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EFFECT OF DIFFERENT SOIL TYPES AND SEASON ON THE VEGETATIVE PROPAGATION OF *Pterocarpus* SPECIES IN THE HUMID TROPIC OF SOUTH EASTERN NIGERIA

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ABSTRACT

In addition to the use of Pterocarpus species as a major source of vegetable and fodder, the recent decline in timber sources has led to logging of Pterocarpus species for timber production. Increase in the use of Pterocarpus species for timber production has led to drastic decline in their population. Consequently, a decline in the availability of the vegetable has resulted to the increase in the cost of the Pterocarpus species vegetable. Thus, there is a need for understanding the factors that may be influencing the propagation and growth of Pterocarpus species.This study was carried out to assess the effect of soil types and season on the rooting ability of stem cuttings of Pterocarpus tree species. Five-centimeter-long leafy stem cuttings of near uniform diameter were collected randomly from healthy parent trees of the selected Pterocarpus tree species (P. mildbraedii, P. santalinoides and P. soyauxii). The cuttings were collected in the morning using secateurs and cutlass, and then placed in humid plastic bags to minimize heat stress till they were planted. A 3 x 2 factorial experiment in RCBD with ten replicates was used to assess the rooting ability and growth pattern of the stem cuttings. From this study, it was observed that season and soil type played important roles in the rooting percentage of the three plants studied. From this study, it was observed that most growth parameters were better on clay soil during the dry season except for the shoot length of P. mildbraedii and the leaf area of P. soyauxii cuttings planted on loamy soil. The plant species type, soil type and the treatment interactions had significant effect (P≤0.001) on leaf number, shoot length, leaf length, root length and shoot fresh weight. It was also observed that clay soil supported growth of the three Pterocarpus species studied over the loamy soil during the rainy season study with the exception of P. santalinoides which recorded higher values for leaf number (24), shoot length (5.19cm) and leaf area of P. mildbraedii (4.45cm) on loamy soil. In conclusion, the growth performances of the three plant species studied were observed to be higher on clay soil than on loamy soil, especially during the rainy season. This could be because of the natural ability of the soil to retain water whereas; the cases when the loamy soil did better could be attributed to the abundant availability of soil nutrients. It is recommended from the success of this research that clay soil should be used as a growth medium for the vegetative propagation of the selected Pterocarpus species studied. This will help in the multiplication of Pterocarpus species from cuttings since the seeds are either seasonal or scarce. Also, this could improve the multiplication and development of Pterocarpus species plantation in the humid tropics like in Nigeria.

Key Words: *Pterocarpus* species, Clay, Loamy soil, Seasons, Plant growth parameters

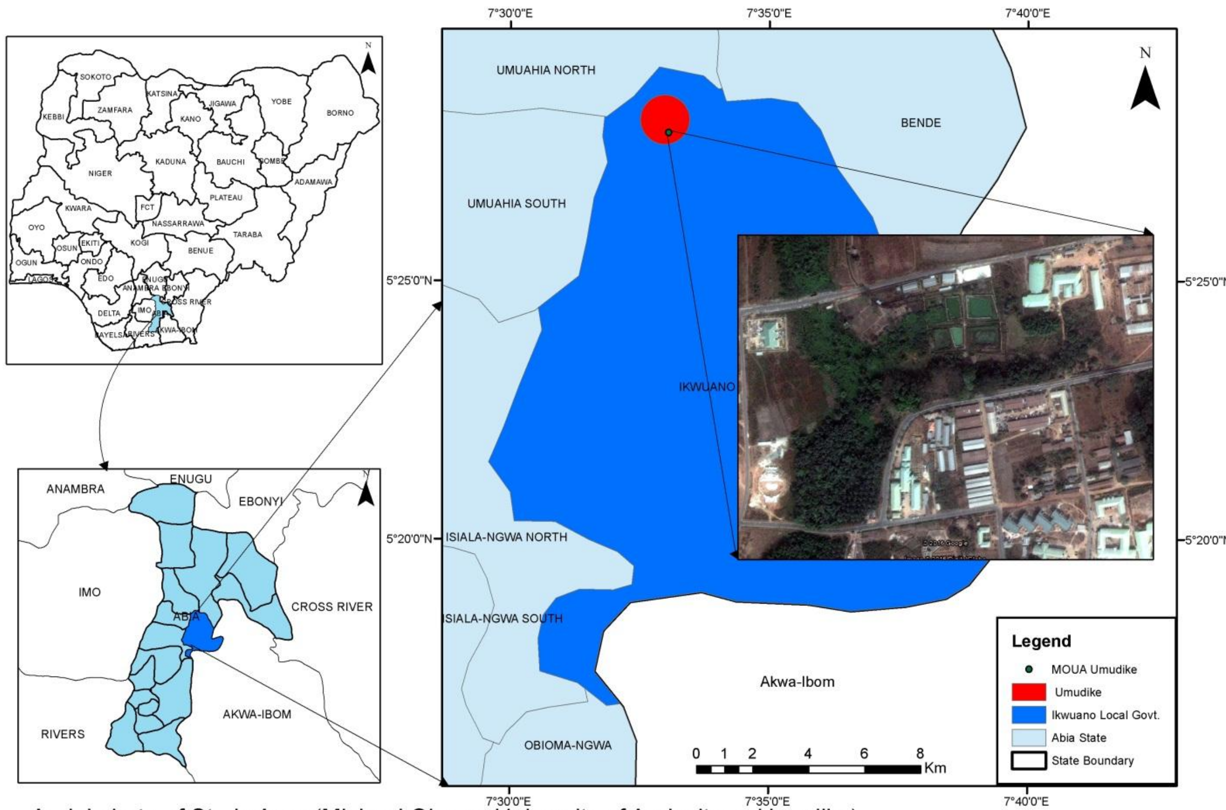
INTRODUCTION

The genus *Pterocarpus* belongs to the family Papilionoideae and has up to twenty (20) species distributed throughout the tropics. The various species can be differentiated using their morphological features (Keay, 1989; Bosch, 2004; Jansen, 2005; Lemmens, 2008). *Pterocarpus santalinoides*, *Pterocarpus mildbraedii* and *Pterocarpus Soyauxii* are the three *Pterocarpus* species commonly found within south-eastern Nigeria. Their benefits range from the provision of edible vegetables to use in native medicine. They are also used in sculptural works, carvings and furniture (Bosch, 2004; Jansen, 2005; Lemmens, 2008). *P. soyauxii* and *P. mildbraedii* have been utilised in timber production especially with the rapid decrease in availability of other major timber species like *Milicia excelsa* and *Ceiba pentandra*. *Pterocarpus* species can be propagated by seeds or by vegetative means however, the seeds are scarce for reasons which include seasonality of fruiting to reduction in the population of mature trees that can bear fruits. Egbe *et al*., (2012) reported that the greatest constraint to forest regeneration projects is the lack of good planting materials (materials that are viable and free from pest and diseases).Vegetative propagation techniques play integral part in tree improvement programs and have been extensively explored for the propagation of many economically valuable species particularly the rare, endangered, and threatened plant species (Jamir *et al*., 2016).Vegetative propagation methods are also used in the tropics for the establishment of commercial plantations for timber and fruit tree species. According to Araya (2005), Ali and Elbasheer (2014), it is the extensively practised and economical means of vegetative propagation for a wide range of woody plants cultivated for use as ornamentals, fruits, agroforestry or for food. Plants propagated from cuttings have the same characteristics as the parent plant whereas in some cases, plants propagated sexually do not have desirable characteristics as were observed in the parent plants (Tiwari and Das, 2010; Oboho and Iyadi, 2013).The ability of a stem cutting to root is dependent on factors such as position of cuttings on the shoots, rooting medium, and season when cuttings were made in addition to physical and environmental factors (Ali and El-Tigani,2003).Another critical factor to successful rooting is the type of rooting medium used (Leakey *et al.*, 1990, Ofori-Gyamfi, 1998, Relf and Ball, 2009) and rooting capacity of the cuttings (Hartmann *et al*., 1990). Cuttings of many species root successfully in a variety of rooting media but the performance of rooting both in number of roots and percentage of rooting may be greatly influenced by the kind of rooting medium used (Leakey *et al.*, 1990). Several authors have reported on the effect of chemical and physical characteristics of growth media on rooting of various tree species (Beyl, 2008; El-Naggar and El-Nasharty, 2009; Akwatulira et al., 2011; Magesa *et al*., 2018). Rapid generation of new adventitious roots is necessary for the plant to transport water and essential nutrients from the soil.

MATERIALS AND METHODS

Study Area

This research was carried out in the Departmental Nursery of Forestry and Environmental Management, Michael Okpara University of Agriculture Umudike (MOUAU). Umudike lies between latitudes 5°25' and 5°32'North and longitudes 7°32' and 7°35'East of the equator. It is in the tropical rainforest zone of Nigeria. It has two distinct seasons - rainy and dry. The dry season begins around November and ends in March. Mid-March to October is the rainy season with rainfall peaks in July and September. There may be a relative break in August. The average annual rainfall is 2,238mm while the mean minimum and maximum temperatures are 23°C and 30°C respectively (Ogbonna *et al*., 2011). The relative humidity is usually high ranging between 70-85% during the rainy season and as low as 45% during the peak of the dry season. It is at an altitude of 122m above sea level and few low rolling hills can be observed throughout the area. The soil is well drained; deeply weathered, sandy loam up to 30cm deep and rich in organic matter with overlying uniform clay content all through the profile depth (FDALR, 1990). The topography is gentle with a gradient of less than 5° in most areas (White, 1983; Dike, 2000, 2003).



Aerial photo of Study Area (Michael Okpara University of Agriculture, Umudike)
Source: Ministry of Lands and Survey, Abia State.

Figure 1: Map showing the location of MOUAU in Abia State, Nigeria, with an aerial photograph of the study site. (Source: Ministry of Lands and Survey, Abia State).

Collection, preparation and care of cuttings

Ten-centimetre-long leafy stem cuttings of nearly uniform diameter were collected randomly from healthy young (between 1-3 years) parent trees of the selected *Pterocarpus* tree species (*P. mildbraedii, P. santalinoides* and *P. soyauxii)*. The cuttings were collected in the morning using secateurs and cutlass then placed in humid plastic bags to minimize heat stress on the cuttings till the time of planting. This is in accordance with the procedure described by Takoutsing *et al*. (2014). The cuttings were made circular at the base to facilitate homogenous root distribution and slantwise at the upper part to facilitate the runoff of water during watering. The rooting media (clay and loamy soils) were put in polypots then arranged in the experimental site. The experiment was carried out in two different seasons (rainy and dry). However, the cuttings were watered at two days intervals during the dry season whereas the experiment relied on rainfall as water supply during the rainy season. This is in accordance with the procedure followed by Avana (2006) and Takoutsing *et al*. (2014). A solution of Epson salt was spread on the study site to check termite infestation and improve environmental hygiene.

Experimental design

A 3 x 2 factorial experiment with ten (10) replicates was used to assess the rooting ability and growth pattern of the stem cuttings of selected *Pterocarpus* species. The first factor was the three *Pterocarpus* species, the second factor was the rooting medium (soil types). A total of three hundred (300) cuttings were planted for this experiment.

Evaluating number of leaves, leaf area and number of branches, meristem length and meristem diameter.

The growth parameters mentioned above were evaluated thus:

a) Leaf number: The number of leaves per rooted stem cuttings was counted.
b) Leaf area: It was obtained using a graph sheet to estimate the areas of the leaves in square centimeters.

c) Leaf Length and Shoot length: This was measured in centimetres using a calibrated meter rule.
d) Number of branches: Counts were taken as the branches appeared on each of the cuttings.
e) Shoot Basal Diameter: A veneer caliper was used to measure the shoot basal diameter in centimetres.

Evaluation of number of roots, rooting percentage and root length

The above parameters were measured in the following ways:

a) Number of roots: This was obtained by counting the number of roots per stem cutting
b) Root length: The length of each of the roots was measured using a meter rule and the average length taken after measuring the roots of all the cuttings. The length of the longest root was also measured in centimetres.
c) Root Fresh Weight, Shoot Fresh Weight and Shoot Dry Matter: This was measured in grams using a sensitive weighing balance after collection and oven drying of all the roots and vegetative parts at 105^{o}C for two hours.

Data analysis and presentation

To determine the effect of experimental factors on the rooting ability of cuttings, the data obtained from measuring the plant growth parameters was analyzed using Analysis of variance (ANOVA). Descriptive statistical presentations such as graphs and tables (Shepherd and Roger, 1991) were used too. Statistical analyses were performed using SPSS statistical package (version 20.0) and Gen Stat for windows. $P \leq 0.05$ was selected as the decision level of significances in line with the specifications of Osuala (2009). The Fisher least significant difference (F-LSD) at $P \leq 0.05$ was used to separate the means according to the procedures of Steel and Torrie (1980).

RESULTS

Analysis of physical growth parameters measured during the dry season

All *Pterocarpus* species irrespective of the soil type on which they were planted sprouted from 1 - 2 nodes on the stem cuttings (Table 1). However, *P. mildbraedii* cuttings sprouted mostly from two nodes on the stem cuttings. The *Pterocarpus* species from which the stem cuttings were sourced had significant effect on the number of sprouted nodes. Season, species-season interaction, species-soil interaction and soil-season interaction also had significant effect on the number of sprouted nodes (Table 2). However, soil type had no significant effect on the number of sprouted nodes.

P. mildbraedii had the highest leaf number (9) on both soil types while the least leaf number (2) were recorded in *P. santalinoides* cuttings planted on loamy soil and *P. soyauxii* planted on clay soil (Table 2). The number of leaves observed on the planted cuttings of each of the *Pterocarpus* species differed significantly. Season and species-season interaction had significant effect on the number of leaves (Table 2, Table 3). However, soil types, species-soil interaction and soil-season interaction had no significant effect on the number of leaves (Table 3).

The shoot basal diameter of the cuttings of all *Pterocarpus* species did better on loamy soil. The *Pterocarpus* species studied were significantly different in their shoot basal diameter values in response to season, species-season interaction and soil-season interaction. Soil and species-soil interaction however, had no significant effect on the shoot basal diameter.Significant differences were recorded on the shoot length considering the effect of species, season, species-soil interaction and species season interaction. No significant effect was observed on the shoot length in response to soil and soil-season interaction (Table 3). Of the three Pterocarpus species cuttings planted in the dry season, *P. soyauxii* produced the highest shoot length on clay soil while *P. mildbraedii* had the least shoot length on clay soil within the dry season. Lower shoot length was recorded in *P. santalinioides* and *P. soyauxii* within the wet season on both clay and loamy soil, while *P. mildbraedii* had the highest shoot length within the wet season (Tables 2).

The species of *Pterocarpus* stem cuttings had significant effect on the leaf length. Season and species-season interaction also had significant effect on the leaf length. Season, species-soil interaction and soil-season interaction had no significant effect (Table 3). Longer leaf lengths were recorded in the wet season compared to the dry season across the *Pterocarpus* species.

The species of *Pterocarpus*, soil types, season, species-soil interaction and species-season interaction all had significant effect on the leaf area, but Soil-season interaction had no significant effect on the leaf area (Table 3). *P. santalinoides* cuttings planted on clay and loamy (except for cuttings on loam soil within the dry season) produced significantly larger leaf area relative to other species across seasons (Table 2).

The number of roots observed on the planted cuttings of each of the *Pterocarpus* species differed significantly. Soil types also had significant effect on the number of roots (Table 3). However, season, species-soil interaction, species-season interaction and soil-season interaction had no significant effect on the number of roots. The root length of the stem cuttings varied significantly in response to the *Pterocarpus* species from which they were sourced and the soil types on which they were planted (Table 3). However, season, species-soil interaction, species-season interaction and soil-season interaction had no significant effect on the root length.

The length of the longest roots on the cuttings of the various species was not significantly different irrespective of the seasons and soil types nor their interactions. However, the longest roots were recorded in *Pterocarpus*. species planted on clay soil in both seasons, while cuttings planted on loamy soil within the wet season produced the shortest roots. Stem fresh weight, root fresh weight and shoot dry weight varied significantly in response to *Pterocarpus* species, soil type and seasons, species-soil interaction, species-season interaction and soil-season interaction (Tables 2 and 3).

Table 1: Effect of soil type, species type and season on the root growth parameters and shoot weight of *Pterocarpus* species stem cuttings.

Species	**Soil type**	**Season**	**Root Length (Mean±SD)**	**Length of Longest Root (Mean±SD)**	**Shoot Fresh Weight (Mean±SD)**	**Root Fresh Weight (Mean±SD)**	**Shoot Dry Weight (Mean±SD)**
P. mildbraedii			11.7±3.79	13.8275±5.27	3.57±0.84	1.00±0.24	0.87±0.21
	Clay		15.25±0.95	18.885±0.52	3.76±0.86	1.06±0.25	0.91±0.21
		Dry	14.3±0.00	19.4±0.00	4.63±0.00	1.30±0.00	1.12±0.00
		Wet	16.2±0.00	18.37±0.00	2.9±0.00	0.81±0.00	0.70±0.00
	Loam		8.15±1.63	8.77±2.02	3.39±0.78	0.95±0.22	0.82±0.19
		Dry	9.78±0.00	10.79±0.00	4.17±0.00	1.17±0.00	1.01±0.00
		Wet	6.52±0.00	6.75±0.00	2.61±0.00	0.73±0.00	0.63±0.00
P. santalinoides			15.25±5.26	15.41±5.28	5.27±1.25	1.49±0.35	1.28±0.30
	Clay		20.31±0.06	19.86±3.11	5.55±1.28	1.57±0.36	1.35±0.31
		Dry	20.37±0.00	16.75±0.00	6.83±0.00	1.93±0.00	1.66±0.00
		Wet	20.25±0.00	22.97±0.00	4.27±0.00	1.21±0.00	1.04±0.00
	Loam		10.19±2.04	10.96±2.53	5.00±1.15	1.41±0.33	1.21±0.28
		Dry	12.23±0.00	13.49±0.00	6.15±0.00	1.74±0.00	1.49±0.00
		Wet	8.15±0.00	8.43±0.00	3.84±0.00	1.09±0.00	0.93±0.00
P. soyauxii			3.32±1.24	4.42±1.54	5.96±1.41	1.67±0.39	1.44±0.34
	Clay		4.35±0.87	5.55±1.28	6.27±1.45	1.75±0.41	1.52±0.35
		Dry	5.22±0.00	6.83±0.00	7.72±0.00	2.16±0.00	1.87±0.00
		Wet	3.48±0.00	4.27±0.00	4.83±0.00	1.35±0.00	1.17±0.00
	Loam		2.31±0.47	3.29±0.76	5.64±1.305	1.58±0.36	1.37±0.32
		Dry	2.77±0.00	4.05±0.00	6.95±0.00	1.95±0.00	1.69±0.00
		Wet	1.84±0.00	2.53±0.00	4.34±0.00	1.22±0.00	1.05±0.00

Table 2: Effect of soil type, plant species type ~~difference~~ and season on the physical growth parameters of stem cuttings of *Pterocarpus* species

Species	Soil types	Seasons	Number of Sprouted Nodes (Mean±SD)	Number of Leaves (Mean±SD)	Shoot Basal Diameter (Mean±SD cm)	Shoot Length (Mean±SD cm)	Leaf Length (Mean±SD cm)	Leaf Area (Mean±SD cm^2)
	Clay		1.46±0.51	12.71±10.94	0.26±0.08	2.94±1.54	4.01±1.54	3.15±2.01
P. mildbraedii			1.88±0.35	10.25±1.28	0.25±0.05	3.47±0.82	3.71±1.07	2.94±0.48
		Dry	1.75±0.5	11.25±0.96	0.28±0.05	2.73±0.16	3.90±0.23	3.38±0.15
		Wet	2±0.00	9.25±0.5	0.22±0.01	4.22±0.24	3.51±1.59	2.51±0.11
P. santalinoides			1.5±0.53	10±4.14	0.22±0.08	2.45±1.42	4.92±1.54	5.61±0.36
		Dry	2±0.00	13.75±1.5	0.29±0.02	3.78±0.21	4.74±0.27	5.83±0.32
		Wet	1±0.00	6.25±0.5	0.135±0.01	1.13±0.06	5.10±2.31	5.38±0.26
P. soyauxii			1±0.00	17.88±18.14	0.30±0.07	2.90±2.13	3.41±1.67	0.90±0.45
		Dry	1±0.00	33.5±10.79	0.35±0.08	4.87±0.47	2.46±0.44	1.32±0.07
		Wet	1±0.00	2.25±0.5	0.26±0.02	0.93±0.05	4.36±1.98	0.48±0.08
	Loam		1.5±0.51	12.67±9.02	0.26±0.06	2.80±1.85	2.69±1.20	2.24±1.52
P. mildbraedii			1.5±0.53	10.38±2.88	0.23±0.05	3.86±1.25	3.00±1.23	2.9±1.56
		Dry	2±0.00	10±1.2	0.21±0.07	3.23±1.52	3.94±0.55	4.35±0.20
		Wet	1±0.00	10.75±4.19	0.26±0.01	4.49±0.49	2.05±0.93	1.45±0.07
P. santalinoides			1.5±0.53	12.5±10.99	0.25±0.05	2.80±2.44	2.88±0.90	2.90±1.41
		Dry	2±0.00	22.75±1.26	0.29±0.02	5.08±0.30	3.69±0.21	1.59±0.08
		Wet	1±0.00	2.25±0.5	0.21±0.01	0.53±0.03	2.07±0.36	4.22±0.19
P. soyauxii			1.5±0.53	15.125±11.19	0.29±0.07	1.73±1.05	2.20±1.42	0.93±0.45
		Dry	2±0.00	25.5±2.08	0.25±0.08	2.71±0.16	1.17±0.64	1.35±0.07
		Wet	1±0.00	4.75±0.96	0.32±0.04	0.76±0.04	3.23±1.21	0.51±0.08

Table 3: ANOVA table of the variation in shoot and root growth parameters of *Pterocarpus* species stem cuttings in response to soil types, season and their interactions

Variables		**Number of Sprouted Nodes**		**Number of Leaves**		**Shoot Basal Diameter**	
	Df	**F**	**Pr(>F)**	**F**	**Pr(>F)**	**F**	**Pr(>F)**
Species	2	21.1844	<0.0001	12.6343	<0.0001	9.9811	0.0003
Soil	1	0.5665	0.4563	0.0015	0.969	0.0004	0.9847
Season	1	128.4179	<0.0001	170.7939	<0.0001	12.3091	0.0011
Species:Soil	2	21.8671	<0.0001	1.9184	0.1608	2.0726	0.1398
Species:Season	2	12.6058	<0.0001	37.3258	<0.0001	9.0922	0.0005
Soil:Season	1	44.4041	<0.0001	0.0373	0.8479	19.6589	0.0001

Variables		**Shoot Length**		**Leaf Length**		**Leaf Area**	
	Df	**F**	**Pr(>F)**	**F**	**Pr(>F)**	**F**	**Pr(>F)**
Species	2	18.1397	<0.0001	3.755	0.0324	121.4623	<0.0001
Soil	1	0.5373	0.4680	16.411	0.0002	26.4208	<0.0001
Season	1	81.2075	<0.0001	0.0442	0.8346	9.5319	0.0037
Species:Soil	2	7.1553	0.0023	1.4129	0.2559	26.1032	<0.0001
Species:Season	2	66.4532	<0.0001	8.7512	0.0007	24.4888	<0.0001
Soil:Season	1	0.0188	0.8917	2.8585	0.0991	0.972	0.3304

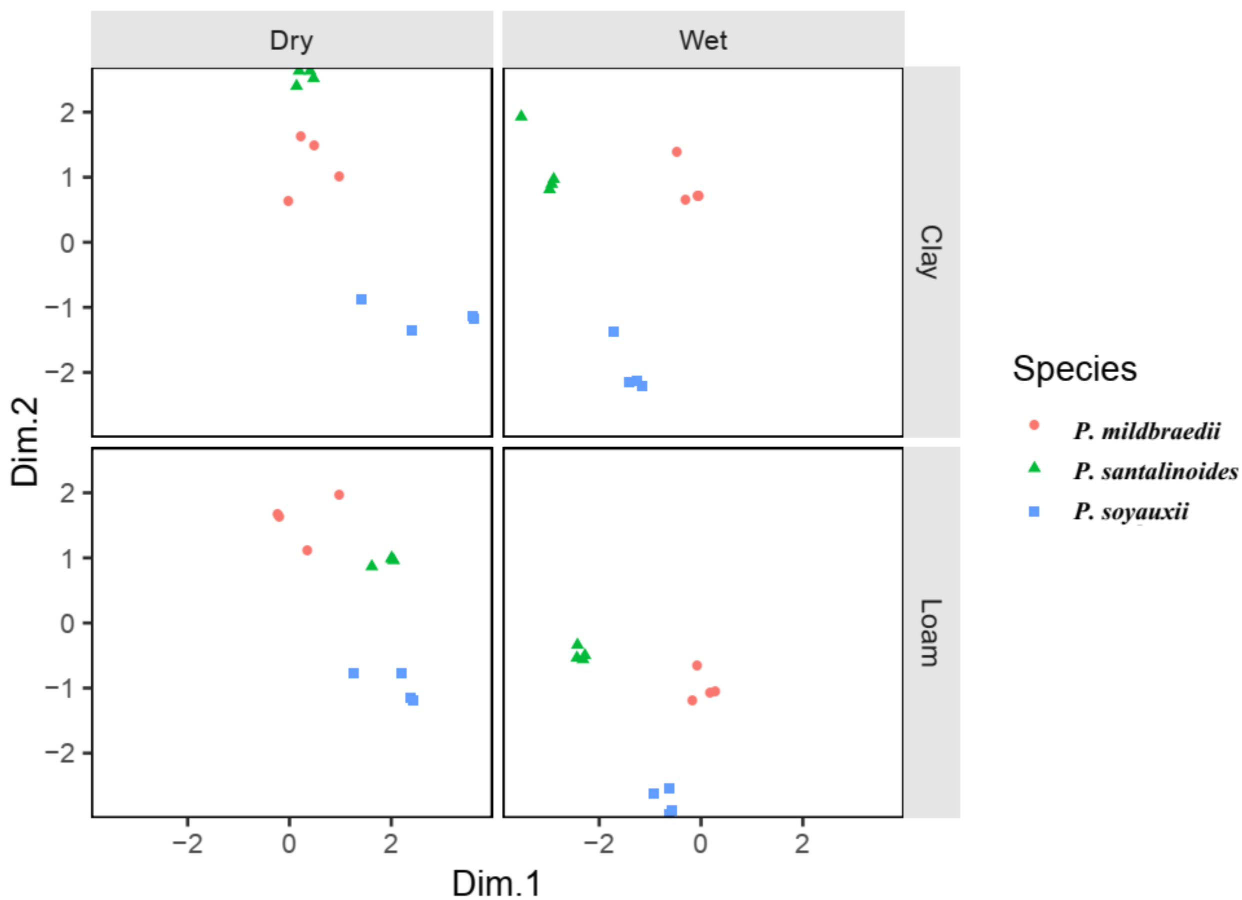
Variables		**Number of Roots**		**Root Length**		**Length of Longest Root**	
	Df	**F**	**Pr(>F)**	**F**	**Pr(>F)**	**F**	**Pr(>F)**
Species	2	24.4909	**0.0392**	60.1258	**0.0163**	14.3233	0.0652
Soil	1	68.0527	**0.0143**	49.6228	**0.0195**	15.3058	0.0595
Season	1	0.3757	0.6023	2.2640	0.2713	0.5397	0.5390
Species:Soil	2	10.7881	0.0848	6.6771	0.1302	1.8136	0.3554
Species:Season	2	0.4783	0.6764	0.2026	0.8315	0.2843	0.7786
Soil:Season	1	0.8497	0.4539	2.3083	0.2680	1.4842	0.3473

Variables		**Stem Fresh Weight**		**Root Fresh Weigth**		**Shoot Dry Weigth**	
	Df	**F**	**Pr(>F)**	**F**	**Pr(>F)**	**F**	**Pr(>F)**
Species	2	7440.814	0.00013	8196.143	0.00012	10717	<0.0001
Soil	1	1003.546	0.00099	1056.571	0.00094	1444	0.0006
Season	1	19236.66	0.00005	21065.143	0.00004	27556	<0.0001
Species:Soil	2	21.247	0.04494	19.857	0.04794	31	0.0312
Species:Season	2	400.897	0.00248	424.714	0.00234	577	0.0017
Soil:Season	1	50.516	0.01922	57.143	0.01705	64	0.0152

Factor Analysis on Mixed Data (FAMD) revealed that all *Pterocarpus* species performed better in the dry season relative to the wet season in relation to the first dimension (Dim.1) which accounted for 29.29% variation in the shoot characteristics of *Pterocarpus* species. The stem cuttings sourced from the three species of *Pterocarpus* performed better in their shoot growth parameters on loamy and clay soil types during the dry season compared to their performance during the wet season on clay soil type (Figure 1). The first dimension (Dim.1) showed positive significant correlation with the number of leaves, shoot length, shoot basal diameter and number of nodes that sprouted, but negative significant correlation with leaf length and leaf area. The second dimension (Dim.2) accounted for 24.21% variation in the shoot growth characteristics, which corresponded significantly with leaf area, number of sprouted nodes, leaf length, shoot length, and shoot basal diameter (Table 4).

Table 4: Shoot growth parameters that significantly correlated with the FAMD dimensions

Variables	Dimension 1		Variables	Dimension 2	
	correlation	***P***		**correlation**	***P***
Leaf number	0.8785	0			
Shoot length	0.7462	0	Shoot length	0.368	0.0101
Shoot basal diameter	0.6525	0	Shoot basal diameter	-0.3059	0.0345
Sprouted nodes	0.4601	0.001	Sprouted nodes	0.6445	0
Leaf length	-0.3237	0.0248	Leaf length	0.4799	0.0006
Leaf area	-0.3901	0.0061	Leaf area	0.8097	0



DISCUSSIONS

Effect of season and soil type on the growth of three selected *Pterocarpus* species

The results of most of the physical growth parameters showed that clay soil supported higher growth (root length, length of longest root, shoot fresh weight, root fresh weight and shoot dry weight) over the loamy soil. This supports the report of Magesa, *et al*. (2018) that red soil media type resulted in the highest rooting percentage of the stem cuttings of hybrid coffee varieties. This may be due to its capacity to retain moisture over other soil types, which in turn aids enzyme activities. According to Hartmann *et al*. (1997) the primary role of a propagation medium is to provide support and moisture while the plants are developing. Bezerra *et al*. (2004) observed that sandy clay soil is optimum for rapid *Moringa* emergence and improves plant establishment including stem diameter branches and height among others. The little or no difference observed on the change in number of sprouted nodes (1-2) over time may be due to the short period over which this research was conducted and the genetic make-up of the *Pterocarpus* species. The high results recorded during the dry season could be as a result of the watering regime used during the culturing stage; Sale *et al*. (2015) reported that watering regime also had significant influence on plant height weeks after treatment with the highest plant height recorded in plants watered twice daily and significantly different from results of those watered once daily and the least height recorded in the control.

In cases where the loamy soil did better than the clay soil may be due to abundant availability of Nitrogen and Phosphorus and Potassium in the loamy soil as reported by Akpan and Williams (2016) that loamy sand soil supported leaf formation thus, increasing the photosynthetic ability of the plant. Experience during this study suggested that there were genetic differences between species which could have resulted in differences in growth ability, just as reported by some authors like Hartmann *et al*., 1997; Puri and Swamy, 1999). The rooting ability has been found to be maximized when the severed cutting can actively photosynthesize and produce assimilates for the development and elongation of the root primordial and when the leaf is not suffering from drought stress (Mesén *et al*., 2001; Leakey, 2004). Generally, the large leaf area observed for *P.mildbraedii* and *P. santalinoides*, may have been the reason they performed better than the *P.soyauxii*. The variation that existed in the plant species leaf area was expected as this would vary between species and clones, depending on specific leaf area (leaf thickness), stomatal density, leaf morphology and the age of the leaf (Leakey *et al*., 1990). In this study, leafless cuttings that failed to produce leaves may not have survived probably due to the rapid use of food reserves and slow reconstitution by cuttings. According to Leakey *et al.* (1990) cuttings with a small leaf area may suffer from poor transpiration and subsequent drought stress, and close their stomata, thereby limiting their capacity to photosynthesize and often triggering leaf abscission. The root number of cuttings grown on clay soil was generally higher than that of the loamy soil which may be said to be related to the leaf area effect which had higher leaf area for clay soil to that of the loamy soil. This agrees with the report of Akpan and William (2016) that soil types had significant influence on some early morphological and physiological characteristics of *Tetrapleura tetraptera.* The higher values observed in shoot fresh weight and dry weight of the species planted on clay soil than those planted on loamy soil could be due the fact that clay soil retains more water which may have promoted enzyme activities and physiological activities during plant growth and development (Nwoboshi, 2000; Donahue *et al*., 1990).

CONCLUSION

Soil type, seasonal variations and watering regime had effect on the rooting and growth potentials of the plants studied – *P. santalinoides*, *P. soyauxii* and *P. mildbreedii*. The three species studied did better in the rainy season than during the dry season. The growth performances of the three plant species studied were also observed to be higher on clay soil than on loamy soil, especially during the rainy season. This could be because of the natural ability of the soil to retain water whereas, the cases when the loamy soil did better – especially in leaf area during the dry season; could be attributed to the abundant availability of Nitrogen and phosphorus in the soil

Recommendations

From the results of this research it is hereby recommended that:

i. Clay soil should be used as a growth medium for the vegetative propagation of the selected *Pterocarpu*s species studied.
ii. Further studies should be carried out on the use of phytohormones to try out on the propagation of *Pterocarpus* species to assess their ability to aid adventitious rooting.
iii. Ex-situ propagation of the studied species will aid in retaining the existence of this species therefore protecting them from increasing threats and extinction.

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