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Original Article

Comparative studies on growth performances of *Bombax costatum* Pellegr and Vuillet seedlings from different provenances

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ABSTRACT

Species selection and improvement contribute to growth potential trees as provenance trials enhance identification of the best and highly adaptable tree species. This study therefore assessed growth performance of *Bombax costatum* seedlings from four different provenances (Aponmu, Oluwa, Ibadan and Oyo) with a view to identifying best source of germplasm for mass production of seedlings of desired quality. Fifty seeds per source from the four provenances were sown in germination trays filled with washed and sterilized river sand under humid propagator. After germination, twenty seedlings at leaf stage per provenance were transplanted into polythene pots that were filled with top soil. The experimental design was 4×6 factorial replicated 4 times. Assessment commenced 2 weeks after transplanting with measurement of seedling height (cm); collar diameter (cm); leaf number; and Leaf areas (cm^2). Dry weights of component parts were assessed at 2 weeks intervals for 3 months to determine the Relative Growth Rate (RGR), Absolute Growth Rate (AGR), Net Assimilation Rate (NAR), and shoot/root ratio. The result shows that there were significant differences ($P < 0.05$) among the provenances on the growth variables. Seedlings from Aponmu provenance had the highest shoot height, Collar diameter, leaf number, and leaf area of 16.9 cm, 0.8 cm, 7.1 cm, and 129.1 cm^2, respectively. Interaction between provenance and period of harvest was significantly different ($P < 0.05$) on seedling growth variables of *B. costatum*. Seedlings from Ibadan had the highest RGR ($5.5 \times 10^{-2\,g}$/week between 2nd and 4th weeks), and NAR (6.3×10^{-3}g/week/cm^2 between 2nd and 4th week), while Ibadan, Oluwa and Aponmu had highest shoot/root ratio (6.1 at 1st and 4th harvest). Provenance and age significantly influence the growth performance of *B. costatum* seedlings within period of study with best performance from Aponmu provenance.

Keywords: Assimilation, biomass, germplasm, growth rate, improvement

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INTRODUCTION

The red kapok tree, *Bombax costatum* is a tree species native to West Africa. Most of its organs or plant parts are of medicinal, food, and economic importance. It is much used for food and medicinal purposes and as timber. Recent ethnobotanical assessments conducted on *B. costatum* in Benin and Burkina Faso; two West-African countries, enumerated eight use categories of which food and medicinal purposes were the most frequently cited and the most culturally important.[1,2] *B. costatum* is a threatened species partly because of its poor regeneration,[3] caused by intensive harvesting of its flowers for domestic and commercial use as a vegetable.[1]

In addition, *B. costatum* can successfully contribute to the solution of insufficient supply of pulpwood to the Nigerian pulp and paper mills. It also has alternative uses as rough wood for concrete works in building construction.[1] This explains the threat being faced by this species and identifies the need to establish its plantation to meet the demand for pulp and paper production. Therefore, for the purpose of conservation and sustainable utilization of *B. costatum*, there is need to establish plantation by growing seedling in the forest nursery. This is because a successful plantation cannot be established unless healthy nursery seedlings or stocks are produced.[4]

Practices relating to species selection, forest maintenance and improvement will contribute to an increase yield of fiber from

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our forest. Many factors are known to be related to tree growth and nutrient availability; among these factors is provenance.[5] Provenance studies in forest trees are very important as it helps in identifying the best and highly adaptable provenance. Variation among the provenances might be attributed to genetic differences caused by the adaptation of different provenances to diverse environmental conditions and soil types.[5,6] In fact forest tree improvement program starts with the scanning of provenances/seed source capable of providing best-adapted trees. Production of seedlings with proper quality is important for planting success. Increase in yield and resistance to disease can be achieved through the selection and use of seed from good provenance.[4,7] This study therefore assessed growth performance of *B. costatum* seedlings from four different provenances (Aponmu, Oluwa, Ibadan and Oyo) with a view to identifying best source of germplasm for mass production of seedlings of desired quality.

MATERIALS AND METHODS

Seeds of *B. costatum* were collected from four provenances in South Western Nigeria. The four provenances were located within the rainforest zone of the country. They are; Aponmu (latitude 7º 23’ and 7º 19’N and longitude 5º 10’ and 5º 05’E), Oluwa (latitude 7º 44’ and 7º 48’N and longitude 3º 91’ and 3º 63’E) in Ondo State, Ibadan (latitude 7º 18’ and 7º 25’N and longitude 3º 42’ and 3º 29’E), and Oyo (latitude 3° 55’ N and 4° 42’ N and longitude 3º 53’ and 3º 47’E) in Oyo State.

Twenty-five trees were sampled from each site. The trees were numbered serially with red paint. All the selected trees were growing naturally and the tree species were within 100 m apart. Seed were collected from the base and middle portion of the crown.

Seed extraction and processing were carried out at the West African Hardwood Improvement Project section, Forestry Research Institute of Nigeria to remove impurities. The seeds were labeled according to their provenances. Fresh weight was determined immediately after the extraction. Dry weight was obtained after 72 h of drying at 70°C in an oven. Seeds weed placed in a desiccator to cool for 45 min and then reweighed. Twenty-five grams of seeds from each seed lot were used for moisture content determination.

Assessment of Seedling Growth

Fifty seeds per source from the four provenances were sown in germination trays filled with washed and sterilized river sand under humid propagator. After germination, twenty seedlings at leaf stage per provenance were transplanted into polythene pots that were filled with top soil. The experimental design was 4 × 6 factorial where the first factor was four (4) provenances and second factor was six (6) period of assessment in four replicates. Assessment commenced 2 weeks after transplanting and the following parameters were measured: seedling height (cm) measured with a meter rule; collar diameter (cm) was measured with a Vernier caliper; leaf number per seedling was visually counted. Leaf areas (cm^2) were determined by the use leaf meter. Dry weights of component parts (leaf, stem and root) were assessed at 2 weeks intervals for 3 months. At each period of assessment, leaves of the seedlings from each provenance were separately gathered so also the stems and roots. Their fresh weights were determined using an electronic balance for biomass estimation. The plant samples were then oven dried at 80°C for 24 h to constant weight after taking the fresh weights of the component parts. The samples were allowed to cool in a desiccator before weighing on electronic balance for dried weight. The data collected on dry weights of the seedlings were used in calculating the Relative Growth Rate (RGR), Absolute Growth Rate (AGR), Net Assimilation Rate (NAR) and shoot/root ratio following[8] as follows:

$$\text{RGR}\ (\text{g / wk}) = \frac{(In\text{W}2 - In\text{W}1)}{(T2 - T1)} \quad (1)$$

$$\text{AGR}\ (\text{g / wk}) = \frac{(\text{W}2 - \text{W}1)}{(T2 - T1)} \quad (2)$$

$$\text{NAR}\ (\text{g / wk / cm}^2) = \frac{\text{AGR}}{((\text{LA}2 - \text{LA}1)} \quad (3)$$

According to Rees *et al*.,[9] the NAR is the AGR per unit leaf area. So

$$\text{Shoot / root ratio} = \frac{\text{Dry weight of shoot}}{\text{Dry weight of root}} \quad (4)$$

Where:
In W_1 = Natural log of initial total dry weight (g)
In W_2 = Natural log of final total dry weight (g)
t_1 = Initial time
t_2 = Final time
LA_1 = Initial leaf area
LA_2 = Final leaf area

RESULTS

The mean highest shoot height was from Aponmu with mean value of 16.9 cm. This was followed by seedling from Oyo at 15 cm and Oluwa at 15.0 cm. The lowest mean shoot height (14.1 cm) was obtained at Ibadan provenance. Variations were observed in shoot height from all the provenances except Oyo and Oluwa, which were not significantly different from each other [Table 1]. Likewise, Table 2 shows that the highest mean shoot height was observed at 12th week (26.7 cm) while the lowest mean shoot height was observed at 2nd week (4.4 cm).

Table 1: Mean value of the effects of provenance of harvest on seedling growth in *B. costatum*

Provenance	Main effects						
	Height (cm)	Diameter (cm)	Leaf number	Leaf area (cm^2)	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)
Oyo	15.4a	0.4a	6.7a	118.5a	7.3a	2.8a	3.5c
Oluwa	15.0a	0.4a	6.4b	124.6b	7.4a	3.4b	2.7b
Aponmu	16.9b	0.8b	7.1c	129.1c	8.1b	4.0c	3.6d
Ibadan	14.1c	0.4a	7.0c	110.1d	5.3c	2.6a	2.1a
LSD	0.1	0.02	0.03	5.13	0.42	0.2	0.002

Means with the same letters along a column are not significantly different from each other. *B. costatum: Bombax costatum*

Table 2: Mean value of the effects of periods of harvest on seedling growth in *B. costatum*

Period	Main effects						
	Height (cm)	Diameter (cm)	Leaf number	Leaf area (cm^2)	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)
2 weeks	4.4a	0.2a	2.8a	73.2a	2.8a	2.0a	1.9a
4 weeks	8.3b	0.3b	5.4b	94.2b	3.5b	2.4b	2.2b
6 weeks	13.3c	0.4c	7.0c	114.5c	6.8c	2.6c	2.7c
8 weeks	17.7d	0.6d	7.9d	128.6d	7.5d	3.2d	3.0d
10 weeks	21.8e	0.7e	8.6e	146.5e	8.2e	3.7e	3.3e
12 weeks	26.7f	0.8f	9.2f	166.7f	9.7f	4.5f	3.8f
LSD	2.31	0.03	0.45	12.7	0.3	0.15	0.07

Means with the same letters along a column are not significantly different from each other. *B. costatum: Bombax costatum*

The interaction effect of provenances and periods of harvest was significantly different ($P < 0.05$) on the mean shoot height of *B. costatum* seedlings.

Aponmu provenance had the highest mean diameter of 0.8 cm, which was significantly different ($P < 0.05$) from other provenances. There were no significant variations in the mean diameter value (0.4) of Oyo, Oluwa, and Ibadan provenances [Table 1]. There were substantial variations in the observed diameter of the seedlings at the periods of harvest. The highest mean diameter was attained at 12th week (0.8 cm). The lowest mean value of 0.2 cm was obtained at 2nd week [Table 2]. Aponmu had the highest mean number of leaves of 7.1, which was not significantly different from Ibadan (7.0). The lowest mean value of 6.4 was observed at Oluwa and this did not vary significantly from Oyo provenance that recorded 6.7 [Table 1]. Significant differences were observed in leaf production of seedlings at the period of harvest. The highest mean number of leaves (9.2) was observed at 12th week, while the lowest mean number of leaves of 2.8 was obtained at 2nd week [Table 2]. The interaction effect of provenances and periods of harvest was significantly different ($P < 0.05$) on the mean leaf production of *B. costatum* seedlings.

Seedlings from Aponmu had the highest mean leaf area of 129.1 cm^2 and this differed significantly from other provenances. Seedlings from Ibadan recorded the lowest mean leaf area of 110.1 cm^2 [Table 1]. The mean leaf area (166.7 cm^2) at 12th weeks was significantly higher than the other periods of harvest. The lowest mean leaf area of 73.2 cm^2 was observed at 2nd week [Table 2]. The interaction effect of provenances and periods of harvest was significantly different ($P < 0.05$) on the leaf area of *B. costatum* seedlings.

The highest mean root dry weight of 3.6 g was observed at Aponmu provenance, although it was not significantly different from Oyo provenance (3.5 g). Ibadan provenance recorded the lowest mean root dry weight of 2.1 g [Table 1]. The highest mean root of 3.8 g was recorded at 12th week while the lowest value of 1.9 was observed at 2nd week [Table 2]. There were significant differences ($P < 0.05$) among provenances on root dry weight.

The highest stem dry weight of 4.0 g was obtained at Aponmu provenance. Ibadan provenance recorded the lowest mean stem dry weight of 2.6 g and this was not significantly different from 2.8 g from Oyo provenance [Table 1]. The highest value (4.5 g) of stem dry weight was observed at 12th week while the lowest (2.0 g) was observed at 2nd week [Table 2]. Stem dry weight as affected by provenance was significantly different ($P < 0.05$). The highest mean leaf dry weight was recorded at Aponmu provenance (8.1 g). This varies significantly from the mean values of the other provenances. Leaf dry weight of Oluwa provenance (7.4 g) and that of Oyo (7.3 g) did not differ significantly from each other. However, the lowest mean leaf dry weight of 5.3 g was recorded at Ibadan [Table 1]. The highest mean leaf dry weight (9.7 g) was observed at week 12 while the lowest value (2.8 g) was observed at week 2 [Table 2].

Table 3 shows the RGR of seedlings from the four provenances. It was observed to vary according to provenance and period of harvest. The highest RGR of 5.5×10^{-2} was observed in Ibadan provenance between the 2nd and 4th weeks of harvest. The lowest value of 1.5×10^{-2} was observed at Aponmu provenance between the 6th and 8th weeks and that of Oluwa provenance between the 8th and 10th weeks of harvest. Table 4 presents the AGR for all the provenances. Aponmu provenance had the highest AGR (5.5×10^{-1}) between the 4th and 6th weeks, 8th and 10th weeks and also between 10th and 12th weeks of harvests. This value was also observed in Oyo provenance between the 10th and 12th, Ibadan and Oluwa provenances had the lowest mean value of 2.5×10^{-1} between the 8th and 10th weeks of harvest.

Table 5 shows that seedling from Ibadan provenance had the highest NAR of 6.3×10^{-3} between the 2nd and 4th weeks. The lowest value of 1.9×10^{-3} was also recorded in the same Ibadan provenance between the 8th and 10th weeks of harvest. Table 6 shows that at the first harvest, Ibadan, Oluwa and Aponmu provenances recorded the highest value of shoot/root ratio of 6:1, while seedlings from Oyo had shoot: root of 5:1. At the 4th harvest, seedlings from Ibadan still recorded the highest value of 6:1, while at the 6th period all the provenances obtained a shoot: root of 4:1.

Table 3: RGR (g/week) for the seedlings of *B. costatum* from different provenances

Provenance	RGR_1	RGR_2	RGR_3	RGR_4	RGR_5
Ibadan	5.5×10^{-2}	4.0×10^{-2}	4.5×10^{-2}	3.0×10^{-2}	3.5×10^{-2}
Oluwa	4.5×10^{-2}	4.0×10^{-2}	3.0×10^{-2}	1.5×10^{-2}	3.0×10^{-2}
Aponmu	3.5×10^{-2}	4.0×10^{-2}	1.5×10^{-2}	3.5×10^{-2}	3.5×10^{-2}
Oyo	4.0×10^{-2}	3.5×10^{-2}	4.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}

RGR_1 = RGR between 2nd and 4th week; RGR_2 = RGR between 4th and 6th week; RGR_3 = RGR between 6th and 8th week; RGR_4 = RGR between 8th and 10th week; RGR_5 = RGR between 10th and 12th week. *B. costatum: Bombax costatum*, RGR: Relative Growth Rate

Table 4: AGR (g/week) for the seedlings of *B. costatum* from different provenances

Provenance	AGR_1	AGR_2	AGR_3	AGR_4	AGR_5
Ibadan	5.5×10^{-1}	3.5×10^{-1}	5.0×10^{-1}	2.5×10^{-1}	3.5×10^{-1}
Oluwa	4.5×10^{-1}	5.0×10^{-1}	3.5×10^{-1}	2.5×10^{-1}	3.5×10^{-1}
Aponmu	4.5×10^{-1}	5.5×10^{-1}	3.0×10^{-1}	5.5×10^{-1}	5.5×10^{-1}
Oyo	4.0×10^{-1}	4.5×10^{-1}	3.5×10^{-1}	3.0×10^{-1}	5.5×10^{-1}

AGR_1 = AGR between 2nd and 4th week; AGR_2 = AGR between 4th and 6th week; AGR_3 = AGR between 6th and 8th week; AGR_4 = AGR between 8th and 10th week; AGR_5 = AGR between 10th and 12th week. *B. costatum: Bombax costatum*, AGR: Absolute Growth Rate

DISCUSSION

Utilization of forest and non-forest products is inevitable. This therefore makes reforestation and afforestation activities needful to avoid deforestation which may cause loss of plant species diversity and also threatens some commercial tree species with extinction.[10] The significant of healthy seedlings for successful reforestation has initially been overlooked in many forestry projects.[11] Nevertheless, initiatives have been undertaken to improve qualitatively the provision of tree seeds for forestry projects. Plantations raised from a broad genetic base and superior phenotypes are good provenances; since both seeds and plants would have been mixed during establishment.[12]

Considerable genetic differences within species in their growth rate have frequently been reportedly between provenances of tropical forest trees as observed in this study for the seedlings of *B. costatum* from the various provenances investigated. There were significant variations in all growth parameters. This is in consonance with the observations of Akaffou *et al*.[10] that plant growth and morphological variability depend greatly on provenance, although genetic factors might be implicated. Likewise, Moya *et al*.[13] reported that variability in the germination response of seeds from different provenances, populations, individuals of the same population, or from different locations is normal and well known. Furthermore

Table 5: NAR (g/week/cm²) for the seedlings of *B. costatum* from different provenances

Provenance	NAR_1	NAR_2	NAR_3	NAR_4	NAR_5
Ibadan	6.3×10^{-3}	3.9×10^{-3}	4.6×10^{-3}	1.9×10^{-3}	3.0×10^{-3}
Oluwa	5.3×10^{-3}	4.7×10^{-3}	2.7×10^{-3}	3.4×10^{-3}	2.2×10^{-3}
Aponmu	5.0×10^{-3}	4.8×10^{-3}	2.3×10^{-3}	3.7×10^{-3}	3.3×10^{-3}
Oyo	4.7×10^{-3}	4.5×10^{-3}	2.9×10^{-3}	2.3×10^{-3}	3.7×10^{-3}

NAR_1 = NAR between 2nd and 4th weeks; NAR_2 = NAR between 4th and 6th weeks; NAR_3 = NAR between 6th and 8th weeks; NAR_4 = NAR between 8th and 10th weeks; NAR_5 = NAR between 10th and 12th weeks. *B. costatum: Bombax costatum*, NAR: Net Assimilation Rate

Table 6: Shoot: root ratio for the seedlings of *B. costatum* from different provenances

Provenance	H_1	H_2	H_3	H_4	H_5	H_6
Ibadan	6:1	5:1	5:1	6:1	5:1	4:1
Oluwa	6:1	5:1	5:1	6:1	5:1	4:1
Aponmu	6:1	5:1	5:1	6:1	5:1	4:1
Oyo	5:	5:1	4:1	4:1	4:1	4:1

H_1 = 1st harvest; H_2= 2nd harvest; H_3= 3rd harvest; H_4= 4th harvest; H_5= 5th harvest; H_6= 6th harvest. *B. costatum: Bombax costatum*

Ani *et al*.,[14] reported that significant variations in growth performance among provenances of *Acacia auriculiformis*. Ngulube *et al*.[15] found that there were significant variations in seedling height and biomass production of *Uapaca kirkiana* species. In *Dalbergia sisoo* Sagta and Nautiyal,[16] observed that height, collar diameter and biomass were significantly different among provenances. Adewusi[8] also recorded total and shoot biomass to be continually highest in Ogbomoso provenance of *Faidherbia albida*. Fasheun and Bello-Kura[17] found out that there was a significant variation in seedlings height, diameter, NAR, RGR and AGR of six provenances of *Acacia nilotica*.

Bahru *et al*.[18] reported that provenance variation is directly associated with a variation in the adaptation potential of tree species at a particular area; such that provenance variation affects the functional characteristics of seedlings and their field performance. Such difference in adaptation potential is demonstrated in various morphological as well as physiological characteristics of plant species. Likewise, Moya[13] reported that provenance and site within provenance had significant effects on most traits and survival of *Nothofagus glauca* an endemic species of Central Chile. Fredrick *et al*.[5] reported that there is a highly significant difference among provenances in seed morphological characteristics, germination, and early seedling growth of *Faidherbia albida*. However, Ngulube and Murabumba[19] found non-significance variation in the growth of *Gliricidia sepium* provenances. Jha and Chhimwal[20] also found non-significant provenance variation in diameter growth of *Eucalyptus camaldulensis*. Likewise, Ivetić and Škorić[7] reported that provenance had a minimal influence on quality of 2 years old seedlings of Austrian pine, regardless to production method.

Period of assessment showed a very high significant effect on all the growth parameters of seedlings of *B. costatum* measured. This is due to the fact that the seedlings produced more roots and leaves with age that enabled them to absorb more nutrients and water from the soil to enhance production of assimilate. The common exhibition of a shoot to root ration of 4:1 is an indication that provenance had little or no effects on shoot to root ratio. However, Bahru *et al*.[18] reported that there is significant different in the effects of provenance on the shoot to root ratio. Furthermore, Fornah *et al*.[4] reported that provenance significantly affected shoot dry weight and total biomass of Gmelina seedlings.

High photosynthetic rates per unit leaf area may be responsible for the differences in growth parameters observed. The variation observed for this species further confirms the fact that primarily genetically fixed characteristics determine a tree's early growth relative to others. Environmental factors such as temperature, rainfall and relative humidity observed in the four provenances (Aponmu, Oluwa, Oyo, and Ibadan) could have effect on seedling growth and their level of adaptability. Selection for planting out will favor seedlings with good vigor. Genetic variations have been documented for *Pseudotsuga menziesu* by Edwards and El-Kassaby.[21] Significant variation observed in early seedling growth of *B. costatum* also agrees with the findings of White *et al*.[22] for *Dalbergia sissoo*.

CONCLUSION

Provenance trials play importance role on the tree improvement program of tree species. Careful identification and selection of the appropriate seed sources could thereafter serve as basis for production of seedlings of good morphological and physiological traits. Findings from the study depict that provenance and constitute an important factor that influence growth of tree species as reflected on the growth potentials of seedlings of *B. costatum* at different period of assessment. Therefore, based on the result of the study, it is recommended that seeds of *B. costatum* sourced from Aponmu are the best and highly adaptable provenance.

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