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Research paper

Provenance variation in seedling growth of *Tetrapleura tetraptera* (SCHUM. AND THONN.) TAUB.

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ABSTRACT Conservation and sustainable use of genetic resources depend on understanding the pattern of genetic variations. Four populations of *Tetrapleura tetraptera* (SCHUM. AND THONN.) TAUB., a multipurpose tree, were evaluated in a completely randomized design for variation in seedling growth traits; height, collar diameter, number of leaves, biomass, relative growth rate (RGR), actual growth rate (AGR) and net assimilation rate (NAR) at nursery stage to identify suitable seed source for improved productivity. Analysis of variance showed significant differences in all growth traits except biomass. Genotypic variance and genotypic coefficient of variance for seedlings' height and the number of leaves were greater than their corresponding environment variance and environmental coefficient of variation. Genotypic variance and broad sense heritability for height and leaves were higher than other evaluated traits. Seedling's height showed a significant positive correlation with altitude and a negative correlation with the relative humidity of seed origin. A significant strong correlation was found between number of leaves and longitude of seed origin. Among the four provenances, the final RGR ranged from 0.71 g/month to 0.86 g/month while the final AGR ranged from 2.68 g/month to 3.48 g/month. The observed variation among provenances of *Tetrapleura tetraptera* implies there is potential for its improvement and conservation of genetic resources.

Keywords: *Tetrapleura tetraptera* (SCHUM. AND THONN.) TAUB, seed source, genetic variation, tree improvement, growth rate.

Introduction

Tetrapleura tetraptera (Fabaceae) is a tree species widely spread throughout the high forest zone, riverian forest and southern savanna of Tropical Africa. It can be found in a secondary forest but grows best in the rainforest and areas where annual temperatures varied between 25 and 30°C. The species prefer mean annual rainfall of 1,700 to 3,000 mm, although it tolerates 1,200 to 5,000 mm. The soil requirement is light to medium, well-drained and pH range of 4.5 to 5.5 (Orwa et al. 2009). It is naturally distributed in West Africa from Benin and Burkina Faso, Chad, Cambodia, Cote d'Ivoire, Gambia, Ghana to Nigeria (Orwa et al. 2009). The tree is deciduous and attains a height of about 20 to 25 m, while the bole diameter ranges from 50 to 90 cm. The crown is spread in the open but thin and rounded in the forest, thus, becoming flat when old. The leaves of *T. tetraptera* are sessile and glabrous with a stalk (15 to 30 cm long), pinnae (5 to 9 pairs) and leaflets that ranged from 6 to 12 on each side of the pinna stalk. The floral is pinkish-cream to orange and is densely arranged on the spike between the upper leaf axils. The fruit is persistent with four longitudinal and wing-like ridges whose length is 15 to 20 cm and 3 to 5 cm wide. The immature fruit is green but turns brown to dark purple in maturity (Orwa et al. 2009). In Nigeria, the species is commonly known as "Aidan" and is one of the most important tree species owing to its nutritional and medicinal attributes (Ajayi et al. 2011).

Extracts of *T. tetraptera* are sedative, hypotensive (Ojewole and Adesina 1983, Amissah et al. 2007), molluscicidal (Aladesanmi 2007), antibacterial, analgesic, anti-malaria (Okokon et al. 2007), anticonvulsant, antioxidant, antidiabetic, anti-inflammatory and hypoglycaemic (Ojewole and Adewumi 2004, Kuate et al. 2015). Phytochemical screening and nutritional evaluation of the fruits showed it is composed of valuable oils, mineral content, fatty acids, crude protein and tannin (Godfrey 2015). The phytochemical composition of *T. tetraptera* fruits also include a significant amount of tannins, saponins, glycosides, steroids, terpenoids, flavonoids, carbohydrates and phenolic compounds that contribute to its documented biological and pharmacological properties (Godfrey 2015). In West Africa, *T. tetraptera* fruit is exploited as an ingredient in cosmetic preparation and drug production for treating inflammation, fever, rheumatic pains and stomach disorder (Uyoh et al. 2013). The fruit has a sweet fragrance and therefore it is used as a spice in food and drinks in zones where it is found (Abii and Elegalam 2007). *Tetrapleura tetraptera* is a leguminous species that can be planted with arable crops in case of alley cropping and/or farming, however, the potential for its inclusion in the agroforestry system will be determined by the productivity of green biomass on a regular basis during seedling growth evaluation.

Unfortunately, the *Tetrapleura tetraptera* population is threatened as a result of urbanization, over-exploitation of fruits and industrialization in Nigeria. Additionally, there is inadequate information on the provenance and genetic variation of *T. tetraptera* in Nigeria. Genetic differences in the physiology and morphology of plant species includ-

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ing *T. tetraptera* are caused by geographic changes in climate, ecology and environment across the distribution range of the species. Such variation will be useful for the selection, improvement and domestication of *T. tetraptera*. Several studies have reported variation in seedling growth variables in correlation with origin of plants in many tropical trees like *Faidherbia albida* (Delile) A.Chev., *Guazuma crinita* Mart. (Rochon et al. 2007), *Tamarindus indica* L. (Azad et al. 2020), *Acacia senegalensis* Britton (Omondi et al. 2014) and *Celtis australis* L. (Kumar et al. 2021). A major decision in forest management is the choice of seed sources for afforestation or reforestation programmes to ensure a successful crop establishment. In the Tropics, scarcity of information on sources of superior planting stocks has been recognized as a major constraint of agroforestry establishment (Simons 1996). Unfortunately, little is known about the early growth characteristics of *T. tetraptera* particularly for different provenances across its geographical range in Nigeria. Evaluation of the pattern of genetic variation within the natural range of a *T. tetraptera* would be imperative to guide the selection of outstanding sources for seed collection and mass propagation. Such genetic variation also enables the adaptation of plant species to changes in environmental conditions (Kumar et al. 2021). Thus, the main objective of this study was to evaluate variation in seedling growth and biomass accumulation in selected provenance of *T. tetraptera* across its distribution range in Nigeria with a view to identifying outstanding seed sources for afforestation and/or reforestation programs.

Materials and Methods

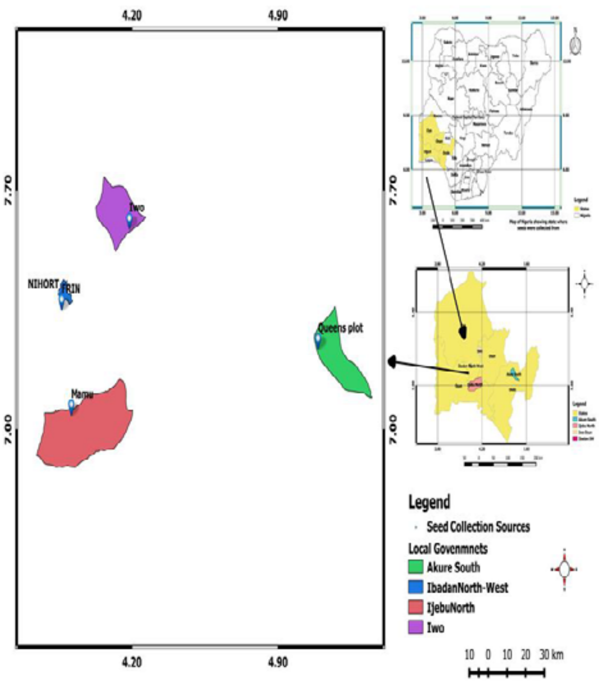
Study area

The study was conducted between February 2017 and January 2018 in the forest nursery of the department of Forest Production and Products, University of Ibadan, Ibadan, Nigeria. The nursery is located on latitude 7°26'58"N and longitude 3°53'49"E with an altitude of 277 m above sea level. The climate is tropical type with distinct dry and wet seasons. The dry season occurs between November and March while the wet season is usually between April and September. The mean minimum and maximum temperatures are 22°C and 34°C while the air humidity was 77.8%.

Seed collection

Four provenances: Ibadan Northwest (Ibadan), Ijebu North (Mamu), Akure South (Aponmu) and Iwo local government areas (Iwo) were sampled across the natural habitat of *T. tetraptera* in the southwestern zone of Nigeria. A provenance was meant to describe a seed source of a distinct geographic origin. Seeds were collected from each source to establish a provenance trial. The description of seed collection sites is shown in Figure 1. Five trees distant about at least 20 m were randomly selected in each provenance to avoid sampling related individuals. In all, a total of twenty individuals of *T. tetraptera* representing four distinct provenances were sampled for the study. One hundred and fifty (150) ripe fruit pods from each provenance were bulked and labeled accordingly in October 2017.

Figure 1 - Seed collection sites of *Tetrapleura tetraptera* from southwestern Nigeria.



Determination of seed weight

Three replicate samples, each consisting of 100 seeds from each source were weighed using an electronic digital weighing balance (Model E300).

Seedling growth evaluation

A nursery experiment was conducted to assess the variability in seedling growth variables. From each seed provenance, two hundred (200) seeds were selected randomly and soaked in concentrated H_2SO_4 acid (90%) for 5 minutes to break the hard seed coat dormancy (Alaba et al. 2006). Thereafter, seeds were washed in distilled water before sowing in germination trays filled with sterilized-washed river sand. Fifty uniformly growing seedlings were selected from each provenance and transplanted into 16 cm x 14 cm x 12 cm polythene pots (filled with forest topsoil). No fertilizer was applied. The seedlings were laid out in a completely randomized design inside the greenhouse with 80% light penetration and watering was done to field capacity once daily.

Data collection

The seedling's height, collar diameter and the number of leaves were measured every two weeks for 24 weeks. The seedling's height was measured with a meter ruler from the soil level to the topmost leaf axis of the main stem. The seedling's collar diameter was measured using a digital caliper while the number of leaves was determined by direct counting. Leaf area, dry weight of leaf, shoot and root were evaluated at 2, 4, 6, 8 and 12 months. At each harvest, five seedlings were randomly harvested from each provenance. Each seedling was uprooted in a bowl of water so that the soils around the roots are carefully dislodged. Thereafter, seedlings were then divided into root and shoot components. Leaf stalks were included in stem biomass. All plant parts were oven-dried at 80°C to constant weight for determining stem and root dry weight. The relative growth rates (RGR), actual growth rate (AGR) and net assimilation rates (NAR) were calculated as:

$$RGR = \frac{lnW_2 - lnW_1}{T_2 - T_1} \text{ (g/month)} \quad \text{(eq. 1)}$$

$$AGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ (g/month)} \quad \text{(eq. 2)}$$

$$NAR = \frac{W2 - W1}{A2 - A1} X \frac{\ln A2 - A1}{T2 - T1} \text{ (g/month)} \quad \text{(eq. 3)}$$

Where W_1 = Initial Dry Weight, W_2 = Final Dry Weight, A_1 = Initial leaf area, A_2 = Final leaf area, T_1 = Initial harvest time, T_2 = Final Harvest Time and *ln* = Natural logarithm.

Tetrapleura tetraptera has a bipinnate compound leaf, thus, calculating the total area of all the pinnules on a leaf using the grid method is laborious and time consuming, hence, the following variables was estimated; The mean area of pinnules (N=50) using the grid method. The mean number of pinnules on 50 pinnae (leaflets), mean number of pinnae on a leaf (N=50 seedlings) and the number of leaves on a seedling.

Thus, the mean leaf area (cm^2) of a seedling = Estimated mean area of pinnules x mean number of pinnules per pinnae x mean number of pinnae per leaf x number of leaves per seedling.

Statistical analysis

An analysis of variance was performed for provenance using the generalized linear model (GLM) procedure in Minitab software version 17 for windows. A one-way analysis of variance was conducted for monthly growth. Tukey's HSD test was performed to determine differences between the means using Minitab and descriptive statistics. Pearson product-moment correlations were conducted to determine relationship between seedling growth traits and geo-climatic variables. Principal component analysis (PCA) was carried out to find out important components which were correlated with other variables of seedling growth of *T. tetrapleura* and environmental variables of seedling origin. The genotypic variance, environmental variance, phenotypic variance, environmental variance phenotypic coefficient of variance, environmental coefficient of variance, genotypic coefficient of variance and broad sense heritability was calculated for each seedling character as given below according to Johnson et al. (1955).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MSP - MS\,(p \times t)}{r} \quad \text{(eq. 4)}$$

$$\text{Environmental variance } (\sigma^2_e) = MSe \quad \text{(eq. 5)}$$

Where MSP = Mean square for provenances
MS (p x t) = Mean squares for time x provenance interaction
p = number of provenances
t = number of years
r = number of replicates

$$\text{Phenotypic variance } (\sigma^2_p) = (\sigma_g^2 + \sigma_e^2) \quad \text{(eq. 6)}$$

Phenotypic Coefficient of Variation (PCV %) =

$$\frac{\sqrt{phenotypic\ variance}}{Mean} \times 100 \quad \text{(eq. 7)}$$

Genotypic Coefficient of Variation (GCV %) =

$$\frac{\sqrt{genotypic\ variance}}{Mean} \times 100 \quad \text{(eq. 8)}$$

Environmental Coefficient of Variation (ECV %) =

$$\frac{\sqrt{Environmental\ variance}}{Mean} \times 100 \quad \text{(eq. 9)}$$

Broad sense heritability (H^2B) =

$$\frac{Genotypic\ variance}{Phenotypic\ variance} \quad \text{(eq.10)}$$

Results

Seedling growth traits

There were significant differences in seedling height, collar diameter and number of leaves among the provenances (Tab. 1). The effect of assessment time was also significant on seedling's height, collar diameter and number of leaves. The interactions between provenance and time were not significant on height and collar diameter. Height, collar diameter and the number of leaves increased with age of seedlings across the provenances (Fig. 2-4). Seedling height varied between 12.5 cm to 87.4 cm across the provenances (Fig. 2). Tukey's test revealed seedling height was significantly lowest (53.0 ± 17.8 cm) in Mamu provenance compared to Ibadan, Aponmu and Iwo provenance. The final collar diameter of seedlings ranged from 4.1 ± 0.8 mm to 4.3 ± 0.8 mm (Fig. 3).

The number of leaves was highest (16.3 ± 3.1) in Aponmu provenance and was lowest (14.1 ± 2.9) in Ibadan provenance (Fig. 4). The interaction between the number of leaves and assessment time was significant (Tab. 1).

Table 1 - Analysis of variance for height, collar diameter and number of leaves of *Tetrapleura tetraptera* seedlings.

		Mean square		
Effect	DF	Height (cm)	Collar diameter (mm)	Number of leaves
Provenance	3	2,804.5**	5.32**	216.57**
Time	11	57,106.8**	258.19**	1,255.43**
Provenance*time	33	87.8ns	0.335ns	10.27**
Error	2,352	76.5	0.51	5.39
Total	2,399			

**significant at P<0.05, ns: not significant (P>0.05), **highly significant P<0.000*

Figure 2 - Growth trend in height of *Tetrapleura tetraptera* seedlings from different provenances in relation to sampling time. Vertical bar denote ± standard error (SE).

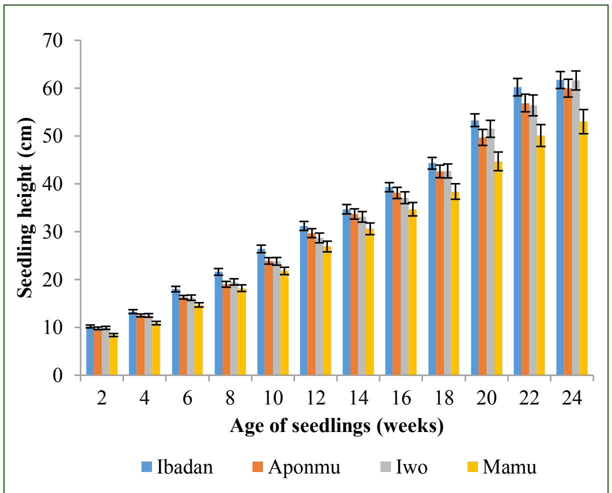


Figure 3 - Growth trend in collar diameter of *Tetrapleura tetraptera* seedlings from different provenances in relation to sampling time. Vertical bar denote ± SE.

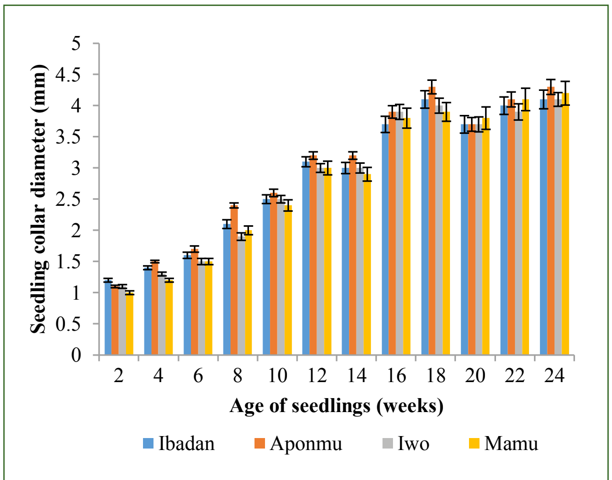
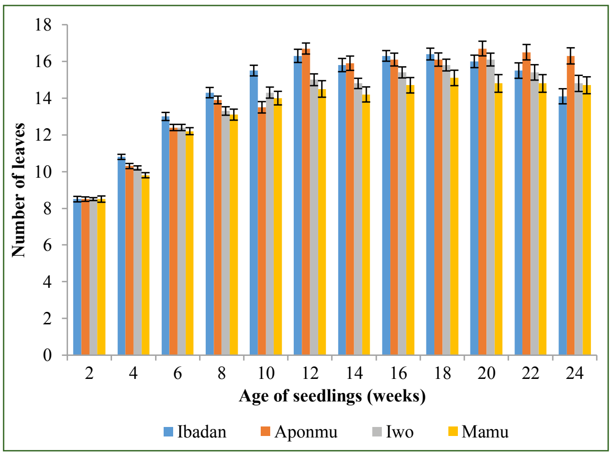


Figure 4 - Growth trend in number of leaves of *Tetrapleura tetraptera* seedlings from different provenances in relation to sampling time. Vertical bar denote ± SE.



Seed weight, root, stem and total dry weight and leaf area

Provenance had a significant effect on the weight of 100-seeds of *T. tetraptera* (Tab. 2). Aponmu provenance had the highest (16.16 ± 0.08 g) seed weight, while the lowest (10.9 ± 0.28 g) was Mamu provenance (Tab. 2). Root dry weight ranged from 5.1 ± 1.9 g to 8.4 ± 6.7 g while stem dry weight ranged from 13.7 ± 2.5 g to 16.4 ± 3.6 g (Tab. 3). Ibadan had the highest total dry weight (26.2 ± 10.2 g), while the least (20.3 ± 3.5 g) was Iwo. Provenance had significant effect on seedling's leaf area but not significant on root and stem dry weight (Tab. 4). The effect of harvest time was significant on leaf area, root and stem dry weight. Ibadan provenance had the highest final leaf area while the lowest was Iwo provenance (Tab. 4).

Table 2 - Seed weight, root dry weight (RDW), shoot dry weight (SDW) and total dry weight (TDW) of *Tetrapleura tetraptera* seedlings from different provenances at 12 months (mean ± sd).

Provenance	Seed weight (g)	RDW (g)	SDW (g)	TDW (g)
Aponmu	16.2a ± 0.1	5.1a ± 1.9	16.4a ± 3.6	21.8a ±5.1
Ibadan	12.5b± 0.2	8.4a ± 6.7	18.2a ± 4.0	26.6a ± 10.2
Iwo	15.3c ± 0.2	6.4a ± 0.9	14.8a ± 5.5	20.3a ± 3.5
Mamu	10.9d± 0.3	6.7a ± 3.5	13.7a ± 2.5	23.1a ± 5.9

Note: Mean with different alphabet are significantly different (P<0.05)

Table 3 - Analysis of variance for leaf area, root, shoot and total dry weight of *Tetrapleura tetraptera* seedlings from different provenances.

		Mean square			
Effect	Df	Leaf area (cm²)	RDW (g)	SDW (g)	TDW (g)
Provenance	3	4,1020*	7.32ns	1.73ns	18.05ns
Harvest time	4	8,4283**	115.06**	563.49**	1209*
Harvest Time* Provenance	12	7,217ns	2.16ns	0.61ns	5.62ns
Error	60	13,711	4.57	4.71	11.13
Total	79				

*Note: *significant at P<0.05, **highly significant P<0.000, RDW (root dry weight), SDW (shoot dry weight), TDW (Total dry weight)*

Table 4 - Leaf area (cm^2) of *T. tetraptera* seedlings (mean ±sd).

	Months after sowing				
Provenance	2	4	6	8	12
Aponmu	538.6 ± 40.4	665.3 ± 111	792.0 ± 114.0	567.6 ± 179.7	686.4 ± 187.9
Ibadan	549.1 ± 34.5	718.1 ± 59.7	699.6 ± 108.8	554.4 ± 52.8	726.0 ± 163.5
Iwo	517.4 ± 63.4	549.1 ± 91.2	660.0 ± 109.9	488.4 ± 50.6	567.0 ± 132
Mamu	517.4 ± 40.4	591.4 ± 124.4	620.4 ± 145.4	567.6 ± 99.9	686.0 ± 202

Variance and coefficient of variability

Genotypic variance ranged from 0.2 (collar diameter) to 108.6 (height) (Tab. 5). Genotypic variance and genotypic coefficient of variability (CV) for height and number of leaves were higher than their corresponding environmental variance and environmental CV. Genotypic CV and phenotypic CV were highest for the number of seedling leaves, closely followed by height while collar diameter had the lowest. However, environment CV was maximum for collar diameter but minimum for height. Estimates of broad sense heritability for height (0.59) and the number of leaves (0.60) were comparable and higher than collar diameter (0.28) (Tab. 5).

Table 5 - Variances and coefficient of variability estimates for seedling's growth character of *Tetrapleura tetraptera*.

Variables	V_g	V_e	V_p	GCV	PCV	ECV	h^2B
Height (cm)	l08.6	76.5	185.1	17.63	23.03	14.79	0.59
Diameter (mm)	0.20	0.51	0.71	10.68	20.16	17.08	0.28
Number of leaves	8.25	5.73	13.64	19.19	24.67	15.5	0.60
TDW (g)	1.73	5.62	7.35	5.76	11.85	10.37	0.24

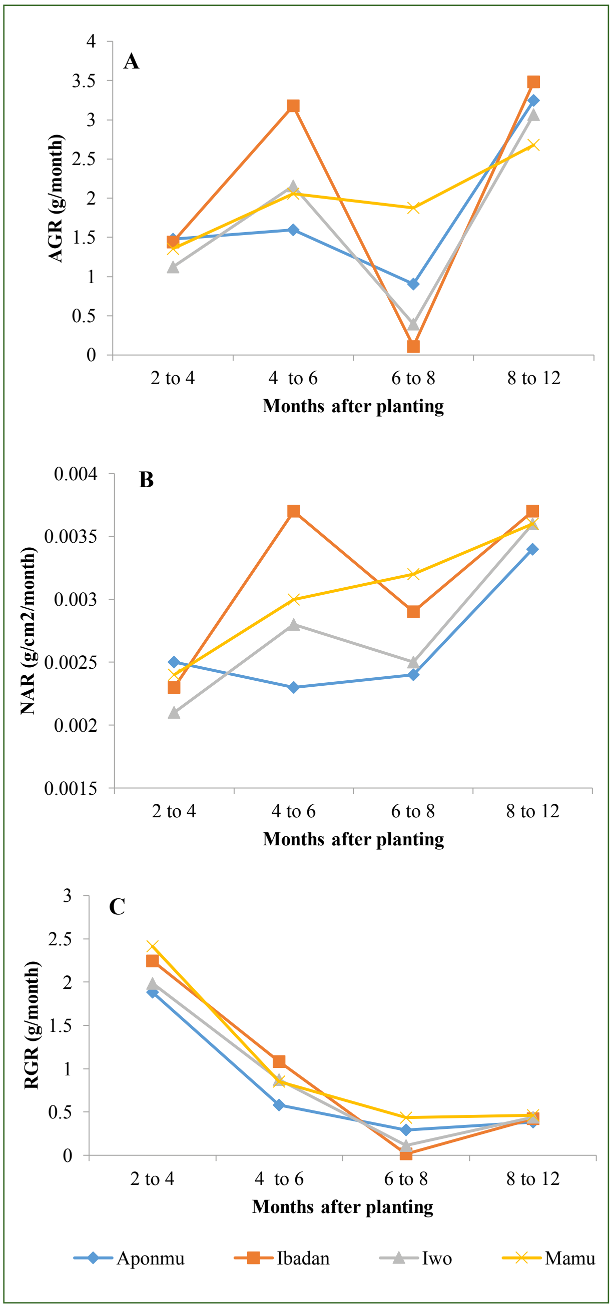
Note: V_g, genotypic variance, V_e, environmental variance, V_p phenotypic variance, GCV, genotype coefficient of variation, PCV phenotype coefficient of variation, ECV environmental coefficient of variation, h^2B, broad sense heritability

Absolute growth rate (AGR), Net assimilation rate (NAR) and Relative growth rate (RGR)

There was a consistent increase in the trend of AGR across the provenances with time of harvest (Fig. 5a). Ibadan provenance had the highest AGR at the final harvest, while the least was Mamu provenance. Aponmu provenance had the highest initial NAR (2.5 x 10^{-3} g/month) at 2 to 4 months while the lowest (2.1 x 10^{-3} g/month) was Iwo (Fig. 5b). The highest final NAR (3.7 x 10^{-3} g/month) was obtained from Ibadan, Iwo and Mamu had 3.6 x 10^{-3} g/month respectively while the least was Aponmu (3.4 x 10^{-3} g/month).

The RGR of *T. tetraptera* seedlings were comparatively similar across the provenance (Fig. 5c). However, RGR was relatively lower in the second harvest than the first harvest but became rapid in the third and fourth harvest respectively. Mamu provenance consistently had the highest initial RGR (2.41 g/month) and final RGR of 0.86 g/month (Fig. 5c). Aponmu provenance recorded the least initial RGR of 1.88 g/month and final RGR of 0.71 g/month respectively.

Figure 5 - Physiological growth characteristics of *Tetrapleura tetraptera* seedlings from different provenances. (A) Absolute growth rate (AGR); (B) Net assimilation rate (NAR); (C) Relative growth rate (RGR).



Relationship between geo-climatic data and seedling growth attributes

There were positive significant strong correlations among height, collar diameter and number of leaves (Tab. 6). Height growth revealed a significant negative strong correlation with relative humidity and a positive significant strong correlation with altitude while number of leaves showed a significant positive strong correlation with the longitude of provenance (Tab. 6). There was no significant correlation between diameter growth and geo-climatic variables.

Principal component analysis

Three components with eigenvalue >1 were selected. The first principal component (PC1) with an eigenvalue of 3.57 contributed 39.7 % to the total variance while the second component (PC2) with an eigenvalue of 2.05 and third component (PC3) with an eigenvalue of 1.54 contributed 22.8 % and 17.1 % to the total variance respectively. Of the four provenances, Ibadan, Iwo and Aponmu form a relatively homogenous group compared to Mamu which form another group (Fig.6). Temperature, altitude and latitude were positively correlated with PC1 while relative humidity was negatively correlated with PC1 (Fig. 7). However, height, diameter, leaf, longitude and rainfall were negatively correlated with PC2.

Discussion

Evaluation of seed sources of tree species is aimed at measuring the pattern of genetic variation to govern the selection of superior phenotype and well adapted accessions. Individual phenotype is influenced by genotype and environment interactions and is expected to be the expression of genotypic variation when environmental conditions are controlled. In this study, significant variations were found in seed weight and some seedling's growth traits of *Tetrapleura tetraptera*. For instance, seedlings obtained from Aponmu, Ibadan and Iwo provenance had greater height than seedlings obtained from Mamu provenance at all time points. Apparently, *Tetrapleura tetraptera* seeds from these provenances had higher weight than Mamu provenance and this might have contributed to higher seedling growth observed in this study. Previous studies have also reported the positive influence of large seed size on the establishment and early growth of seedlings (Singh and Bhatt 2008, Assogbadjo et al. 2010, Fornah et al. 2017). The present study revealed that genotype rather than environment contributed largely to the observed significant phenotypic variations in seedling's growth traits. This can be explained by higher genetic variance and genotypic CV of some seedling growth characters particularly height and leaf growth, as compared to their corresponding environmental variance and environmental CV in this study. Such variability suggests the selection of superior phenotype within the best provenance would be beneficial for *Tetrapleura tetraptera's* trait improvement. Meanwhile, similar results have

Table 6 - Peason's correlations between seedling growth traits and geoclimatic variables of *Tetrapleura tetraptera* from different provenances.

	Altitude (m)	Temperature (ºC)	Relative humidity (%)	Latitude (N)	Longitude (E)	Height (cm)	Diameter (mm)
Temperature	0.67						
Relative humidity	-0.33	--0.60					
Latitude	0.69	0.98*	-0.43				
Longitude	0.81	0.10	-0.01	0.13			
Height	0.96*	0.80	-0.95*	0.85	0.63		
Diameter	-0.56	-0.25	0..74	-0.11	-0..60	0.93*	
Leaves	-0.26	0.23	0.44	0.36	0.97*	0.74*	0.85*

significant at P<0.05

Figure 6 - Scoreplot of *Tetrapleura tetraptera* provenances from principal component analysis.

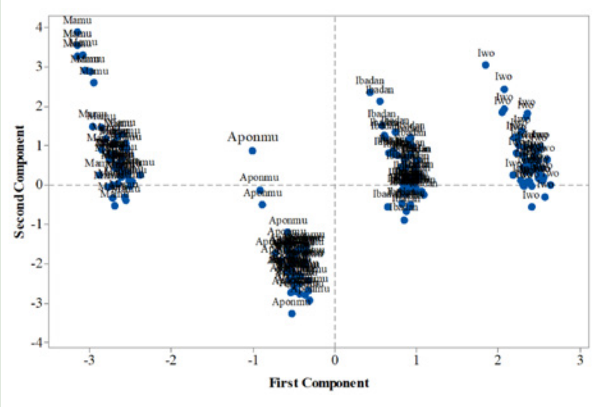
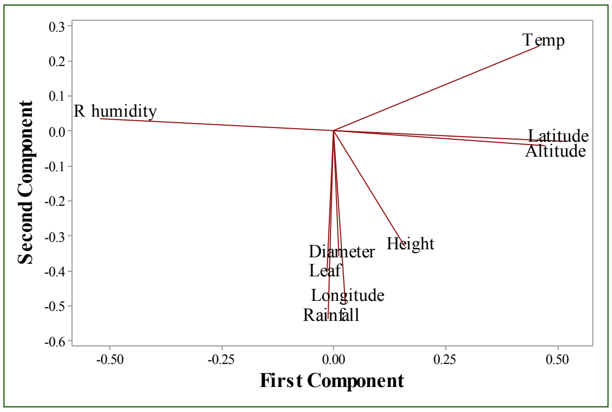


Figure 7 - Loading plot of *Tetrapleura tetraptera* seedlings' growth variables and geo-climatic variables from principal component analysis.



also been reported for *Adansonia digitata* L. (Assogbadjo et al. 2006), *Magnolia officinalis* Rehder & Wilson (Shu et al. 2012) and *Anthocephlus cadamba* (Roxb.) Bosser (Sudrajat 2016). Moreover, genotypic variation and broad sense heritability for height and number of leaves were higher than other traits indicating that these traits are genetically controlled and could be selected for improvement. However, a higher environmental CV for collar diameter compared to other traits suggests that collar diameter might be influenced by variations in environmental conditions. This result is consistent with the findings of other studies that collar diameter is more sensitive to environmental conditions than height (Costa and Durel 1996). Similarly, it has been largely reported in most studies on tropical trees that variation in seedling growth traits is greatly controlled by genetic factors while environmental factors have little effect (Shankar and Synrem 2012, Omondi et al. 2014, Kumar et al. 2021). Among the seedlings growth character observed in this study, seedling's height had the highest genotypic variance (108.6) and environmental variance (76.5), and this suggest height can be employed as indicator for early selection. Lack of significant variation in the root dry weight, shoot dry weight and total dry weight among *Tetrapleura tetraptera* provenances could imply that the variation for these traits are species-specific or the study might require a longer growth period for expression of genetic potential for this trait. The significant correlations of seedling's height and number of leaves with some geo-climatic factors in this study are consistent with findings of other studies (Loha et al. 2006, Azad et al. 2020). This is apparent that these traits are not only heritable but also controlled by environmental variations. The positive strong and significant correlation between seedling height and altitude suggests seedling height increase with increasing altitude. Similar result has been reported for *Celtis australis* (Singh et al. 2006). In addition, positive correlations between leaf growth and longitude of provenance in this study also suggest the number of leaves increase with increasing longitude. The significant and strong negative correlation between height and relative humidity of provenance in the present study may indicate an adaptation of climatic condition of the seedling growth and establishment. This is evident that environmental variations contributed to the observed variation in this study. Geo-climatic factors such as altitude, temperature, light and day length in addition to maternal factors affects seeds and/or seedling growth attributes (Loha et al. 2006). Positive strong correlations found among seedling's morphological traits in this study would imply that improvement in one character will correspond to improvement in another. Inter-character correlations have also been reported for *Magnolia officinalis* (Shu et al. 2012). The result of PCA in this study revealed two distinct groups of seedling origins. The most important characters measured in PCA were height, diameter, leaf growth, rainfall and longitude. It appeared PC1 explained the variation in geo-climatic factors while PC2 explained that in growth traits (height, collar diameter, number of leaves) and geo-climatic factors (longitude and rainfall). Ibadan and Iwo provenance comprised of seedlings with higher height while Aponmu provenance are characterized with seedlings with higher number of leaves.

Comparing the RGR and AGR of seedlings from different provenances, Mamu provenance performed best in RGR while Ibadan provenance had the highest AGR. Meanwhile, the NAR in this study appeared to be influenced by the significant variation in leaf area from different provenance. The leaf is the photosynthetic site of a plant therefore, the number of leaves produced by a plant influences the photosynthetic rate and how other organs of the plant store food over time. Similar observations have also been reported in previous research (Shipley 2006).

Conclusion

The present study provides evidence of considerable variation in seedling growth traits among provenances of *Tetrapleura tetraptera*. Seed collection or selection of superior phenotype for seedling production or ex-situ conservation might be made from Ibadan in Nigeria as seedlings from this provenance performed better than others. Height growth can be employed as an indicator for early selection of *Tetrapleura tetraptera* for breeding purposes. Further research should investigate the response of genotype and environment interaction at different sites over one-third of the rotation period. Genetic marker analysis of growth traits could be considered to identify genetic variation within and among seedling provenances.

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