Original Research Article

Effect of variegated forest soil amendments on the germination and early growth of *Irvingia gabonensis* (O Rorke, Baill)

Abstract

This study evaluated the early germination and growth variables of *Irvingia gabonensis* under organically primed and thermally amended soil media. Six media were prepared from Gmelina plantation topsoil by amendment with poultry waste (T2), river sand (T3) and combusted forest floor litters for 5 (T4), 10 (T5), 15 (T6) and 20 (T7) minutes respectively to contrast a control topsoil (T1). Soil media were analyzed for critical nutrient properties and engaged in the germination and early growth trial of Irvingia replicated three times, and arranged in a completely randomized design. Data collected were analyzed with ANOVA and significant means separated with the Duncan multiple range test. The results showed that Ca/Mg ratio was widest for T3, least CEC (13.2 meq/100g soil) by T7 and slightly acidic pH (H_2O) for T1 and T2 while T3, T4, T6 and T7 were alkaline. Germination at 6WAS was T4 (100%)> T1=T2=T5 (85.71%) > T3 (71.43%) > T6 (42.86%) > T7 (0%). The growth variables of seedling varied significantly ($P<0.05$) with T3 and T4 comparing favorably in collar diameter ($4.50x10^{-1}\pm$ 0.05mm) and leaf area ($35.08\pm4.85mm^2$) although T3 recorded the highest stem height (117.79±0.42mm). The study recommends the use of least thermally modified media (T4) and primed topsoil-riversand (T3) for fast germination in view of conserving food reserve for the critical early growth period of *I. gabonensis* in pursuit of its domestication in nutrient degraded soils.

Key words: Thermal soil amendment, organic priming, topsoil, cation exchange capacity (CEC), *Irvingia gabonensis*

INTRODUCTION

The enrichment of forest soils for the growth of forest tree species is intrinsically receiving attention as way of reducing the long gestation periods of these species in view of domestication. This approach is significant as the original natural forest with its succession capability is currently under threat due to various anthropogenic activities especially the proximate drivers of deforestation (Dolor, 2013; Adelani et al, 2014; Egwunatum, 2018). Consequently, a good proportion of indigenous forest tree species have become threatened on the IUCN list as a result of deforestation and the inadequate management of declining forest soil resource alongside observed threats which potentially jeopardize attempts to effectively domesticate before disappearance in the wild. This is because the hitherto forest soils under luxuriant vegetation were often enriched with litters of twigs, leaves and other component bi-products of natural interaction within the forest to provide capacity for fallen seeds to germinate in the wild, and where this capacity is lost, the germination potential of seeds as well as growth of seedlings become critical as the food reserves contained in the cotyledons declines with prolonged, retarded early growth (Bargali and Tewari, 2004).

Irvingia gabonensis also known as dika nuts belong to the Irvingiacae family. It is an evergreen tree species with sufficiently dense crown that can grow up to 15-40m tall and girth not less than 100cm (Burkil, 2004) and commonly distributed on a hotspot belt that runs from Nigeria in West Africa through Central to South Africa. The tree produces yellowish varieties that are either edible fibrous fruit with turpentine flavor or bitter acrid taste that have various industrial, commercial and medicinal values (Nya *et al*, 2000; Okafor, 2005). The tough, heavy and tannin-immune wood content makes Irvingia less susceptible to bio deterioration and increases its susceptibility as choice tree species for exploitation as timber.

Currently, *Irvingia gabonensis* has been classified as “Near threatened” in the list of threatened species (IUCN, 2006) due to logging operations and poor natural regeneration which may not be unconnected with degraded soil nutrients owing to loss in vegetation vis-à-vis low litter falls. It is therefore critical to source for appropriate soil media through modification with available organic matters under oxygen to produce organo-mineral materials that have imbued properties which compare more favorably than the prevailing degraded forest soil nutrients. This opinion is in line with the articulations of FAO (1999) and Giller (2002) that combined application of organic matter and inorganic fertilizers is essential for optimum crop production and arrest of soil nutrient depletion in West Africa. Optimum plant media for germination and early seedling do not only require water but has the capacity to retain sufficient moisture, supply nutrients, and produce adequate aeration as any condition short of these leads to poor germination of seeds (Goyne and Mcintyre, 2003; Ahmad *et al*, 2009).

Although there is a general consensus that significantly more carbon store in the world soils exceeds that present in the atmosphere, (Sulman, et al, 2018) the availability of these soil organic matter for plant growth through decomposition is vital. Current debate on the sensitivity of organic matter decomposition to changes in temperature is therefore in order (Davidson and Janssens 2006; Gillabet et al, 2010; Xu et al 2019; Moinet et al, 2020; Neal, et al, 2020; Wang et al, 2020) particularly in view of declining forest vegetation and litter yield. It is against this backdrop that this study was conducted to evaluate the potency of topsoil from the readily available and fast growing exotic *Gmelina arborea* plantation by modification with temperature and organic matters as growth media for the early growth of *Irvingia gabonensis* for domestication purposes.

METHODS AND MATERIALS

Description of study area

This study was carried out in the Professor Nnabuife Screen House at the Department of Forestry and Wildlife, Faculty of Agriculture, Nnamdi Azikiwe University Awka, Anambra State. The University is located in the eastern part of Nigeria and lies between latitudes 6˚06'N and 6˚16'N, longitudes 7˚01'E and 7˚10'E. Climatic condition of the area is tropical, dominated by rainfall pattern ranging from 1828mm – 2002mm. The average annual temperature and relative humidity is approximately 26.3˚C and 80% respectively (NiMet, 2016).

Media procurement and preparation

Litter-free top soil was technically collected from a litter-raked forest surface floor area of 5 x 5m at a depth of 0-20cm in the *Gmelina arborea* forest plantation within the Nnamdi Azikiwe University, Awka. The river sand was collected directly from a dredger in the River Niger at the Onitsha axis while the poultry floor waste was obtained from a local poultry in Awka.

The control, topsoil (T1) and river sand were then sieved with a 2mm mesh size filter while the river-sand was further sterilized at 160^{o}C for 24 hours in an oven. The topsoil was then primed by mixing with poultry floor waste and sterilized river sand in a uniform ratio of 4:3 to produce T2 and T3 soil amendments respectively.

The forest floor litters from the Gmelina plantation were screened for metals before it was sun-dried at screen house temperature 25-30^{o}C for 48hours and then combusted in the presence of minimal oxygen with underlying topsoil in relatively covered metallic buckets in the ratios 5:1, 10:1, 15:1 and 20:1 of litter to soil for 5, 10, 15 and 20 minutes to produce T4, T5, T6 and T7 thermally amended soils respectively.

The different soil amendments were sampled and analyzed for pH, Nitrogen, Calcium, Magnesium, Sodium, Potassium and Cation exchange capacity (CEC). Soil pH was determined in water by means of Bechman's pH meter using a soil to water ratio of 1:2.5 (Thomas, 1996). Exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) were extracted with 1N NH_4OAc at pH 7; Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) while K and Na were determined by Flame Photometry (Jackson, 1962). Cation exchange capacity was measured using ammonium acetate leaching at pH 7.0 (Rhoades, 1982). Exchangeable acidity was extracted with normal KCl solution. The exchangeable acidity and exchangeable Aluminum were determined by titrate as described by Thomas (1996). The exchangeable hydrogen was obtained by subtracting exchangeable acidity (Al+H) – Exchangeable Al= Exchangeable H. Total nitrogen was determined by the micro Kjeldahl distillation method (Bremner, 1996).

Fruit preparation and germination

Five hundred and fifty (550) ripe fruits of *Irvingia gabonensis* procured from the Department of Forestry of Anambra State Ministry of Environment were de-pulped manually with knife to scrap off the mesocarp. The obtained seeds were subjected to viability test by flotation method (Himanen, 2015) and five hundred and forty three (543) that passed the test were sun dried at the screen house temperature of 25-30^{o}C for 24hours.

Seventy (70) seeds were then sown in seven open wooden germination beds measuring 2.5m x 1.5m x 0.3m filled with the 6 different soil amendments and the control of unamended top soil. These were watered once with 5 liters of water by sprinkling and monitored for germination at 3 and 6 weeks after sowing respectively. Seed germination was obtained by observation of the viable protrusion on the soil surface of at least 0.50cm of the cotyledon and hypocotyls of the seedlings.

At the end of 6weeks, forty (40) sturdy seedlings each were pricked from promising amendments into uniform poly pots of 20 x 10 x 10cm^3 containing the respective soil treatments and watered with 5 liters of water daily for 7days under screen house conditions. These were thereafter monitored for early growth variables for a period of 6weeks. The stem height was obtained with a steel meter rule from the soil level to the terminal bud while the leaf area was determined using portable leaf area meter (L1-COR 3000C). The collar diameter was measured with the digital vernier caliper while the number of leaf per plant was obtained by counting the number of leaves per pot per treatment.

Data collected were analyzed with the analysis of variance (ANOVA) and significant means separated at 5% level of significance with the Duncan multiple range test.

RESULTS

Characteristics of soil used in the study

The chemical properties of soil amendments used in the study are as shown in Table 1. The highest Ca content was recorded by the T5 (40.67meq/100g soil) while the T7 (13.16meq/100g soil) was least. The control topsoil (T1) had calcium (Ca) content of 31.67meq/100g soil while the T2 (29meq/100g soil) and T3 (23.34meq/100g soil).

The magnesium content was highest in T5 (12.5meq/100g soil) while T7 (2.80meq/100g soil) recorded the least. The T4 (6meq/100gsoil) and T1 (5meq/100g soil) recorded higher content than T2 (4.17 meq/100g soil) , T6 (3.83meq/100g soil) and T3 (3.33meq/100g soil). Sodium contents ranged from 0.11 meq/100g soil in T4 to 0.28 meq/100g soil in T3.

The cation exchange capacity (CEC) ranged from 27.80 meq/100g soil for the T6 (15M-FTS) to 62.12meq/100g soil (10M-FTS). The control treatment (T1) recorded a CEC of 56.91meq/100g soil while the T2 and T3 recorded CEC of 43.87meq/100g soil and 31.29meq/100g soil respectively.

The exchangeable acidity (H+ Al) was highest for T1 (19.75meq/100g soil) and least for T6 (1.75meq/100g soil). The EA for T2 and T3 was 10.5meq/100g soil and 10.38 meq/100g soil respectively. The T2 and T3 recorded total nitrogen contents of 0.23% and 0.19% respectively while T7 was least. The soil reaction was in the order T7 (8.1) > T6 (8.0) >T5 (7.0) > T3 (6.9) T4 (6.6) > T1 (6.2) > T2 (5.9).

Table 1: Chemical characteristics of soil amendments

Variables	Ca	Mg	Na	K	H^+	Al^{3+}	CEC	N	pH	Ca/Mg
	meq/100g soil							(%)	(H_2O)	ratio
T1	31.67	5.00	0.17	0.32	9.25	10.5	56.91	0.15	6.2	6.33
T2	29.0	4.17	0.18	0.27	4.50	5.75	43.87	0.23	5.9	6.95
T3	23.34	3.33	0.28	0.59	2.00	8.38	31.29	0.16	6.9	7.01
T4	25.83	6.00	0.11	0.36	6.25	8.25	46.81	0.19	6.6	4.31
T5	40.67	12.5	0.14	0.31	4.00	4.50	62.12	0.17	7.0	3.25
T6	22.24	3.83	0.14	0.34	1.50	0.25	27.80	0.14	8.0	5.81
T7	13.60	2.80	0.18	0.28	1.75	1.50	44.87	0.11	8.1	4.86

Key: T1= Topsoil; T2=Topsoil + poultry waste; T3= Topsoil + river-sand; T4= 5mins combusted (topsoil + Gmelina forest floor litter); T5= 10mins combusted (topsoil + Gmelina forest floor litter); T6= 15mins combusted (topsoil + Gmelina forest floor litter); T7= 20mins combusted (topsoil + Gmelina forest floor litters).

Effect of soil amendments on germination

The germination of sown Irvingia seeds on the various amended soil at 3 and 6 weeks are shown (Table 2). At 3weeks after sowing, T4 recorded the highest number of germination percentage of 72.5% while the T2 recorded a germination percentage of 57.5%. The T1, T3 and T5 recorded 42.5 percent each while T6 supported the least germination percentage (28.57%). The T7 did not support the germination of any seed.

However at 6weeks after sowing, the T4 maintained the highest germination percentage of 100% as all the 40 sown seeds germinated. The T1, T2 and T5 supported germination to the same capacity of 85.5% while the least germination percentage of 42.5% was shown by T6 at 6weeks. The T7 recorded zero germination at 3weeks and a germination percentage of 15% at 6weeks.

Table 2: Effect of soil amendments on germination of Irvingia seeds

Variables	No of germinated seeds		Germination percentage (%)	
	3weeks	6weeks	3weeks	6weeks
T1	17	34	42.5	85.0
T2	23	34	57.5	85.0
T3	17	29	42.5	72.5
T4	29	40	72.5	100.0
T5	17	34	42.5	85.0
T6	11	17	27.5	42.5
T7	0	1.00	0.00	15

Key: T1= Topsoil; T2=Topsoil + poultry waste; T3= Topsoil + river-sand; T4= 5mins combusted (topsoil + Gmelina forest floor litter); T5= 10mins combusted (topsoil + Gmelina forest floor litter); T6= 15mins combusted (topsoil + Gmelina forest floor litter); T7= 20mins combusted (topsoil + Gmelina forest floor litters).

Effect of amendments on growth variables

The results showed that T3 amendment recorded the highest height of 117.9±0.42mm while the T2 least height (6.51±1.07mm) as shown in Table3. There were significant differences in all the effects of treatments on the height of Irvingia.

There was no significant difference in the leaf number of T3 and T1 as well as between T4, T5 and T2. The highest leaf number was recorded by T3 (3.39±0.24) while the least by T2 (2.00±0.43). There were significant differences in the leaf areas of seedlings and was in the order T3 (35.08±4.85mm^2) > T5 (25.94±5.44mm^2) > T4 (22.75 ±4.09mm^2). The least leaf area (14.09± 3.44mm^2) was recorded by T2.

There was also significant difference (P<0.05) in the collar diameters of seedlings as influenced by the various growth media. The order of influence was T3 (4.50x10-1 ± 0.05mm) > T4 (3.80x10-1 ±0.05mm) > T1 (3.20x10-1 ± 0.03mm)> T2 (2.80x10-1 ± 0.51mm).The least collar diameter of 1.90x10-1 ± 0.22mm was recorded by T5.

Table 3: Effects of soil amendments on Growth variables of Irvingia gabonensis seedlings

Amendments	Stem height	Collar diameter	Leaf area	Leaf number
T1	97.1 ± 0.79^{b}	$3.20x10^{-1}\pm0.03^{c}$	20.66 ± 2.85^{d}	3.06 ± 0.33^{a}
T2	65.1 ± 1.07^{e}	$2.80x10^{-1}\pm0.51^{d}$	14.09 ± 3.44^{e}	2.00 ± 0.43^{bc}
T3	117.9 ± 0.42^{a}	$4.50x10^{-1}\pm0.05^{a}$	35.08 ± 4.85^{a}	3.39 ± 0.24^{a}
T4	89.8 ± 0.71^{c}	$3.80x10^{-1}\pm0.05^{b}$	22.75 ± 4.09^{c}	2.78 ± 0.25^{b}
T5	69.1 ± 0.41^{d}	$1.90x10^{-1}\pm0.22^{e}$	25.94 ± 5.44^{b}	2.39 ± 0.34^{b}
Mean	87.8 ± 3.93	$3.20x10^{-1}\pm0.19$	23.68 ± 18.68	2.72 ± 1.43
S.E	0.41	0.02	1.98	0.15

Means ±Std. deviation with the same superscript and column are not significantly different (P < 0.05)

DISCUSSIONS

The germination potential of T4 and T5 which are temperature amended media producing the highest germination percentages at 3 and 6 weeks may not be unrelated to the resultant enhanced moisture content of the media. This is because of the ability of such media to hold and supply water to the seeds to imbibe, activate the enzymatic process needed to initiate seed germination (Ekebafe *et al*, 2012) as well as promoting better root development to facilitate germination. This may also be due to a probable release of mineral elements as a result of the thermal treatment which may have solicited the release of mineral elements from combusting litters to form organo-mineral compounds that have the potential to break seed dormancy faster than sole organic materials. The soil reaction values clearly support this assertion as the thermally modified amendments showed a-two spectrum pH range from neutral (T4 and T5) to moderately alkaline (T6 and T7) that are quite different from the original primed media.

The neutral pH range materials was able to attain 100% germination while T3 (topsoil + riversand) with strongly alkaline status gave 72.5% germination. This result did not only support Dolor (2011) that recorded great success with sand +topsoil for seed germination of *Irvingia wombulu* and David *et al* (2014) that reported highest sprouting from top+ river soil, but further advanced thermally modified media as a potentially better germination treatment media for the Irvingiaceae family.

The presence of organo-mineral elements accounted for significantly high cation exchange capacity (CEC) of T4 and T5 which compared favorably with T1 and T2 that recorded the same percentage germination percentage at 6weeks after sowing. The CEC of thermally amended media increased with time from T4 to T5 and then fell at T6. This finding agrees with that of Cheng *et al*, (2006) which revealed that interactions between organic matters and soil particles increases the CEC with age and time to produce a range of functional groups at the soil surfaces.

The performance of T6 and T7 extended thermally treated soil media was abysmally poor. This may not be unexpected as according to Melillo et al, 2010, 2017, depending the timing and magnitude of thermal exposure of soils, depletion of microbial accessible carbon pools, microbial reduction as well as a shift in microbial use efficiency and modification of microbial community composition results which ultimately will result in poor seed germination rate and seedling performance. Subsequently, T6 and T7 were not considered promising enough to warrant trials in the growth variable experiment even though T6 recorded 27.5% and 42.5% at 3 and 6 weeks respectively. This poor performance may also not be unrelated to the wide time lag which may have degraded the originally resultant organo-mineral elements attained at T4 and T5 time periods. In fact, the moderately alkaline (7.9-8.4) pH of T6 and T7 support this finding because alkaline conditions do not favor germination of tree crop species (Acquash, 2005). TheT3, T4 and T5 were neutral (6.6-7.3) on the pH scale and recorded germination percentages of over 70%. The pH inclination of T3 towards thermally amended media which could equally have contributed to its efficacy may be as a result of the initial sterilization. But the biologically charred forest floor litters may have significantly accounted for the difference in performance.

The initial nitrogen content of T1 (0.15%) may have been enhanced by priming with poultry floor waste (Acosta-Martinez and Barmel, 2006: Adeli et al., 2009) and river-sand as well as the thermal modification of the media. However, the nitrogen content of thermally amended media reached maximum enhancement at T4 which later declined with increase heating time, becoming seemingly denitrified and immobilized at T6 and T7 with significant reduction on the exchangeable acidity (Al + H). This is because organic amendments can be used as a sink for reducing the bioavailability of metallic colloids in soils (Park et al. 2011), which in proportionate term was highest in the 20minutes combusted Gmelina forest floor litter-soil (T7).

However, in the growth variable trials the T3 performed best in the stem height, collar diameter and leaf area. This may be due to its high potassium content which is important in plant metabolism, protein synthesis and chlorophyll development (Nwoboshi, 2000), and may also have accounted for the T4 and T5 that were next to T3 in the growth of collar diameter and leaf area respectively. Apart from the leaf numbers, the differences in the growth variables performances of T4 and T5 which differed significantly ($P < 0.05$) can be attributed to the nutrient retention capacity that seem to be particularly higher inT4. This may not be unconnected with the wider Ca/Mg ratio of T4 in comparison with T5 indicating lower chances of leaching and reduction in the possibility of calcium deficiency for meristematic cell elongation and division. The Ca/Mg ratio of the organic amendments, T2 and T3, equally followed the same trend with wider ratio than the thermal amended soil media which perhaps conferred them with greater efficacies. The widest Ca/Mg ratio of T3 accounted for the highest performance of the growth variables.

CONCLUSION

The results of this study established that germination and early growth of *Irvingia gabonensis* depended on the Gmelina forest topsoil primed with river sand and the 5minutes thermally amended Gmelina plantation floor litter. It showed that the thermally amended soils led to the early and 100% germination of seeds while the river sand-primed amendment had greater influence on the growth variables although the former media compared favorably. These two types of soil media performed better than the traditional control top soil because of the capacities to hold water for protoplasmic activities and retain nutrients for vegetative development respectively thereby greatly minimized leaching. Therefore, the domestication of this near threatened and economic forest tree species is possible with a combination of these cheap and readily available amendments at the nursery and plantation establishment phases.

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