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Evaluation of germination and early growth performance of *Pterocarpus santalinoides* seedlings at different light intensities

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ABSTRACT
This study evaluated the effect of light intensities on the germination and seedling growth of *Pterocarpus santalinoides*. The experiments were laid out in a Completely Randomised Design (CRD) in which 80 seeds were selected and used for the four (4) light intensities (330 lux (full). 180 lux (medium), 120 lux (moderate) and 80 lux (low)) investigated. Seeds were directly sown in polybags filled with sterilized topsoil. Each polybag was taken as a replicate of its own. Data were collected on germination percentage, germination emergence, germination duration, mean daily germination, seedling height, collar diameter, leaf production and biomass (dry shoot and root, weight and total dry weight). A one-way analysis of variance (ANOVA) was used to test for significant difference in the measured germination and growth attributes among the different treatments. Seeds sown at 120 lux had the highest mean germination percentage (GP) (70 %), while those at 300 lux had the lowest GP (50 %). Germination emergence was earliest in seeds sown at 180 lux and 330 lux (8 days) and latest in 80 lux (14 days). The longest (27 days) and the shortest (17 days) germination duration were observed at 330 lux and 180 lux respectively. Light intensity significantly ($p \leq 0.05$) affected seedling height, collar diameter, leaf number and biomass, but did not affect root length ($p > 0.05$). 120 lux and 180 lux (medium shading) were the most suitable for germination, while, seedling at early growth require full light intensity (330 lux) for enhanced growth with reference to height, collar diameter, leaf production, root length and biomass.

Keywords: *Pterocarpus. santalinoides*, light intensities, germination emergence, early growth, biomass

INTRODUCTION

There are lots of indigenous forest species (woody plants) with edible vegetables and fruits of high nutritive value that are consumed by most people in Nigeria (Uluocha *et al.*, 2016). These indigenous species have played crucial role in providing food for the people, thereby solving the problem of food security over time and currently serve as means of generating income by both rural and urban dwellers (Kola-Oladiji *et al.*, 2006). Like most *Pterocarpus* species, "*P. santalinoides* is a multipurpose tree that deserves more attention" (Lemmens, 2008). According to Lemmens (2008), the species "may not gain importance as a timber tree because, it is too small and provides wood of moderate quality", but can be integrated into agriculture for soil enrichment due to its ability to fix nitrogen, thereby improving soil fertility. The species is used to control weeds as it out-competes them; it also provides forage and fuelwood for the people. The wood is locally used as fuelwood, for sculpturing, making fences and boxboard and for temporary construction. According to David (2013), *Pterocarpus santalinoides* are good sources of pulp and paper based on their density. Both the seeds, leaves, stems, barks, trunks and roots of the species are very useful medicinally and economically. Despite the importance of indigenous tree species, not much effort have so far been directed on the areas of knowledge of their reproductive biology including fruiting and flowering pattern, fauna ecology, pollination and biology.

The presence or absence of light fluctuations are known to be the most common factors of the environment which control seed germination (Ferreira *et al.*, 2001). According to Anjah *et al.* (2013), light is a crucial physical factor that impacts tree growth at the stage of germination and seedling, and is an environmental factor necessary for plant growth (Chanhsamone *et al*., 2012; Mukhtar, 2016a). It is a source of energy for photosynthesis (Bolanle-Ojo, 2014). "Light is required for germination of seed in some species although the seeds of most cultivated plants are known to germinated in the presence or absence of light" (Lone *et al.*, 2014). Most forest species may not germinate in the canopy unless there is an opening that gives the seedling ample light for development (Siegel and Rosen, 1962; Jamhari, 2018). Light is very important for both dormancy and release and is a mechanism for the adaptation of plants to specific environment which often interact with temperature (Anjah *et al.*, 2013). Nwoboshi (1982) noted the seedlings of various species of trees have various requirements for light, as some excel in environments where others fail. Variations in light intensity are very crucial in tropical silviculture (Anjah *et al.*, 2013). Seeds classification based on its sensitivity to light is a very important factor for testing germination (Mayer and Poljakoff-Mayber, 1989). A good understanding of *P. santalinoides'* germination and growth response to light intensity is necessary as it will enable the identification of the most suitable light intensity under which it can germinate and grow successfully. Therefore, the objective of this study was to assess the effect of light intensity on seed germination and early seedling growth of *P. santalinoides*.

MATERIALS AND METHODS

Study Area

The research was conducted at the Forest Nursery of the Department of Forestry and Wildlife Management, Faculty of Agriculture, University of Port Harcourt Rivers State, Nigeria, located at the Choba Campus of the University. The university is situated within Latitude 04°52' 30"N and 04°55' 0"N and longitude 6°54' 0" E and 6°55'30"E on an area land of about 400 hectares in Choba community which is found in Obio/Akpor Local Government Area of Rivers State, Nigeria (Chima *et al.*, 2017). The region is considered to have two seasons, the rainy and dry seasons, with rainfall distribution throughout the year (Aiyeloja *et al*., 2014). The total annual rainfall is about 2400 mm and temperature ranges from 25^{o} C to 38^{o} C in the dry season (Wokoma, 2008).

Seed Collection

Mature fruits of *P. santalinoides* used for this study were harvested from healthy mother trees in Eziama Ntigha Autonomous Community in Isi-alangwa North Local Government Area, Abia State, Nigeria. Viability test was done to know the seeds that are viable before sowing; this was carried out by using floatation method where seeds were soaked for three hours. The seeds that sank were taken to be viable seeds and used for the study, while the seeds that floated were discarded.

Experimental Design

This experiment was set up in a Completely Randomized Design (CRD) in which 80 selected seeds were used for the four (4) light intensities (330, 180, 120 and 80 lux) (i.e. 20 seeds for each of the 4 light intensities to make 80 experimental units). Seeds were directly sown in polybags measuring 15 cm x 15 cm x 20 cm and filled with sterilized topsoil. Each polybags was taken as a replicate of its own. Forty seedlings of equal height (i.e. 10 seeds per light intensities) were pricked into polybags filled with sterilized forest topsoil. No form of fertilizer was applied to the soil. Plants were watered twice a day (morning and evening) for a period of two months and once thereafter, while weeding was carried out often throughout the experiment. The different intensities were achieved by using a wooden frame covered with a mesh net with three layers to produce 80 lux light intensity (T1), two layers to produce 120 lux light intensity (T2) and one layer, to produce 180 lux light intensity (T3) (Plate 4). For 330 lux light intensity (T4), plants were kept directly under full sunlight (Mukhtar, 2016a: Fredrick *et al.*, 2020). The light intensities of the different propagators were taken severally using a light meter and the average were determined and used as the actual light intensity of the propagator.

Biomass Determination

Five seedlings were chosen for each treatment at the end of the experiment and carefully removed from the polypots and the root system exposed were carefully washing off with water to remove the growth media from the roots, absorbent paper was used for blotting excess moisture from the plants. Seedlings were then cut into shoot and root components by cutting at the collar. The root length, fresh weight of shoot (including the leaves) and root were taken and then placed in a paper bag for drying. The shoot and the root samples were dried in the oven at 70° C for three days (72 hours).

Data Collection

Germination of seeds was monitored and recorded on a daily basis; after thirty days, this was ended. "A seed was considered to have germinated when the hypocotyls hook is evident above the soil surface" (*Fandohan et al.,* 2010). Germination data was used to determine germination percentage (GP), germination emergence (GE) germination duration (GD) and mean daily germination (MDG) using the equations below;

Germination percentage (GP) = $\frac{Total\ germinated\ seeds}{Total\ seeds\ sown} * \frac{100}{1}$

Germination emergence (GE) = Time to germinate after sowing.

Germination Duration (GD) = First day germinate occurs to last day of germination after sowing

Mean Germination Time (MDG) = $\frac{Total\ number\ of\ germinated\ seeds}{Total\ number\ of\ days}$

Shoot parameters measurement was done on all seedlings for twelve (6) months. Seedling height, stem collar diameter, leaf number and survival rate data were collected. "Measurement on seedling height was done from the substrate level to the tip of the youngest leaf using a meter rule; on stem collar diameter was done at the root collar using a digital caliper; on leaf number was determined by directly counting the number of leaves", while root length was also measured using a meter rule. Seedling survival rate (SR) was determined using the formula below;

$$\text{Survival Rate (SR)} = \frac{\textit{Number of seedlings that survived}}{\textit{Number of seedlings transplanted}}$$

The seedlings were weighed using a digital weighing scale calibrated in grams (g) to determine dry weights of shoot and root, while total dry weight (TDW) was calculated using the following equation.
Total Dry Weight (TDW) = shoot dry weight + root dry weight

Data Analysis
Average values and standard errors were determined with respect to light intensities. Data collected on germination and early growth were analysed using the Analysis of Variance (ANOVA) in SPSS statistical software (SPSS version 21.0, SPSS Inc.) to determine the variation among treatments and F value was significant at $P \leq 0.05$. Mean separation was done using the Duncan Multiple Range Test (DMRT). Microsoft Excel 2010 was used to plot the graphs presented.

RESULTS

Effects of Light Intensity on Germination and Seedling Growth of *P. santalinoides*
Influence of light intensities on germination of *P. santalinoides* seed are shown in Figures 1, 2 and 3 below. The mean germination percentage varied from 50 % to 70 %. Seeds sown at T2 exhibited highest germination percentage (70 %), followed by T1 (63 %), while, T4 had lowest germination percentage (50 %) (Figure 1). The number of days which seeds of *P. santalinoides* took to emerge after sowing varied between 8 and 17 days. Emergence was earliest in seeds sown at T3 and T4 (8 days) and latest in T1 (14 days) (Figure 3). Seeds sown at T4 had longest germination duration (27 days) followed by T1 (25 days), while shortest duration was observed in T3 (17 days) (Figure 2). Mean daily germination ranged from 0.43 to 0.68 days with T3 exhibiting highest mean daily germination and T4 lowest (Figure 3).

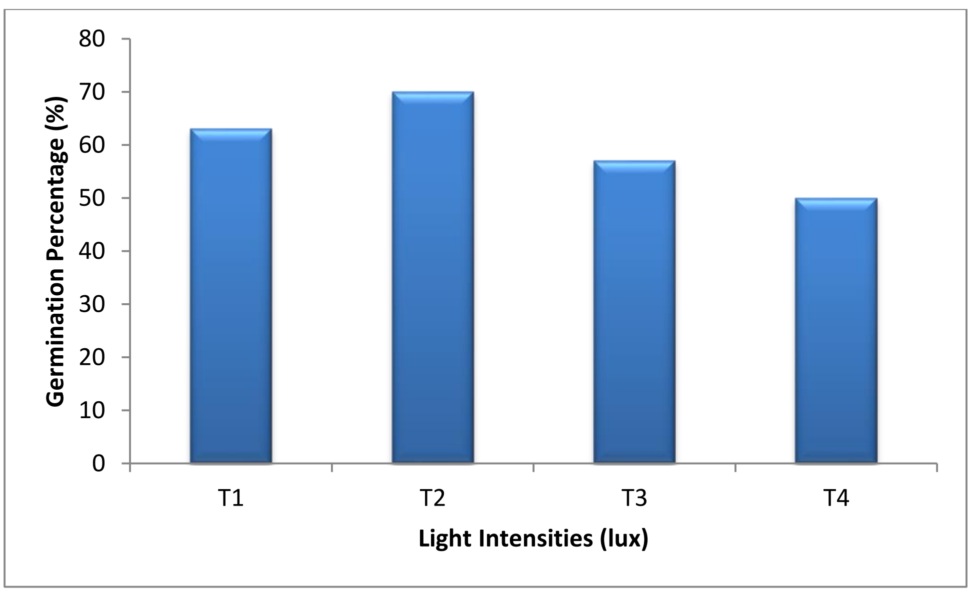

Fig. 1. Effect of light intensity on germination percentage (GP) of *P. santalinoides* seeds. Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux

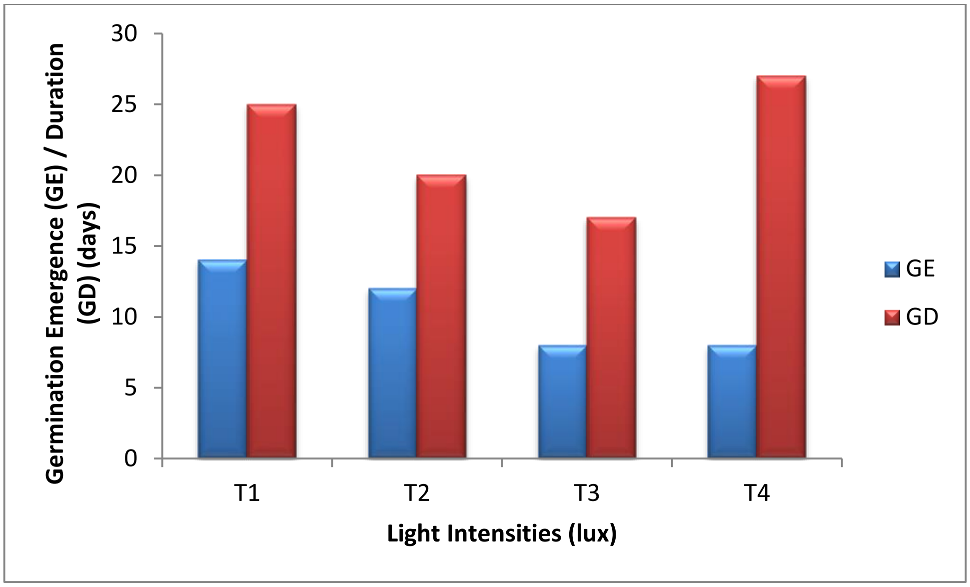

Fig. 2. Effect of light intensity on germination emergence (GE) and duration (GD) of *P. santalinoides* seeds. Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux

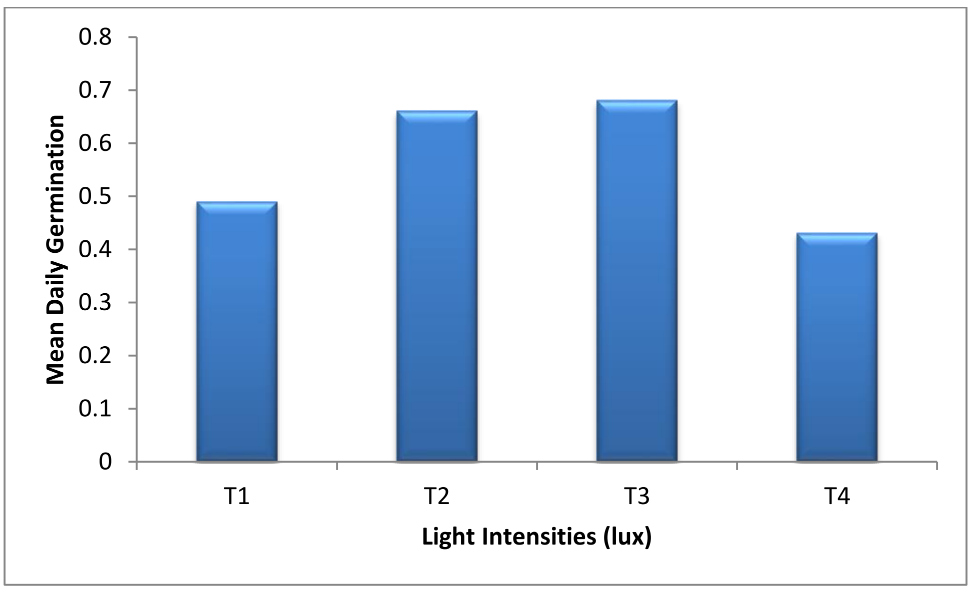

Fig. 3. Effect of light intensity on mean daily germination (MDG) of *P. santalinoides* seeds. Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux

Effects of Light Intensity on Seedling Growth of *P. santalinoides*

Light intensity significantly ($p \leq 0.05$) affected height of seedling, collar diameter and number of leaf, but did not affect root length ($p > 0.05$). The highest growth attributes (seedling height, collar diameter, leaf number and root length) were observed in T4 (52.15, 7.47, 47.3 and 35.49) respectively, followed by T3 (51.42, 7.41, 45.6 and 34.96) respectively, T2 (45.07, 6.93, 42.5 and 33.33) respectively, while, the lowest growth attributes were observed in T1 (44.50, 5.98, 41.5 and 31.81) respectively (Table 1).

Table 1: Effects of light intensity on growth attributes of *P. santalinoides* (μ±SE)

Light Intensity (lux)	Seedling Height (cm)	Collar Diameter (mm)	Leaf Number	Root Length (cm)
T1	44.50±0.85[a]	5.98±0.11[a]	41.5±0.73[a]	31.81±1.81
T2	45.07±2.23[a]	6.93±0.35[a]	42.5±0.73[a]	33.33±1.05
T3	51.42±1.01[b]	7.41±0.11[a]	45.6±0.54[b]	34.96±1.11
T4	52.15±1.13[b]	7.47±0.27[b]	47.3±0.78[b]	35.49±1.47
Mean	48.29±0.88	6.95±0.15	44.23±0.50	33.90±0.81
P value	<0.001	<0.001	<0.001	0.377

Means with the same alphabet on the same column do not differ significantly ($p > 0.05$). Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux.

Effects of Light Intensity on Biomass of *P. santalinoides* Seedlings

Seedlings of *P. santalinoides* subjected to different light intensities displayed significant differences ($p \leq 0.05$) in shoot dry weight, root dry weight and total dry weight. Seeds grown at T4 exhibited highest shoot and root dry weights and total dry weight (3.46, 1.44 and 4.90 respectively), followed by T3 (3.41, 1.37 and 4.78 respectively), T2 (3.36, 1.36 and 4.72 respectively) and T1 (2.76, 0.99 and 3.75 respectively). However shoot and root dry weights and total dry weight did not vary significantly among the T2, T3 and T4 (Table 2).

Table 2. Biomass of *P. santalinoides* seedlings under different light intensities (μ±SE).

Growth Attribute	Light Intensities (%)				
	T1	T2	T3	T4	P value
SDW (g)	2.76±0.073[b]	3.36±0.145[a]	3.41±0.151[a]	3.46±0.081[a]	<0.001
RDW (g)	0.99±0.035[b]	1.36±0.079[a]	1.37±0.070[a]	1.44±0.062[a]	<0.001
TDW (g)	3.75±0.098[b]	4.72±0.181[a]	4.78±0.179[a]	4.90±0.060[a]	<0.001

Means with the same alphabet on the same row do not differ significantly ($p > 0.05$). Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux.

Effect of Light Intensity on Seedling Survival Rate of *P. santalinoides*

The survival rate of *P. santalinoides* seedlings under the different light intensities showed that survival rate varied from 80 % in seedlings grown under T3 and T4 to 100 % in seedlings grown under T2 light intensity (Figure 4).

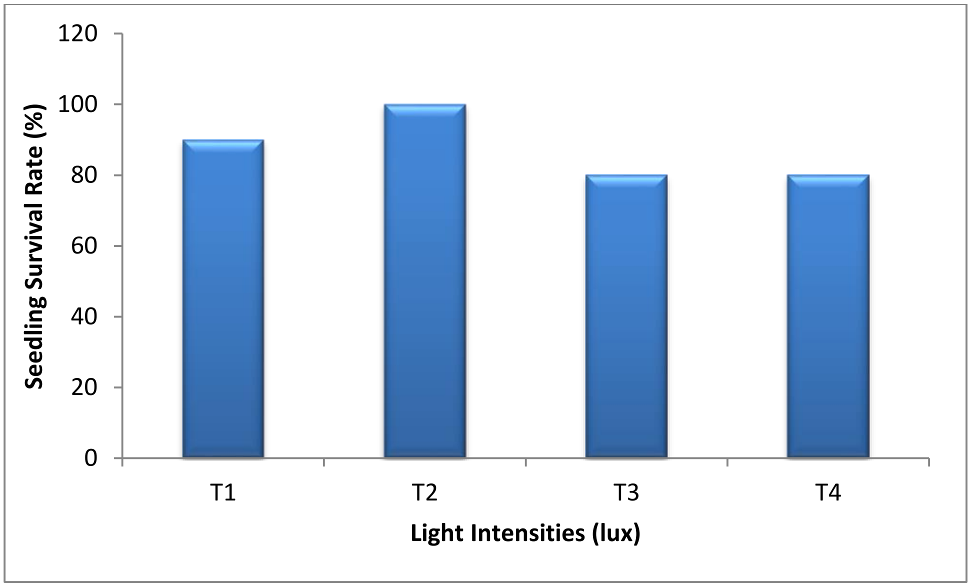

Fig. 4. Effects of light intensity on the survival rate of *P. santalinoides* seedling. Where (T1) = 80 lux, (T2) = 120 lux, (T3) = 180 lux and (T4) = 330 lux

DISCUSSION

Higher germination percentage was observed in seeds sown at reduced light intensity (80 and 120 lux) which indicates that high light is not needed for germination in *Pterocarpus santalinoides* seeds. Sacande and Some (1992), noted that seeds usually germinate in low light intensities. This findings agrees with that of Aniele *et al.* (2017) who reported that "seeds of *Copaifera oblongifolia* under high light had a lower germination percentage than seeds sown under low light intensity and darkness" and Onyekwelu *et al.* (2012) also observed that highest germination of *Chrysophyllum albidum* seeds occurred under forest canopy, while, least was obtained under 100 % light. But this disagrees with that of Aref (2002) who noted that "full light intensity was superior to low light intensity in all tree species studied" and Oyedeji *et al.* (2018) stated that higher germination was observed in seed of *Dialium guineense* exposed to light than those in the dark. Earliest emergence observed in 180 and 330 lux light intensities implies that seeds exposed to light require shorter time to germinate. This contradicts the report of Aniele *et al.* (2017) that "seeds exposed to high light required more time to germinate". Also, shorter germination duration and highest mean daily germination observed in 180 and 330 lux light intensities concurs with that of Jahn *et al.* (1986) who observed that the germination of the seeds of *Moringa oleifera* was influenced by light conditions and half shade for germination was recommended. According to Sacande and Some (1992), heavy shade is required by some species before germination to keep the soil moist and fresh while others can germinate without shade.

Significant variations were noticed in seedling growth parameters of *P. santalinoides* including seedling height, collar diameter and leaf number and non-significant difference in root length with seedling grown under full light intensities (330 lux) exhibiting highest seedling height, collar diameter leaf production and root length and decreased with decrease in light intensity. Significant variations observed in height of seedling, collar diameter and number of leaf of *P. santalinoides* agrees with the result of Fredrick *et al.* (2020) who observed significant variations in seedling growth of *Tetrapleura tetraptera* among different light intensities but does not agree with that of Mukhtar (2016b) who reported non-significant variations in *Adansonia digitata* seedling growth. The non-significant variation noticed in root length implies that the root length of *P. santalinoides* seedlings can be enhanced both in light and dark conditions preferably under full light.

Highest seedling growth parameters (height of seedlings, collar diameter, number of leaf and root length) observed at full light (330 lux) intensities indicates that seedlings of *P. santalinoides* require high light for optimum growth because the process of photosynthesis of *P. santalinoides* could be more efficient under full light intensity. Liang (2000) and Yuncong *et al.* (2007) opined that light stimulates plant growth and development by photosynthesis process. This is consistent with the outcome of Ologundudu *et al.* (2013) who stated that "most variables analysed in their study revealed that growth of species used were greatly promoted under higher light conditions when compared with its growth under the shade"; Ahmed (2000) who reported better growth of two *Acacia* species under full light intensity. and that of George *et al.* (2012) "who reported highest growth (stem height, diameter and leaves) in full light intensity on seedlings of *Salvia officinalis*" but disagrees with that of Fredrick *et al.* (2020) who noted that seedling of *Tetrapluera tetraptera* grown under 50 (two layers of mesh net) and 75% (one layer of mesh net) light intensities exhibited higher height of seedling, collar diameter and leaf development and implied that they need some amount of shade for early growth. Variations observed in different species subjected to light intensity treatment were due to variations in the light requirement of species (Droppelmann *et al*., 2000).

Significant differences were observed in seedling biomass of *P. santalinoides* with seedling grown under full light intensities (330 lux) exhibiting highest biomass. This implies that seedlings of *P. santalinoides* need full light for biomass production. According to Adelani *et al.* (2020), photosynthesis under higher light intensity enhances plant growth and development as well as biomass production. Significant differences observed in biomass production of *P. santalinoides* corresponds with that of Fredrick *et al.* (2020) and Mukhtar (2016) who observed significant differences in biomass production of *Tetrapleura tetraptera* and *Balanites aegyptica* seedlings respectively among light intensity treatments. The highest biomass observed at full light intensity (330 lux) also agrees with that of Fredrick *et al.* (2020) and Mukhtar (2016) who observed that full light (100 %) produced higher biomass in seedlings of *Tetrapleura tetraptera* and *Balanites aegyptica* respectively. Oyedeji and Akinyele (2016) noted that exposure of seedling of *Dialium guineense* to full light intensity (100 %) promoted their growth and biomass accumulation. The higher biomass produced by plants under high light intensity could be due to a relationship known to exist between photosynthesis rates and radiation of light. Lowest height of seedling, collar diameter, number of leaf, length of root and biomass observed at low light intensity (80 lux) indicates that *Pterocarpus santalinoides* seedlings are not shade-loving. Fredrick *et al.* (2020) also observed lowest growth performance in seedlings of *Tetrapleura tetraptera* under low light intensity (25 %). Also, higher survival rate observed in seedlings sown under 80 and 120 lux light intensity confirms that seeds of *P. santalinoides* require low to moderate light to survive.

CONCLUSION

The germination percentage was enhanced at 120 lux (medium shading), while, germination emergence, duration and mean daily germination were enhanced at 180 lux (medium shading). Root length was not significantly affected by light intensity but "seedling height, collar diameter, leaf production, and biomass" were influenced by light intensity with 330 lux (full) exhibiting better growth characteristics although seedling survival percentage was enhanced at 120 lux (medium shading). It was observed that 80 lux (low) light intensities did not enhance the germination and growth of *P. santalinoides*. Therefore, 120 and 180 lux (medium shading) light intensities are the most suitable for germination, while, seedling at early growth require full light intensity for enhanced growth with reference to "height, collar diameter, leaf number, root length and biomass". Medium shade (120 to 180 lux) should be used for the germination of this species and full light for its growth.

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