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Research article

Early growth of selected indigenous tree species in response to watering regime

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Abstract: The research was carried out to investigate the early growth of selected indigenous tree species in response to watering regime. Four different tree species *Terminalia ivorensis, Terminalia superba, Mansonia altissima* and *Cleistopholis patense* were collected from Aponmu Forest in Ondo state, Nigeria The seeds were subjected to cold water pre-treatment for 24 hours before sowing as a means of breaking the seed dormancy. Upon removal, the pretreated seeds of the respective species were sown in polypots and distributed to the experimental treatments which include three levels of watering regime (daily, twice weekly and thrice weekly) and replicated thrice. The planted seeds were subsequently watered ones daily; twice weekly and thrice weekly for a period of 96 days. The seedlings growth parameters: seedling height, branchlets count and collar diameters were monitored and assessed for 96 days. The result obtained shows that watering twice weekly was best for *Mansonia altisima* and *Cleistopholis patens* seedlings while thrice watering was best for *Terminalia ivorensis* and *Terminalia superba* seedlings. It is therefore recommended that the seedlings of *Terminalia ivorensis, Terminalia superba, Cleistopholis patens and Mansonia altisima* may be effective for improving the physiological growth which can enhance the domestication and cultivation of these seedlings in the environment when watered with well water, subjected to full light intensity and watered twice or thrice weekly.
Keywords: Pre-treatments - Treatments - Sowing - Physiological growth.

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INTRODUCTION

Water is an important natural resource that supports life and growth of plants, but there is a growing concern on water availability (Goyne & McIntyre 2003). With the effects of climate change, water will become increasingly scarce in most geographical zones of the world (Morrison *et al*. 2009). Availability of permanent water supply has been one of the major challenges in tree nursery establishment and management, especially in the drier regions of the tropics and sub-tropics. Initial growth of seedlings largely depends on stored food reserves contained in the cotyledons and also availability of soil moisture. However, after depletion of food reserves, seedlings rely on photosynthesis for their continued growth and survival (Bargali & Tewari 2004). Soil moisture plays a key role in this process and also for nutrient uptake from the growing media to support plant growth (Shao *et al*. 2008). Regular watering is necessary for nursery trees to produce good quality seedlings at economic rate as any stagnation in seedling growth or subsequent mortality translates into economic loss to a nursery operator. The losses can be huge because seedlings take long to reach an appropriate size for grafting (Mhango *et al*. 2008) and transplanting or for sale.

Water use requirements depend on tree species, growth stage and time of the year and hence, it is necessary to establish this for each tree species as there are differences in growth rates. Seedlings with small size, shallow roots and little food are less tolerant to harsh environments (Bargali & Tewari 2004). Most tree seedlings take more than a year to reach a suitable rootstock size for grafting or sale as seedlings (Mhango *et al*. 2008). Establishing optimal water requirements for tree seedlings in the nurseries, promotes sustainable water use. In case of commercial nurseries, reduced production costs associated with it is important. Our knowledge on optimal water requirements of most indigenous tree seedlings that thrive in semi-arid environments is limited.

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This gap in knowledge, constraints ability of nursery operators to make informed management decision about their operation. Commercial nursery operators invest in water supply (irrigation facilities), while poor resource-endowed nursery operators in the rural areas continue to face challenges in water supply for their tree seedlings.

MATERIALS AND METHODS

Study area

The study was conducted at the nursery site of the Department of Forestry and Wood Technology, Federal University of Technology, Akure, Ondo State, Nigeria which lies between latitude 7º 18′32.64″ North and 5º 10′35.79″ East and longitude 7º 16′34.93″ North and 5º 7′38.97″ East. The mean annual temperature of about 25ºC (minimum 19ºC and maximum 34ºC); relative humidity 84% and mean rainfall of 76mm is obtainable in the study area (Oyun *et al.* 2006).The elevation is about 350 m above sea level with gently undulating landform. The soil is classified as ferruginous tropical soil (alfisols) on the crystalline rock of basement complex and belongs to the Egbeda series (Smyth & Montgomery 1962).

Data collection

Morphological parameters (number of leaves, collar diameter and Height) were measured at an interval of 2 weeks starting from one month after sowing (when germination is complete). Seedling heights were measured by taking the vertical distance from the ground level to the tip of each tree seedling using a long meter ruler; collar diameter was obtained by measuring the diameter at the collar point with the use of a Vernier calliper while the number of leaves was obtained by visual counting.

Evaluation of physiological parameters

Growth rates which include relative growth rate (RGR), seedlings growth rate (SGR), net assimilation rate (NAR) and leaf area ratio (LAR) were evaluated using the biomass, land area and leaf area of the growing tree seedlings.

Assessment of biomass

Biomass assessment was done twice. The first assessment was carried out after the first three weeks from germination and the second biomass determination was done two months after germination. Thirty-two (32) selected plants were subjected to destructive sampling three weeks after germination while another (32) plants were also subjected to destructive sampling two months after germination. Stems and roots of the seedlings were cut with a sharp matchet while leaves were picked up with hand. The leaves were separately collected as well as the stems and the roots; while the root was washed in clean water to remove attached soil. Their fresh weights was determined using an electronic weighing balance and then oven - dried to constant weights for 24 hours at 70ºC. The oven dry weight samples were taken as plant biomass

$$\boldsymbol{Biomass = Dry\ weightof\ plant}$$

Land area

Thirty-two (32) plants were randomly selected from each experimental unit and their land areas were obtained by tracing the canopy of the plants down to the ground. The length and the breadth of the land areas around the seedlings were measured using measuring tape. This was done twice at three weeks and at two months. The data obtained was used in calculating the plant growth rates.

Leaf area

Thirty-two (32) plants were randomly selected from each experimental unit. Three categories of leaves: biggest, medium and the smallest were collected from the plants, and their areas were measured separately using destructive method. The three areas were added and their mean(s) was obtained. These were used in calculating the growth rates.

The data obtained from the above ground biomass was also used in calculating the growth rates *i.e.* (SGR), (RGR), (NAR) and (LAR). The formula for calculating the growth rates are indicated below:

i. Seedlings Growth Rate (gm^2 day^{-1}): The dry matter accumulation rate per unit land area is referred to as seedlings growth rate, normally expressed as grams per square meter of land area per day {g (m of land area) - ^{2} Day – 1} (Olaiya *et al.* 2012). It shall be determined using equation 1:

$$\textbf{Seedling Growth Rate} = \frac{W}{\text{SA}\ (\text{t2} - \text{t1})} \qquad \textbf{Equation 1}$$

Where, W is the plant biomass, t_1 and t_2 are corresponding days and SA is the land area occupied by the plant sampling.

ii. Relative Growth Rate (gg^{-1} day^{-1}): Relative Growth Rate of a plant at any given time (t) is defined as the increase of plant material present per unit of time (Hoffmann & Poorter 2002). It will be determined using equation 2:

$$\textbf{Relative Growth Rate} = \frac{\textbf{LnW}}{\textbf{t2} - \textbf{t1}} \qquad \textbf{Equation 2}$$

Where, LnW is the natural logs of plant biomass and time t_2 and t_1 is the initial time while t_2 is the final time.

iii. Net Assimilation Rate (gm^2day^{-1}): The dry matter accumulation per unit of leaf area is termed net assimilation rate (NAR) and is expressed as g (m of leaf area)$^{-2}$ day^{-1} (Brown 1984). It will be determined using equation 3:

$$\textbf{\textit{Net assimilation rate}} = \frac{dw}{A \times dt} \qquad \textbf{Equation 3}$$

Where, A is the leaf area, while d_w is the change in plant dry matter and d_t is change in time.

RESULTS

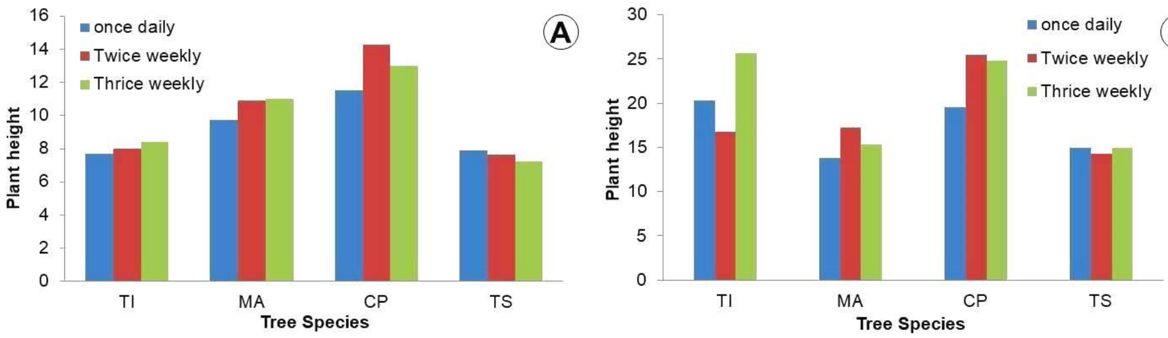

Figure 1. Effect of watering regimes on plant height of test species: **A**, at four week; **B**, at twelve week.

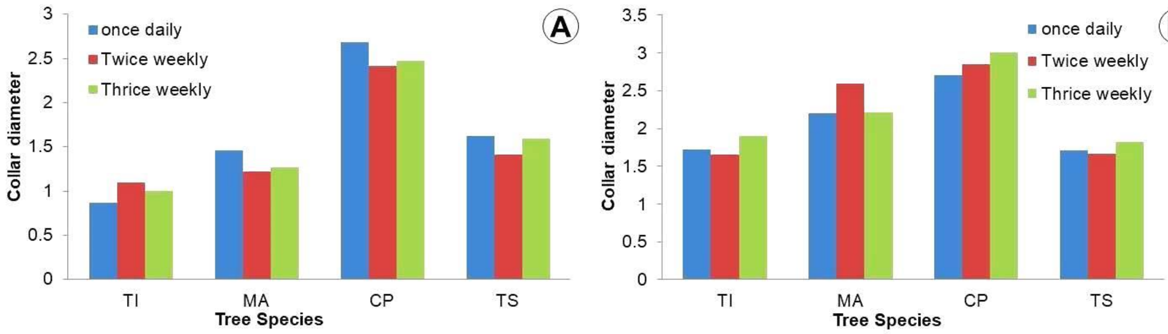

Figure 2. Effect of watering regimes on collar diameter of test species: **A**, at four week; **B** at twelve week.

The response of the test species to watering frequencies (once daily, twice and thrice weekly) as treatment with respect to plant height, collar diameter and number of leaves developed at 4weeks after planting (4WAP) and 12weeks after planting (12WAP) are presented in bar graphs and shown in figure 1, 2 and 3 respectively. For plant height, *Cleistopholis patens* (Benth.) Engl. & Diels, show higher plant height at 4WAP followed by *Mansonia altisima* (A.Chev.) A.Chev. and *Terminalia ivorensis* A.Chev. which exhibited the same pattern of growth rate while *Terminalia superba* Engl. & Diels show least plant height (Fig. 1). However at 4WAP, plant heights of *Terminalia ivorensis, Mansonia altisima* and *Cleistopholis paten* were higher when watered twice and thrice weekly while plant height of *Terminalia superba* was higher when watered once daily. It was however noticeable that at 12WAP *Mansonia altisima and Cleistopholis paten* showed higher plant height when watered twice weekly while *Terminalia ivorensis and Terminalia superba* showed higher plant height when watered thrice weekly. The response of the test species to watering frequency with respect to collar diameter showed a different pattern at 4WAP and 12WAP. As shown in figure 2; *Terminalia superba, Mansonia altisima and Cleistopholis paten* recorded slightly higher plant diameter when watered once daily while *Terminalia ivorensis* recorded higher plant diameter when watered twice weekly at 4WAP. Also, *Terminalia ivorensis, Terminalia superba and Cleistopholis paten* recorded higher plant diameter when watered thrice weekly while *Mansonia altisima* recorded higher plant diameter when watered twice weekly at 12WAP. For the number of leaves at 4WAP, *Terminalia* ivorensis and *Cleistopholis patens* developed higher number of leaves when watered twice weekly. However, *Terminalia superba* and *Mansonia altisima* had higher number of leaves when watered thrice weekly. At 12WAP, *Terminalia ivorensis* and *Terminalia superba* developed higher number of leaves when watered thrice weekly while *Mansonia altisima* and *Cleistopholis patens* had higher number of leaves when watered twice weekly (Fig. 3). Generally it was observed that *Terminalia ivorensis* and *Terminalia superba* develop higher number of leaves than the other two test species when watered thrice weekly.

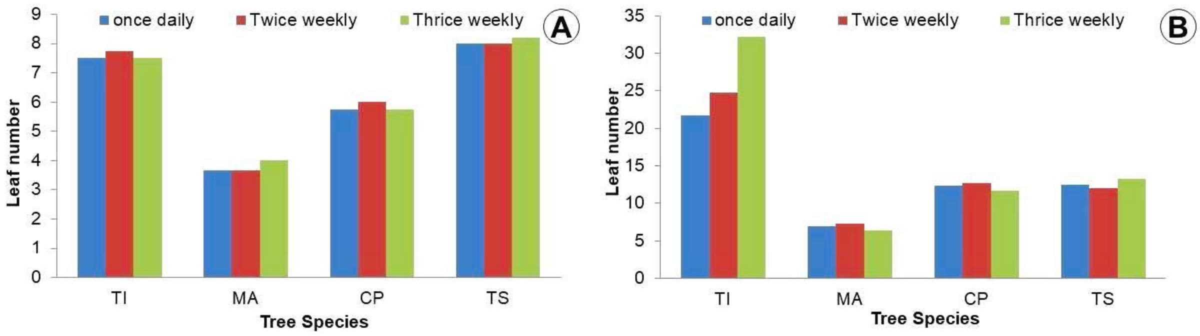

Figure 3. Effect of watering regimes on leaf number of test species: **A**, at four week; **B**, at twelve week.

As indicated by the result of the Analysis of variance (ANOVA) and subsequent mean separation, seedlings of *Terminalia superba* watered once daily had significantly higher plant diameter (1.62 cm) than those watered twice and thrice weekly which has a mean of 1.41 cm and 1.58 cm at 4WAP. Also, for *Mansonia altisima* seedlings watered once daily show higher plant diameter (1.45 cm) than those watered twice and thrice weekly which recorded mean diameter of 1.22 cm and 1.27 cm respectively (Table 1). For the other test species, the plant height, collar diameter and leaf count were not significantly different when watered with either stream or well water (Table 1). At 12WAP, the plant height (25.72 cm) of *Terminalia ivorensis* seedlings watered thrice weekly was significantly higher than those watered once daily and twice weekly. Also, collar diameter (3.01 cm) of *Cleistopholis patens* seedlings watered thrice weekly was significantly higher ($P<0.05$ cm) than those watered once daily and twice weekly which has a mean value of 2.71 cm and 2.85 cm respectively (Table 2).

Table 1. Effect of Watering regime on early growth of the test species at 4WAP.

	Once Daily Treatment			Twice weekly Treatment			Thrice weekly Treatment		
Test Species	**Plant Height**	**Collar Diameter**	**Leaf Count**	**Plant Height**	**Collar Diameter**	**Leaf Count**	**Plant Height**	**Collar Diameter**	**Leaf Count**
Terminalia ivorensis	7.72^{a}	0.86^{a}	7.50^{a}	8.02^{a}	1.27^{a}	7.75^{a}	8.37^{a}	1.00^{a}	7.50^{a}
Terminalia superba	7.92^{a}	1.62^{a}	8.00^{a}	7.66^{a}	1.41^{a}	8.00^{a}	7.22^{a}	1.58^{b}	8.20^{a}
Mansonia altisima	9.73^{a}	1.45^{a}	3.60^{a}	10.93^{a}	1.22^{b}	3.60^{a}	11.00^{a}	1.27^{c}	4.00^{a}
Cleistopholis patens	11.52^{a}	2.68^{a}	5.75^{a}	14.27^{a}	2.41^{a}	6.00^{a}	12.97^{a}	2.46^{a}	5.75^{a}

Note: Mean with the same letter along the row are not significantly different (DMRT).

Table 2. Effect of watering regime on early growth of the test species at 12WAP.

	Once Daily Treatment			Twice weekly Treatment			Thrice weekly Treatment		
Test Species	**Plant Height**	**Collar Diameter**	**Leaf Count**	**Plant Height**	**Collar Diameter**	**Leaf Count**	**Plant Height**	**Collar Diameter**	**Leaf Count**
Terminalia ivorensis	20.32^{ab}	1.72^{a}	21.75^{a}	16.82^{a}	1.64^{a}	24.75^{a}	25.72^{b}	1.89^{a}	32.25^{a}
Terminalia superba	14.90^{a}	1.71^{a}	12.50^{a}	14.27^{a}	1.66^{a}	12.00^{a}	14.90^{a}	1.81^{a}	13.25^{a}
Mansonia altisima	13.80^{a}	2.20^{a}	7.00^{a}	17.20^{a}	2.59^{a}	7.33^{a}	15.30^{a}	2.21^{a}	6.33^{a}
Cleistopholis patens	19.56^{a}	2.71^{a}	12.33^{a}	25.50^{b}	2.85^{b}	12.66^{a}	24.76^{b}	3.01^{c}	11.66^{a}

Note: Mean with the same letter along the row are not significantly different (DMRT).

Effect of watering regime on seedling growth rate, relative growth rate and net assimilation rate of selected indigenous tree species

Table 3. Effect of watering regime on Seedling Growth Rate of selected indigenous tree species ($\times10^{-5}$).

Treatment	TI	MA	CP	TS
Once daily	0.40 ± 2.67	5.74 ± 4.62	6.22 ± 3.33	1.06 ± 3.39
Twice weekly	9.28 ± 2.67	0.61 ± 4.62	7.90 ± 3.33	8.55 ± 3.39
Thrice weekly	5.32 ± 2.67	6.51 ± 4.62	2.64 ± 3.33	4.36 ± 3.39

The effect of watering frequencies on seedling growth rate (SGR), relative growth rate (RGR) and net assimilation rate (NAR) analysis for the test species were presented in tables 3, 4, 5, 6, 7 and 8 respectively. The tables showed the mean values for each SGR, RGR and NAR between daily, twice and thrice watering respectively. As shown in table 4, 6 and 8, the mean SGR, RGR and NAR values performed better for once daily watering on the tree species under investigation ($1.04{\times}10^{-4}$, $3.89{\times}10^{-2}$, $1.74{\times}10^{-4}$) while the least was recorded for thrice weekly watering on the tress species ($7.21{\times}10^{-5}$, $3.43{\times}10^{-2}$, $1.44{\times}10^{-4}$) respectively.

Table 4. Effect of Treatments only on Seedling Growth Rate.

Treatment	
Once daily	$1.01{\times}10^{-4a}$
Twice weekly	$9.01{\times}10^{-5a}$
Thrice weekly	$7.21{\times}10^{-5a}$

Table 5. Effect of watering regime on Relative Growth Rate of selected indigenous tree species ($\times10^{-2}$).

Treatment	TI	MA	CP	TS
Once daily	4.11 ± 0.24	4.88 ± 0.37	2.91 ± 0.68	3.61 ± 0.11
Twice weekly	4.25 ± 0.24	4.17 ± 0.37	4.10 ± 0.68	3.04 ± 0.11
Thrice weekly	3.78 ± 0.24	4.35 ± 0.37	4.06 ± 0.68	1.54 ± 0.11

Table 6. Effect of Treatments only on Relative Growth Rate.

Treatment	
Once daily	$3.89{\times}10^{-2a}$
Twice weekly	$3.88{\times}10^{-2\ a}$
Thrice weekly	$3.43{\times}10^{-2a}$

Table 7. Effect of watering regime on Net Assimilation Rate of selected indigenous tree species ($\times10^{-4}$).

Treatment	TI	MA	CP	TS
Once daily	1.08 ± 1.65	3.11 ± 9.86	1.32 ± 1.66	1.47 ± 2.80
Twice weekly	1.21 ± 1.65	1.67 ± 9.86	1.52 ± 1.66	1.87± 2.80
Thrice weekly	0.88 ± 1.65	1.22 ± 9.86	1.64 ± 1.66	2.01 ± 2.80

Table 8. Effect of Treatments only on Net Assimilation Rate.

Treatment	
Once daily	$1.74{\times}10^{-4a}$
Twice weekly	$1.57{\times}10^{-4a}$
Thrice weekly	$1.44{\times}10^{-4a}$

DISCUSSION

Plant roots require proper soil environmental conditions for good growth. These conditions include the appropriate amounts of water, air and minerals, the proper pH and temperature, these requirements are related to the physiology of the plant.

However, the result of this study shows that watering thrice weekly was best for *Terminalia ivorensis* and *Terminalia superba* while watering twice weekly was best for *Mansonia altisima* and *Cleistipholis patens* seedlings (Table 1 and 2) as too much water encourages the growth of bacteria and fungi which might cause disease in the plant. The findings have been supported by Oyun *et al.* (2010) who reported that, watering twice weekly is most suitable for tending the seedlings of *Acacia senegal* in the nursery. This is evident because daily watering produced fragile seedlings that may not be able to withstand the harsh drought condition in the field. This is also in conformity with the observation made by Awodola (1984) and Huang *et al.* (1985). Similarly, Luvaha *et al*. (2012) reported that, mango seedlings under mild water deficit (watering once or twice in a week) promote growth rate as compared to well-watered seedling (watering once or twice daily). This results also support the findings of Abdelbasit *et al*. (2012), who reported that water stress causes significant variation on seedlings relative growth rate (stem length, leaf, root and total plant biomass) in tree provenances (Elgetiana, Halfa Elgadida and Shandi) of Sudan. (Cregg 1993), they also reported significant variation in both morphological and physiological adaptation to water stress in tree species provenances. Water is essential for the transport of minerals, for leaf turgor pressure, and for photosynthesis. When water fills the air spaces of the soil, the roots may not receive the oxygen they need for respiration. Low rates of respiration inhibit mineral and water uptake and reduce the health of the roots, making them vulnerable to infection as minerals are needed as co-factors in enzyme reactions and as constituents of some complex organic molecules. The pH of the soil influences mineral ion availability. Temperature has a great influence on the rate of water uptake, on enzyme reactions, and on the general health of the roots.

However, changes in plant temperature may also affect the carbon balance, and even determine heat stress by increasing temperature above some optimum value for a process. Water deficiency imposes huge reductions in crop yield through diminished leaf carbon fixation and general growth inhibition (Chaves & Oliveira 2004).

Seedling plants are tender and are therefore more responsive to water availability. Thus, water sources that possess low salt content alongside optimum nutrient and aeration for plant growth will be an advantage in nursery industry.

Although, water is required for the germination and early growth but the result of analysis of variance revealed that there was a significant difference in the measured parameters (*i.e.* leaf count, collar diameter and plant height) of *Cleistopholis patens* where the seedlings watered thrice weekly was significantly higher than those watered once daily and twice weekly at 12 WAP (Table 2), while there was a significant difference in the plant height and collar diameter of *Terminalia ivorensis* and *Terminalia superba* but no significant difference in their leaf counts. However, a significant difference exists in the collar diameter and leaf counts of *Mansonia altisima* but no significant difference exists in the plant height. Mature seeds are extremely dry and need to take in significant amounts of water, relative to the dry weight of the seed, before cellular metabolism and growth can resume. Most seeds need enough water to moisten the seed but not enough to soak them. The uptake by water is called imbibition, which leads to the swelling and the breaking of the seed coat. When seeds are formed, most plants store a food reserve with the seed, such as starch, proteins, or oils. This food reserves provides nourishment to the growing embryo. When the seeds imbibe water, hydrolytic enzymes are activated which break down these stored food resources into metabolically useful chemicals. After the seedling emerges from the seed coat and starts growing roots and leaves, the seedling's food reserves are typically exhausted; at this point photosynthesis provides the energy needed for continued growth and the seedling now requires a continuous supply of water, nutrients and light.

The effect of watering regime on the physiological parameters (Seedling Growth Rate, Relative Growth and Net Assimilation Rate) of *Terminalia ivorensis*, *Terminalia superba*, *Mansonia altisima* and *Cleistopholis patens* under different watering frequencies was presented in table 4, 6 and 8. It was revealed from the tables that the application of water on the seedlings once daily gave a better result which was not significantly different from applying water twice and thrice weekly. This disagree with the findings of Gush & Moodley (2007),who stated that water use of Jatropha is generally low, therefore, frequent application of water around 7 times in a week or 5 times in a week seems to reduce seedling vigor significantly, thus, this may result into water logging.

CONCLUSION AND RECOMMENDATIONS

Various benefits are claimed for indigenous forest tree species. Apart from their value for timber production, they are documented for their contributions to farming systems, the welfare of rural populations, and protection of the environment. Hence, Improved silvicultural practices / nursery management is likely to enhance the early growth and survival of the species.

However, the after planting result from the experiment showed that watering three times in a week enhances early seedling development of *Terminalia superba* and *Terminalia ivorensis* while watering twice weekly enhances the development of *Mansonia altisima* and *Cleistopholis patens* significantly. Watering once in a week also sustain the plant adequately. It can be inferred from the experiment that watering of the seedling twice and thrice weekly is adequate to maintain the seedling in the nursery because it was discovered that the seeds requires less water for early growth performance in the nursery. It is therefore recommended that watering of *Terminalia ivorensis,* and *Terminalia superba* seedlings should be done thrice weekly, while *Mansonia altisima,* and *Cleistopholis patens* seedlings should be watered twice weekly in the nursery as an adequate amount of water is essential for plant growth and maintenance of essential plant processes.

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