

Assessment of seed germination and shade impact on early growth of seedlings of *Piptadeniastrum africanum* (Hook f.) Brenan in an arboretum

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ABSTRACT

Seed germination and shade impact on early growth of seedlings of *Piptadeniastrum africanum* (Hook f.) Brenan were evaluated in an arboretum in University of Benin, Benin City, Nigeria. The variables assessed were: “days to plumule emergence; germinant count, type, crook and spike stages of germination and post-emergence cotyledonal position” for germination, while “height and number of leaves / pinnae” were measured under three understorey treatment regimes – zero shade (control), canopy gap and heavy shade – in a Completely Randomized Design (CRD). Germination data were analysed using descriptive statistics while growth data were subjected to Analysis of Variance and means separated using LSD ($p=0.05$). Results show that plumule emergence started eight days after sowing (DAS) and peaked 11 DAS with 80% germination success. Seedling crook stage commenced 10 DAS and peaked 12 DAS while spike stage spanned 10 to 24 DAS. *P. africanum* seed has transient dormancy / viability, and undergoes epigeal (phanerocotylar) germination. Seedlings propagated in zero shade had most abundant leaves / pinnae while canopy gap had best height and were significant ($p<0.05$). The correlation between results obtained in zero shade and canopy gap elucidates the ecological temperament of *P. africanum* as a non-pioneer light demander (NPLD). While zero shade and canopy gap significantly enhanced seedling growth; the effect of ‘heavy shade’ was passive – suggesting that, barring mortality, seedling growth often ceases when light is low or at compensation point. It is recommended that *P. africanum* seeds should be promptly sown following detachment from mother tree while seedlings should be propagated under open to low shade condition.

Keywords Epigeal germination, illumination, seedling growth, plumule emergence, understorey shade

INTRODUCTION

Piptadeniastrum africanum (Hook f.) Brenan is one of West-Central Africa’s multi-utility timber highly threatened mono-generic species. It belongs to the family Fabaceae (Mimosoideae) and commonly called Dabema, Dahoma and African greenheart in English, and Dabéma in French (Jiofack Tafokou, 2008). In Nigeria, it is locally called Ekhinmi in Edo, Kariya kurmi (Kiryàr kùrmì) or Dóòràwa kurmi in Huasa; Ufi (Ofie, Ohie) or Ohen (Ohi) in Igbo and Agboin (Agbonyin, Aga-igi in Yoruba (Keay,

1989; Aigbokhan, 2014). *P. africanum* is a deciduous or evergreen large tree up to 50 m tall having a straight and cylindrical bole that is sometime sinuous – having many curves and twists (Katende, Birnie and Tengnas, 1995). The young tree has a rounded crown which develops into two distinct layers, of which the lower one disappears later and the upper one develops horizontally and ultimately becomes fragmented (Ken, 2014). According to Ken (2014), adult trees have huge flat crowns that spread in the upper canopy of the forest; often briefly

deciduous, but frequently do not shed all leaves at the same time.

P. africanum occurs in a low land evergreen and semi-deciduous forest, up to 1200 m altitude (Jiofack Tafokou, 2008). In Ghana, it shows a preference for evergreen forest (Hawthorne, 1995). In Gabon, it occurs scattered in primary forest, but may be locally more abundant in old secondary forest (Hawthorne and Jongkin, 2006). Some species of *P. africanum* prefer hillside and moist but well-drained level ground as it has been observed in Sierra Leone. *P. africanum* is also commonly found in fringing forests in Nigerian (e.g. Keay, 1989). In Uganda, it is common and characteristic of the forest in the Lake Victoria belt (Katende Birnie and Tengnas, 1995).

Seedlings of *P. africanum* are often common in regenerated forest floor, even in dark shade (Jiofack Tafokou, 2008). However, they grow very poorly in such shade due to the limited sunlight penetrating through the canopy level to the forest floor (Whitmore, 1990). Saplings and young trees demand light and are usually found in small gaps in the forest since many shade intolerant plant species are dependent on gaps to succeed in their respective environments (Brokaw, 1985). Thus, the need to study the proper shade requirement of *P. africanum* is of importance as seedlings under shade may take three years to reach a height of 20-35 cm, whereas, they may reach up to 150 cm tall after 4 years in less shaded conditions in the forest (Jiofack Tafakou, 2008).

Although *P. africanum* does not appear to be under serious threat due to its wide distribution across West and Central African forests, it is seriously gaining importance as a commercial timber tree, while the bark is increasingly becoming important for orthodox and ethno-medicinal uses (Neuwinger, 2000). This may make the species liable to genetic

erosion in the nearest future (Jiofack Tafokou, 2008). In Nigeria, *P. africanum* is increasingly declining in all its geographic ranges owing to diverse threats, particularly indiscriminate exploitation and destruction of forest ecosystems where it is endemic. The study evaluated seed germination as well as response of juveniles of *P. africanum* to different shade levels.

MATERIALS AND METHODS

Study Site

The study was carried out in the Department of Forest Resources and Wildlife Management arboretum in University of Benin, Benin City, Edo State, Nigeria. The physicochemical properties of the soil show that it is acidic and sandy (e.g. Kohnke and Franzmeier, 1995): pH (5.8); organic carbon (17.2 mg/kg); total N (0.82 mg/kg), P (6.54 mg/kg); K (0.35 mg/kg); Mg (0.28 mg/kg); clay (57.4); silt (56.2); sand (886.4). University of Benin, Benin City is located in the moist rainforest zone of Nigeria (Latitude 06° 24' 56" N and Longitude 05° 37' 25" E). The average annual rainfall is 2500 mm while minimum and maximum temperatures range between 27° C to 33° C. The relative humidity is between 75 % at noon to 95 % at dawn (UNIBEN Master Plan, 1993).

Experimental Design and Data Collection

Matured fruits of *Piptadenastrum africanum* were collected under the mother tree in Edo State Government House, Benin City, Nigeria on Tuesday January 5, 2016. Six germination trays (1m × 1m) were filled with sterilized river sand collected from the nearby Ikpoba River while topsoil was collected from the floor of the arboretum. Three hundred and twenty-five (325) freshly collected seeds of *P. africanum* were de-winged and sown at 4 cm × 3 cm in six germination trays on January 9, 2016 (Figure 1).



Figure 1: Fresh seeds of *Piptadeniastrum africanum* used for the experiment

Seedlings were pricked into 6 kg polythene pots filled with topsoil on February 3, 2016. Watering of both the germination trays and polythene pots was carried out twice daily. Plumule emergence was observed and recorded until the attainment of the crook stage, that is, when the seedlings have broken through the soil but before the hypocotyl has become erected (Wanjura and Buxton, 1972); and the spike stage i.e. emergence stage in which the leaves are still slightly rolled to form a spike (Finch- Savage *et al.*, 1998).

A lux meter Model Lx-101 was used to measure the amount of PAR in the treatment plots four times daily at 10 am, 12 noon, 2 pm and 4 pm for two weeks. Although the lux meter has been described as inaccurate – because it is uncalibrated – nevertheless, it provided reliable information on levels of PAR in treatment plots in the absence of a more accurate data logger (Isikhuemen, 2005). Means of PAR data were computed and the illumination available to the seedlings at the three treatment locations in the forest understorey were found to be significantly

different ($p=0.05$) from each other: zero shade (open condition) (90.2 %), medium shade (44.3 %) and dense shade (4.9 %).

Seedling variables, namely; height (cm), number of leaves and number of pinnae were observed and measured fortnightly for 24 weeks. Data were analysed in two-way Analysis of Variance (ANOVA) and means were separated using Duncan's Multiple Range Test (DMRT) at 5 % level of significance.

RESULTS

Plumule emergence

Plumule emergence was first observed eight days after sowing (DAS). From the total of 325 seeds sown, 260 seeds (or 80%) germinated within a period of 16 days; between 8 and 24 DAS. Daily records of plumule emergence and corresponding number of germinant at crook and spike stages of germination are shown in Figure 2.

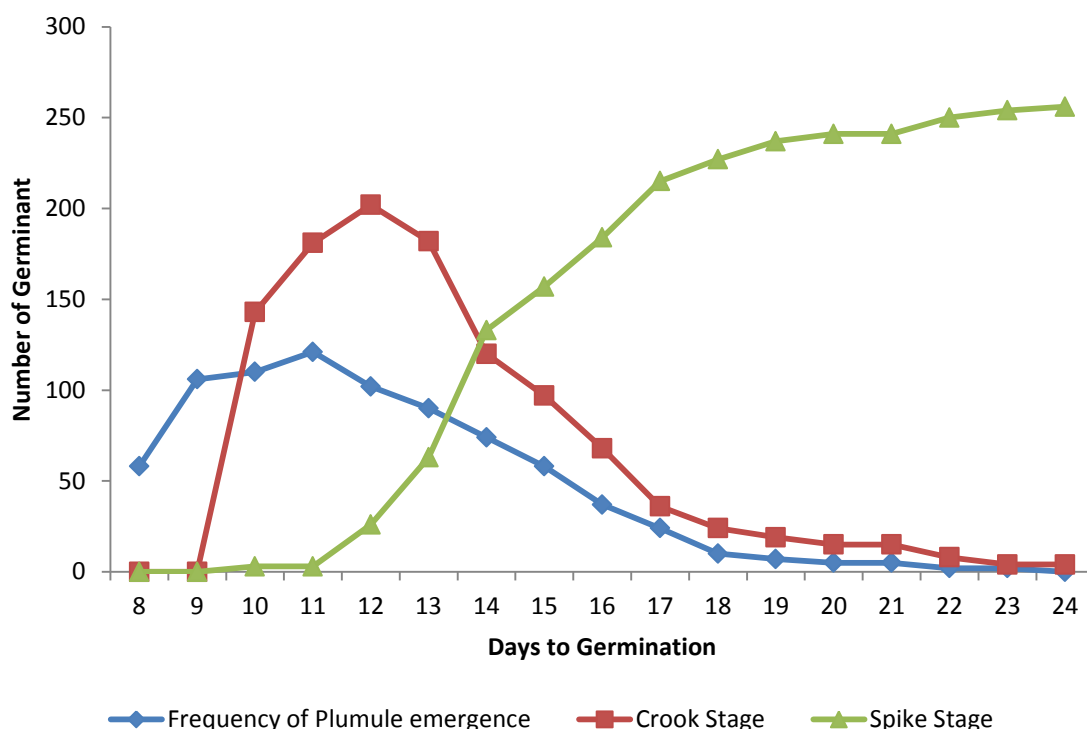


Figure 2: Plumule emergence through crook and spike stages of germination

Days to germination denotes the day seed germination commenced up to the day it ended. Frequency of plumule emergence denotes number of germinant per day. Crook stage: when seedling has emerged from the soil before the hypocotyls becomes erect; and Spike stage: period following crook stage in which leaves are rolled to form a spike.

Effect of shade on seedling growth

The results of seedling response to shade levels revealed that there were no significant differences in height and number of leaves among seedlings grown

under zero and medium shades. However, differences were recorded in number of pinnae for seedlings raised under the three different shades ($p < 0.05$) (Table 1).

Table 1: Mean comparison for shade at 24 Weeks After Pricking-out (WAP)

Shade	Seedling height	Number of leaves	Number of pinnae
1 (Zero shade)	13.63 ^a	9.792 ^a	107.25 ^a
2 (Medium shade)	12.01 ^a	9.958 ^a	83.04 ^b
3 (Dense shade)	7.31 ^b	9.021 ^a	27.52 ^c

Means with same alphabet within columns indicate no significant difference ($p > 0.05$).

Number of Leaves

Seedlings that received Medium shade had the most abundant leaves, but were not significantly different from those that

received Zero shade and Dense shade (which had the least number of leaves) at 24 WAP ($p > 0.05$) (Figure 3).

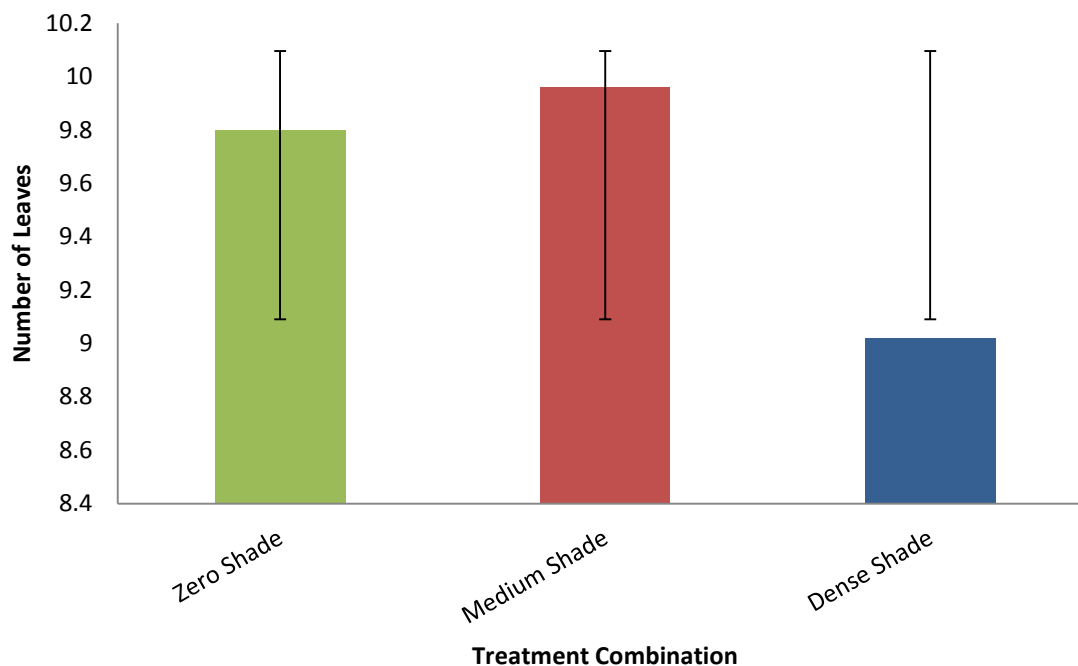


Figure 3: Number of leaves at 24 Weeks After Pricking-out (WAP)

Seedling Height

Seedlings under Zero shade had the best height growth and were not significantly different from seedlings under Medium shade ($p>0.05$). However, they were

significantly different from all the seedlings raised under Dense shade ($p>0.05$) (Figure 4).

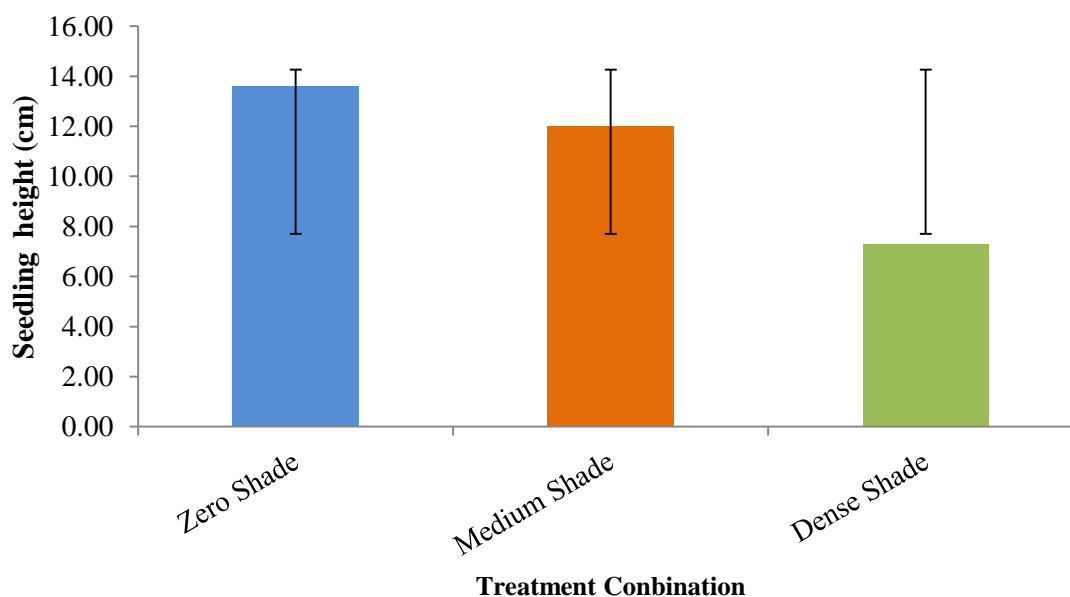


Figure 4: Seedling height growth at 24 Weeks After Pricking-out (WAP)

Number of Pinnae

The greatest number of pinnae occurred under Zero shade, but there were no significant differences between them and those grown under Medium shade. However, the number of pinnae recorded under the two shade regimes were

significantly different ($p < 0.05$) from those in the seedlings raised under Dense shade which had poorest results at 24 WAP (Figure 5).

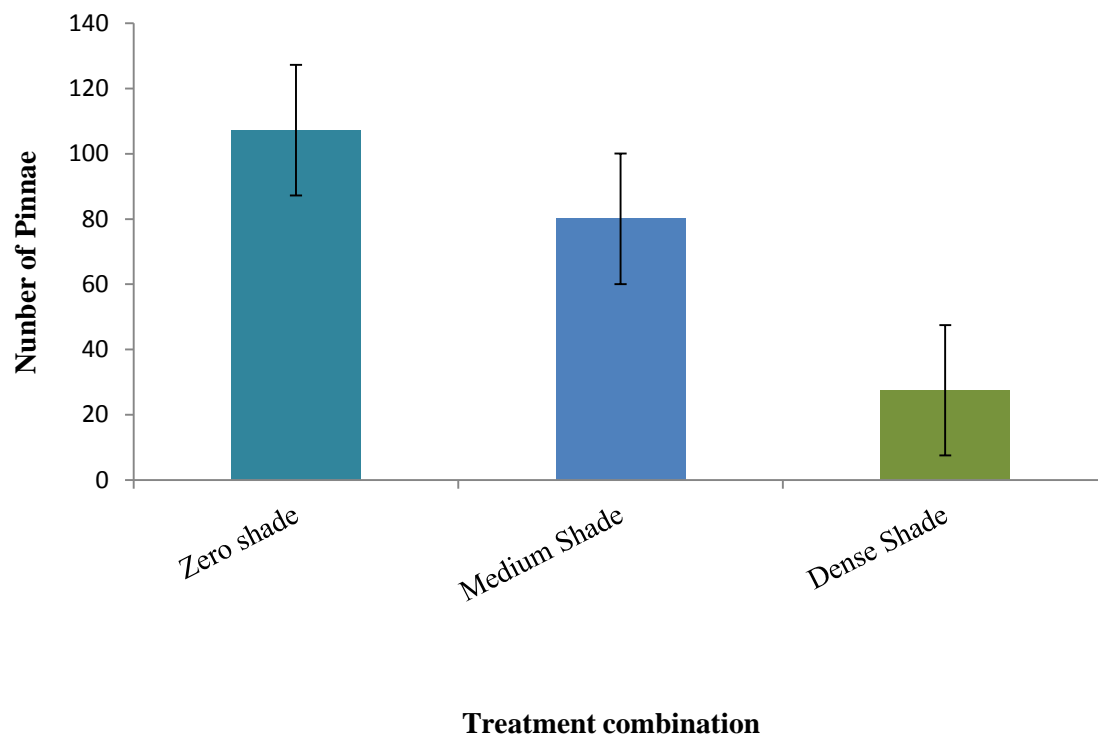


Figure 5: Number of Pinnae at 24 Weeks After Pricking-out (WAP)

DISCUSSION

The outcome of the study on germination revealed that plumule emergence was accomplished within 16 days after sowing (DAS) with 80 % success rate in an open nursery as against Jiofack Tafokou (2008) who recorded 96 % success rate in a germination test within 8 days. The observed dissimilarity in the two results might not be unconnected with the time interval and condition of seed from the point of collection to broadcast as well as the strategy used. The study revealed that the seeds of *P. africanum*: (a) undergo phanerocotylar germination; (b) are recalcitrant and progressively decline in viability with age, and (c) as they get older the colour of the seed coat tarnishes – and

changes from light- to dark brown – thus signifying weakening of viability.

Seed viability is a function of its vitality and capacity to remain healthy and germinable; this is the basis upon which seeds are generally classified as orthodox or recalcitrant – orthodox seeds are usually dormant, retain viability for longer periods while recalcitrant seeds present short or zero dormancy, cannot be dried or stored below critical moisture content (Khurana and Singh, 2001). The study also showed that seed germination in *P. africanum* is epigeal (i.e. phanerocotylar – the fleshy thick cotyledons turn green before excising). According to Farjon and Styles (1997) “when germination is epigeal (phanerocotylar), the cotyledons assume

two shapes: (a) leaf-like (foliaceous) – thin, green and presumably primarily photosynthetic, and (b) fleshly – thick, non-green and presumably primarily food-storing.”

The above average results recorded in germination suggest that some of the seeds might have diminished in vigour before sowing. This result is in accordance with Bentsen (2002), who acknowledged that, aged seed with reduced vigour could particularly face a number of stress factors during germination; while, Jiofack Tafokou (2008), affirmed that, *P. africanum* has transient viability (and can hardly be stored for more than one month). Successful germination and seedling establishment primarily depend on the vitality of the seed which is closely related to its development (Chen *et al.*, 2012).

In a study of natural regeneration among rainforest tree species in Nigeria, Onyeachusim (1985) found that 50 or (78 %) out of 64 trees species had epigeal germination. Generally, the rate of seed germination and seedling survival during the pre-establishment stage in the floor region of the forest are governed largely by several inherent and environmental factors, namely: seed size and type, photosynthetic surface area of cotyledons; condition and position of seed and anchorage potential of the soil; the litter standing crop, decomposition and turn-over rate as well as species guild and season (Isikhuemen and Ola-Adams, 2011). The classification of rainforest species into guilds (pioneer, non-pioneer light demanders and climax species) has direct relationship with the functional roles that mature trees play in partitioning the light resource reaching the canopy as well as the ability of their juveniles to efficiently utilize illumination (i.e. photosynthetically active radiation) and/or irradiance for germination, growth and development (survival) in the forest understorey.

Seedlings of species restricted to, and growing rapidly in open and high light areas are called shade-intolerant, while those restricted to close understories are called shade-tolerant (Kio, 1981; Whitmore, 1989; Walters and Reich, 1996;;). Kio (1981) reported that a typical tolerant species differs from an intolerant one in being able to reproduce under shade and persist for many years as an understorey individual, while yet retaining the capacity to respond quickly to light upon release (Kio, 1981). But, *P. africanum* shares the features of both intolerant and tolerant species, thus confirming its status as non- pioneer light demander (NPLD). A typical NPLD can perform its physiological functions at low light levels (i.e. compensation point) under the forest understorey but would take advantage of any opening in the canopy to maximize available illumination for growth enhancement.

Light quality in the forest understorey is shifted to lower red: far red ratios than in open sky conditions but high red: far red ratios have been shown to strongly affect morphology (e.g. greater stem elongation) but not growth in low light (Schmidt and Wulff, 1993) and morphology and growth in high light (Ballare, Scopel and Sanchez, 1996). Seedlings of *P. africanum* are often common in the forest, even in dark shade (Jiofack Tafokou, 2008); however, they grow very poorly in such shade due to the limited sunlight penetrating through the canopy to the forest floor (Whitmore, 1990)

Attempts by ecologists to probe niche differentiation among ecologically related sympatric species, which allow complex interactions and co-existence in the species rich rainforest ecosystem, have led to the execution of several *ex situ* studies (i.e. outside the species natural environment), particularly under artificial or controlled conditions (Isikhuemen and Ola-Adams, 2011). Riddock, Leehto and Grace (1991b)

found in a glasshouse experiment with two Nigerian tree species (*Entandrophragma angolense*, *Nauclea diderrichii*, NPLD and pioneer respectively) a positive response of photosynthesis to added mineral nutrients including a significant interaction between nitrogen and light. The average number of pinnae recorded among seedlings under zero- and medium shades at 24WAP falls within the range of 25 – 60 pairs reported by Jiofack Tafokou (2008). But, Press *et al.* (1996) have asserted that shade tolerant seedlings shift most of their above ground growth to leaf replacement when heavily shaded while light demanding species allocate about 65 % of above ground dry matter to stem and branches under all conditions.

CONCLUSION AND RECOMMENDATION

P. africanum is a non-pioneer light demander (NPLD) with transient dormancy. The seed undergoes epigeal (phanerocotylar) germination with exposed fleshy cotyledons. The ability of the seeds of *P. africanum* to germinate is contingent upon age and several environmental factors. The contention by Jiofack Tafokou (2008) that “the growth of seedlings *P. africanum* is slow and that they could stay in the nursery for more than one year before planting out” should be re-evaluated in the light of the outcome of this study.

For successful regeneration and investment in large scale plantation establishment, *P. africanum* seeds should be promptly sown following detachment and collection from mother trees while seedlings should be propagated in open-canopy gap receiving reasonable amounts of illumination (Photosynthetically active radiation).

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