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Seed Germination and Seedling Growth of Terminalia ivorensis (A. Chev) in Different Growth Media

[1]Ibe, A.E., [1]Adeyemi, A.A., [1]Nwuda, B.N., [2]Asiabaka, C.C. and [3]Onuoha, G.N.

[1]Department of Forestry and Wildlife Technology, Federal University of Technology, Owerri, Nigeria
[2]Department of Agricultural Extension, Federal University of Technology, Owerri, Nigeria
[3]Department of Chemistry, Federal University of Technology, Owerri, Nigeria

Corresponding Author's E-mail: Adesoji.adeyemi@futo.edu.ng

Abstract
This study evaluated the performance of *Terminalia ivorensis* seedlings under different sowing media and watering regimes. The experiment was laid out in a completely randomized design. Twelve (12) germination trays each were filled with each of the three sowing media. Each of the trays was sown with thirty (30) *T. ivorensis* seeds making 360 seeds per sowing medium. A total of 1080 seeds were used for the experiment. Each of the media was divided into three for subjection to watering regimes. Three watering regimes adopted were twice daily, once daily and every-other day. There were four (4) replicates per watering regime under each sowing medium. 0.25 litre water was used for watering on each occasion. Data were collected on germination and seedling growth parameters including heights, collar diameters, leaf areas and leaf production. Data were analyzed using descriptive statistics (frequencies and percentages), Z-test and One-way analysis of variance. The highest germination percentage was recorded under topsoil with 9.4 % while sterilized river sand had 2.5 % germination, and there was zero germination under sawdust. The result revealed that mean seedling heights and leaf areas were significantly different between topsoil and river sand ($P < 0.05$). However, there was no significant difference in mean collar diameters under the river sand and top soil ($P > 0.05$). Mean leaf productions significantly differed between river sand and top soil ($P > 0.05$). There were no significant differences in mean seedling heights, leaf areas, collar diameters and leaf productions among the three watering regimes ($P > 0.05$). The study showed *T. ivorensis germination* was best in topsoil. This study also showed that the best watering regime for the propagation of *T. ivorensis* is twice daily for the sterilized river sand and once every other-day for topsoil.

Keywords: Growing media, Terminalia ivorensis, emergence, seedling growth, development

1.0 Introduction

Terminalia ivorensis, of the family *Combretaceae* is an important timber species in Nigeria. The tree of the species attains the heights of up to 50 m and girth of 5 m, while young trees often attain only 1-1.5 m height after 5 years, compared to some other timber species, which are fast-growing. For instance, *T. superba* could grow up to 1.8 m in height in one year (MacGregor, 1984; Hazlett, 1989; Lori *et al.*, 1999; Osei-Begyina, 2007). The branches are whorled in young shoots and foliage (Keay, 1989). It is used for construction and other wood-based purposes. It also serves as reforestation and afforestation species for devastated forest ecosystem (Jones and Averre, 2000). It occurs in evergreen and moist semi-deciduous forests, where larger trees are most common in low-lying localities or lowlands (Bakshi *et al.*, 1972; Keay, 1989). It is most abundant in the transition zone between humid semi-deciduous and evergreen forests. It is sometimes found in rainforest conditions but predominantly a tree of seasonal forest zones (Orwa *et al.*, 2009). *Terminalia ivorensis* is an emergent in the upper storey of seasonal forest but sometimes loses its vertical-growing leader resulting in considerable variation in height of mature trees. Regeneration is often sparse, but locally, secondary forests can be dominated by young trees of *T. ivorensis*. As one of the principal timber species of West Africa countries, *T. ivorensis* is widely harvested from natural forest and has been introduced into many other tropical countries as a promising timber plantation species. It is also grown as a shade tree in cocoa plantations in Nigeria (Igboanugo, 1990).

It has been reported that the species is threatened by habitat loss and poor regeneration, and attempts at plantation growth have generally failed through frequent diebacks. The species has also been

classified as 'vulnerable' by the IUCN (Hawthorne, 1998). Despite these facts, plantation of *T. ivorensis* is still scarce in the country, and non-existent in Imo State. With so much emphasis today on ecosystem management and maintenance of natural forests, sustainable artificial regeneration of tree species for large-scale plantation development has become expedient, especially in the area, where oil exploration has led to serious deforestation of several valuable timber species. However, not much work has been done in Nigeria. While seeds of *T. superba* do not experience challenges during germination, those of *T. ivorensis* germinate with great difficulty (Roederer, 1988). There is however a dearth of information on the best conditions for the propagation of the species. With deliberate efforts being made by the Nigeria Government to conserve some valuable plant species, *ex-situ*, resources may be invested without desired results, if basic growth requirements of individual tree species are not known.

A better knowledge of conditions for raising a timber species like *T. ivorensis* would go a long way in reducing initial cost of plantation establishment. Moreover, it has been noted that qualities of seedlings are usually influenced by the composition of the growing media (Salami, 2002; Baiyeri, 2003; Baiyeri & Mbah, 2006). Therefore, it is pertinent to ascertain the best growing media in order to ensure optimum growth performance of the species. This study therefore investigated the germination and development of *Terminalia ivorensis* seedlings under different growth media and nursery practices.

2.0 Materials And Methods

This study was carried out at the Federal University of Technology, Owerri, Nigeria. Owerri is located on the latitude 5° 29'0" N and longitude 7° 2'0" E. The rainfall pattern is bimodal with peaks in June and September. Relative humidity is about 90 % at optimum level, while average temperature range is between 25°C and 35°C. The seeds were thoroughly mixed and randomly selected to reduce errors, and eliminate bias. The experiment was conducted between March and July of the 2015 cropping season. Three (3) growing media namely: sawdust, sterilized river sand and garden topsoil were used. The experiment was laid out in a completely randomized design with four replications. Twelve (12) germination trays each were filled with each of the three growing media. Each of the trays was sown with thirty (30) seeds of *T. ivorensis* making 360 seeds per sowing medium. A total of 1080 treated seeds of *T. ivorensis*, air-dried to 18% moisture content were used for the study. The media were also subjected to three watering regimes including applications of 0.25 litre of water twice daily, once daily and every-other day. The watering was carried out in the morning by 7:00 am and in the evening by 6:30 pm.

2.1 Data Collection

The total number of seeds that germinated under each growing medium was recorded in order to compute the percentage seed germination for each of the growing media. Data on the time and period of seedling emergence were taken. The seedlings were left to stabilize for another two (2) weeks to allow an upsurge in their shoot growth and growth of other morphological parameters before the commencement of measurements, following the methods of Igboanugo (1990). Measurements of growth parameters commenced 2 weeks after seedling emergence and were carried out subsequently on weekly basis for eight (8) weeks. The seedling heights were measured from the level of the growth medium to the tip of the plant, using measuring tape. Seedling collar diameters were measured, using vernier caliper. The number of leaves on each seedling was determined by counting every visible leaf on the plant. Leaf area was measured using leaf area metre.

2.2 Data Analysis

Percentage seed germination was calculated as:

$$\%\ \text{germination} = \frac{Number\ of\ seeds\ germinated}{Total\ number\ of\ seeds\ sown} \times 100$$

Z-test was used to compare mean seedling growth parameters under the two sowing media (i.e. sterilized river sand and top soil). This was because seedling emergence was observed only on two of the three media used for the experiment. Data on measured seedling growth parameters (i.e. height, collar diameter, leaf number and leaf area) under different watering regimes were analyzed using the analysis of variance and means separated with LSD at 5% level of probability.

3.0 Results And Discussion

Table 1 presents the result of *T. ivorensis* germinations under the three sowing media. Highest germination percentage was recorded under topsoil, which had 9.44 %. This was followed by the 2.5 % recorded under sterilized river sand. No germination was recorded under sawdust within the period of the experiment. Moisture availability is a major determinant of germination (Shaban, 2013).

Therefore, the capacity of the topsoil to retain more moisture than river sand and sawdust may have impacted on the germination results. An average of 47 days elapsed before seedlings emerged in the topsoil treatment. In sterilized river sand, seedlings emerged after 51 days on the average. Generally, the species had very low germination. This may be probably due to the hard seed coat, which may require pre-treatment to break dormancy. This is in consonance with the work of Roederer (1988), who noted that seeds of *T. superba* germinate readily while those of *T. ivorensis* germinate with great difficulties.

Among the three sowing media, topsoil was relatively the best and no germination took place in sawdust. *It is possible that sawdust inhibited the germination of the species*. The higher germination rate recorded under topsoil may have resulted from the fact that seeds were in closer contact with the medium. It could also be that topsoil is more favourable and suitable for *T. ivorensis* germination as a result of higher nutrient contents as well as moisture retention ability. This is in line with the findings of Okunomo *et al.* (2000); Okunomo *et al*. (2009), who reported a higher germination percentage in topsoil with *Dacryodes edulis* and *Persia americana,* respectively. This study also corroborates the work of Okunomo (2010), who noted a higher germination percentage in topsoil for *Parkia bicolor*. This may be due to the fact that some soil conditions such as nutrients, microbial activities and moisture content play important roles in the germination of the species in topsoil.

The result also corroborates the findings of Agboola *et al*. (2006), who reported highest germination percentage in topsoil for *T .ivorensis*. However, Dolor (2011) reported high germination percentage in river sand for *Irvingia wombolu*. Anber and Hassanein (2010) obtained highest germination percentage in sand medium with *Bauhinia variegate* and *Delonix regia*. The result of this study is not in consonance with the work of Omokhua *et al.* (2015), who reported highest germination percentage in sawdust. The generally low germination rates recorded in this study may be due to the fact that *T. ivorensis* seed coat is hard and impermeable, preventing easy germination. As observed by McDonald and Omoruyi (2003), seed germination can be enhanced with the aid of acid treatment to scarify the seeds, especially for seeds with impermeable seed coat.

Table 1: Germination percentage of *T. ivorensis* under the three sowing media

Sowing medium	No. of seeds sown	No. germinated	% germination	Average days
Sawdust	360	0	0	-
Sterilized river sand	360	9	2.5	51
Topsoil	360	34	9.4	47

Figure 1 presents the effect of media on seedling emergence of *T. Ivorensis* under different sowing media. The result showed that the first seedling emergence occurred in topsoil after 34 days and the last was recorded after 81 days of sowing in the same medium. With regards to sterilized river sand, the first germination occurred after 45 days of sowing and the last was recorded after 60 days of sowing. The result also showed that the highest number of seedling emergence occurred in topsoil with 5 seedlings each on the 40th and 50th days, while the highest number of seedling emergence occurred under sterilized river sands on the 46th day of sowing with 3 seedlings. There was no seedling emergence in sawdust.

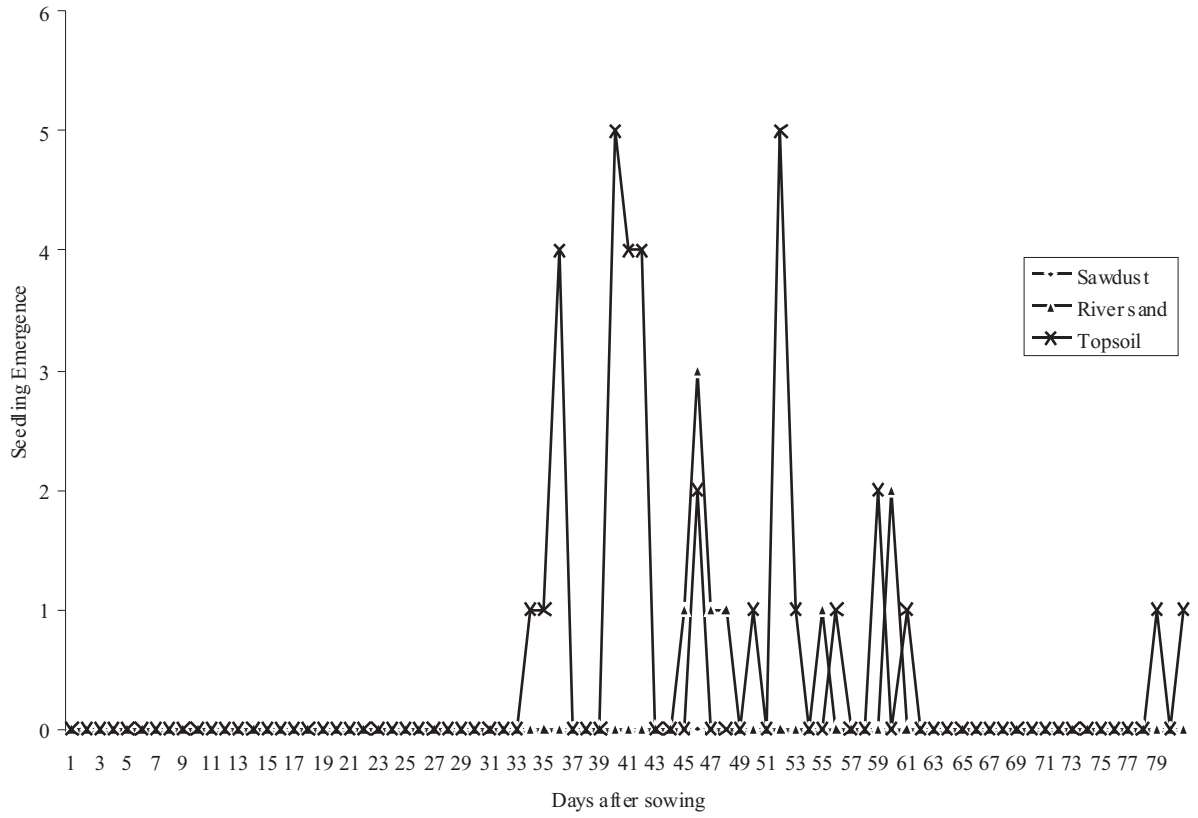

Figure 1: Effect of media on seedling emergence of *T. ivorensis*

The result of germination for different watering regimes under sterilized river sand is presented in Table 2. The result showed that watering twice daily had the highest germination percentage of 4.2 %. This was followed by watering once every-other day with 2.5 %. Watering once daily was the least with 0.8 %. On average, it took *T. ivorensis* about fifty-three (53) days to emerge from sterilized river sands, when watered twice a day. However, seedlings emergence were noticed within 47 and 48 days, respectively in the trays that were watered once daily and once every-other day under sterilized river sand.

In topsoil, the result showed that watering once every-other day had the highest germination percentage with 12.5 %. This was followed by watering twice daily, which had 9.2 %. Watering once daily was the least with 6.7 %. *Terminalia ivorensis* seedling emerged after 51 days when watered once daily in topsoil. On the other hand, averages of 46 and 45 days were expended before the seedlings emergence when watered daily and once every-other day, respectively. Details of the germination percentage of *T. ivorensis* under different watering regime in river sand and topsoil are shown in Table 2.

The best result was recorded in topsoil when watered once every-other day may be due to the fact that topsoil has a high water-retention capacity and do not drain quickly, which may have enhance better seedling emergence because of temporary soaking effect compared to the other media used. This agrees with Kozlowski (1997), who noted that soaking of seeds for a few hours hasten germination. The available water contents of the different media may have exerted different effects on the germination rates of seeds. This disagrees with the work of Keever & Cobb (1985), who stated that plant growth can be increased significantly if irrigation is applied daily in the evening. In river sands, the best germination rate was recorded when watered twice daily. This may be attributed to the fact that sand retains lesser water compared to topsoil, and therefore require more watering.

With regards to watering regime in topsoil, the number of days required for seed to germination can

be reduced by a day to 46 days if watered twice daily. This may be as a result of the effect of moisture in softening the seed coat, thereby hasten faster seedling emergence. In sterilized river sands, least number of 47 days was expended before seedling emergence, when watered once a day. The relatively high temperature experienced in the day time may have caused the soil to lose water as a result of the evapo-transpiration of the soil. Hence the longer days compared to the case in topsoil. This corroborate the work of Tisadale and Nelson (1975), who noted that temperature directly affects the plants functions of photosynthesis, respiration, cell wall permeability, absorption of water and nutrients transpiration, enzyme activity and protein coagulation.

Table 2: Germination percentage of *T. ivorensis* under different watering regimes in

Medium	Watering regime	Seeds sown	No. germinated	% germination	Average days
River sand	Twice Daily	120	5	4.2	53
	Once Daily	120	1	0.8	47
	Every Other Day	120	3	2.5	48
Topsoil	Twice Daily	120	11	9.2	46
	Once Daily	120	8	6.7	51
	Every Other Day	120	15	12.5	45

Table 3 presents the result of Z-test for comparing *T. ivorensis* seedlings growth parameters under different growth media. The result revealed that mean seedling heights were significantly different from each other between the two media $P < 0.05$. This implies that mean seedling height growths under sterilized river sands were significantly different from the mean height growth under the topsoil. Similarly, the mean leaf areas significantly differed under the two growth media ($P < 0.05$). However, there was no significant difference in mean collar diameters under the sterilized river sands and the topsoil ($P > 0.05$). In the same vein, the mean leaf productions under the sterilized river sands and the topsoil were not significantly different under the two media since $P > 0.05$.

The highest mean seedling height of 7.26 ± 1.21 cm was recorded under sterilized river sand. This result is not in agreement with the findings of Anber and Hassanein (2010), who reported highest seedling heights in topsoil with *Bauhinia variegate* and *Delonix regia*. The best medium for *T. ivorensis* development was topsoil in terms of leaf area, collar diameter and leaf production. This could be as a result of the moisture and organic matter content of the topsoil that enabled the seedlings to take up nutrients easily.

Table 3: Result of the Z-tests for seedling growth parameters in different sowing media

Variable	Media	N	Mean ± SD	df	Z_{cal}	P-value	Remark
Seedling height	Sterilized River sand	27	7.26 ± 1.21	41	3.52	0.0011	sig.
	Topsoil	105	6.34 ± 1.23				
Leaf area	Sterilized River sand	27	8.09 ± 3.54	41	2.14	0.040	sig.
	Top soil	105	9.63 ± 2.38				
Collar diameter	Sterilized River sand	27	0.16 ± 0.04	41	0.08	0.94	ns
	Top soil	105	0.16 ± 0.04				
Leaf production	Sterilized River sand	27	8.56 ± 1.25	41	1.47	0.14	ns
	Top soil	105	9.03 ± 2.17				

N.B: $\alpha = 0.05$; sig.- significant; ns- not significant; $Z_{tab} = 1.96$

The results of ANOVA for comparing seedling growth parameters under the three different watering regimes are presented in Table 4. The result revealed that mean seedling heights, leaf areas, collar diameters and leaf productions were not significantly different under the three watering regimes (i.e. twice daily, once daily and every-other day), since $P > 0.05$ in each of the cases. Table 5 presents the results of mean separations or least significant difference (LSD) tests for seedling growth parameters under different watering regimes. For seedling heights, there were no significant differences in means. However, the highest mean height growth of 7.00 ± 1.27 cm was recorded in seedlings that were watered once a day. The least mean height growth of 6.75 ± 1.41 cm was recorded in seedlings that were watered once every-other day. With respect to seedling leaf areas, the highest value of 9.40 ± 2.03 cm^2 was recorded under watering regime 1 (i.e. twice daily). The least value of 8.62 ± 1.90 cm^2 was recorded in seedlings that were watered once daily.

The result for seedling collar diameters revealed that seedlings that were watered once every-other day produced the highest mean value of 0.175 ± 0.037 cm, with the least value of 0.142 ± 0.038 cm recorded in seedlings watered once daily. Similarly, the result for leaf productions revealed that those watered every-other day produced mean leaf number of 10.00 ± 2.33/plant while the least mean leaf production of 9.56 ± 2.01/plant was recorded in seedlings that were watered once daily.

The relationship between soil water content and watering regime revealed that the species requires a moderate watering. These explain why better results were gotten from seedlings watered once every-other day in topsoil. When a given volume of soil is compacted, soil particles are crushed together and pore space reduced. In many places, water is a limiting factor for raising tree seedlings. The prudent use of water becomes imperative to ensure that the young trees are not subjected to water-stress. The best watering regime for seedling height and leaf area development was once daily while once every-other day supported collar diameter growth and leaf production. The available water content of the topsoil might have affected the germinability of the seeds. In general, plants irrigated once daily produced the healthiest plants with the greatest water utilization efficiency. *Terminalia ivorensis* seedlings watered once every-other day had good growth performance. It has also been found that frequent watering of the seedlings of some tropical rainforest tree species reduced their growth rates and encouraged damping-off (Oni and Bada, 1991). These findings may be due to the fact that frequent watering of seedlings can impair good aeration for the seedlings roots therefore reduce their growth. The reduced rate of evaporation of soil water experienced in the evening also helped in the performance of seedlings watered once every-other day. The seedlings were able to collect more moisture and soil nutrient, which may have aided seedling development.

Table 4: Results of ANOVA for seedling growth parameters under different watering regimes

Growth parameter	SV	df	SS	MS	F	P-value	Remark
Height	Watering regime	2	0.38	0.19	0.12	0.888	ns
	Error	41	65.98	1.61			
	Total	43	66.37				
Leaf area	Watering regime	2	3.49	1.75	0.47	0.627	ns
	Error	41	151.63	3.70			
	Total	43	155.13				
Collar diameter	Watering regime	2	0.0074	0.0037	2.73	0.077	ns
	Error	41	0.0556	0.0014			
	Total	43	0.0630				
Leaf production	Watering regime	2	1.21	0.60	0.16	0.852	ns
	Error	41	153.97	3.76			
	Total	43	155.18				

N.B: $\alpha = 0.05$; ns - not significant

Table 5: LSD results for seedling growth parameters under different watering regimes

atering regime	Mean value			
	Height (cm)	Leaf area (cm^2)	Collar diameter (cm)	Leaf production/plant(cm)
Twice daily	6.86 ± 1.08^a	9.40 ± 2.03^a	0.173 ± 0.004^a	9.88 ± 1.26^a
Once daily	7.00 ± 1.27^a	8.62 ± 1.90^a	0.142 ± 0.038^a	9.56 ± 2.01^a
very-other day	6.75 ± 1.41^a	9.09 ± 1.84^a	0.175 ± 0.037^a	10.00 ± 2.33^a
LSD	1.0070	1.5227	0.0396	1.5350

N.B: means with the same alphabets as superscripts under each column are not significantly different from each other

4.0 Conclusion

The study has shown that topsoil is the best in terms of seed germination rates and seedling growths. Sawdust did not support the germination of *T. ivorensis* as no germination was recorded under the medium within the period of the experiment. With regards to watering regimes, the best watering regime in terms of mean seedling height and leaf area developments was once daily while once every-other day supported collar diameter development and leaf production. In general, seeds of *T. ivorensis* germinate with great difficulty and in a very long period of time, probably due to the hard and impermeable seed coats. It is therefore recommended that pre-sowing treatments species seeds in subsequent studies. This may include scarification using acid at different concentrations and temporary boiling in hot water as well as partial cracking of the seed coats. The best watering regime for the propagation of *T. ivorensis* was twice daily under river sand and once every-other day for topsoil.

The application of water of 0.25 litre, twice daily, appeared to be the most appropriate for *T. ivorensis* germination and seedling development, and it therefore recommended for medium- and large-scale propagation of the species. Since sawdust produced no result for germination, it is recommended that the medium should not be considered in subsequent studies in order to avoid a waste of time and resources. In addition to the foregoing, understanding of some aspects of biology of the species is vital for large-scale production of seedlings. The use of topsoil as sowing medium for small- and large-scale propagations of the species is recommended.

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