 3500 seeds per kg. Seed weight was related to tree age in *Pericopsis elata*. In fact, Rowe (1964) suggests that parental plants and the seed they produce are greatly affected by local edaphic and climatic factors, and this leads to a "preconditioning" of the seed that affects germination behavior and subsequent development. Mother tree age has significant effect on seed production. With the increase of age, *Cistus albidus* showed the highest fecundity at the middle age (Müller et al. 2014).

Seed germination is vital for the establishment of plant individual, especially in unfavorable environments (Cendan et al. 2013). The highest germination rate was obtained with the middle age of mother trees [70-80 cm[with 42% and is significantly higher than the values obtained in the minimum age of mother tree [50-60cm[and [40-50cm[and comparable with the maximum age of mother tree [80-90cm[and [90-100cm[. In fact, some tree species exhibited the highest seed germination rate in the middle age, such as *Sorbus torminalis* (Espahbodi et al. 2007) and *Pinus echinata* (Grayson et al. 2002).

Relationship between mother plants diameter classes and germination rate reveals that the percentage of germination depends on the diameter of the seed trees. This result confirm that of Andrianoelina (2009) who found that in *Dalbergia monticola* (Fabaceae) young mother trees have the best germination rate compared to old mother trees. Seeds of *P. elata* germinated between 09 and 10 days after sowing, confirming the results of Tchatat (2009) which showed in the southern Cameroon region that seed germination of *P. elata* occurs at 8 to 10 days after sowing.

Age of mother tree did not show significant differences in the early seedling growth. Seedlings

from the minimum and maximum age of mother tree had higher collar diameter, root length and lower viability rate than from the middle age of mother trees [70-80cm]. Moreover, the middle age mother tree also had higher relative height growth rate. This result is in accordance with those of Mao et al. (2014). The highest viability rate 98% obtained by the seedlings belonging to the diameter class [70-80 cm] shows generally that the seedlings produced from *P. elata* seeds normally develop in nurseries. These results are in agreement with those of Onana (2013) who revealed in the eastern and southern regions of Cameroon that the reeducation of the *P. elata* in the nursery gives very good results at the end of 120 days.

CONCLUSION

In this paper, we found that age of mother tree had important role on their offspring' seed germination and seedling growth. The seeds of *P. elata* showed better purity percentages (64.28% and 70%), respectively, in mother tree diameter classes [40-50cm] and [50-60cm], with about 4450 seeds per kg for the mother tree belonging to the lowest diameter classes and 3500 seeds per kg for the mother tree belonging to the highest diameter classes [70-80cm], [80-90cm] and 90-100cm]. *P. elata* expressed a germination period of eight to nine days. The best germination percentage observed in this study was 42%, for the middle mother tree diameter class, ie [60-70cm]. The percentage of germination shows a strongly relation with the diameters of mother trees. At the end of the 120 days of seedling follow-up, the best viability rate of the seedlings is 98%, resulting from the seeds belonging to the mother tree class diameter [70-80cm]. The study of the growth parameters, in particular the height and the diameter of the seedlings, reveals that, in a selection framework of *P. elata* seedlings, the best seedlings would be those belonging to the mother tree diameter class [70-80cm]. It seems that, in various plant species, seeds with different germinability develop on the same mother plant and on plants of the same species growing in different environments; maternal position and environmental factors cause these differences by their influence on plant development and seed maturation. However, in cases where seeds are collected from plants grown under natural conditions, it is difficult to distinguish between true age effects and the effect of the changed seasonal environment under which the later seeds develop. Moreover, we should also consider maternal effects and physical environments and their interaction in order to elucidate natural regeneration mechanism of the *P. elata*.

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