Sahel Journal of Life Sciences FUDMA (SAJOLS)
September 2025 Vol. 3(3): 112-119
ISSN: 3027-0456 (Print)
ISSN: 1595-5915 (Online)
DOI: *https://doi.org/10.33003/sajols-2025-0303-14*

Research Article

Variation In Seedling Growth of *Balanites aegyptiaca* (l.) Delile from Different Seed Sources in Arid and Semi-Arid Nigeria

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ABSTRACT

The influence of seed sources on the growth characteristics of a fast-declining important edible wild fruit tree species (*Balanites aegyptiaca*) was investigated. Seeds sourced from 8 locations were sown on different seed beds representing the locations. 100 seedlings of similar height growth from each seed bed were transplanted into polythene bags. The experiments were arranged in a Completely Randomize Design (CRD) with 5 replicates. The stem diameter (SD mm), stem height (SH cm), number of leaves (NL), root length (RL), absolute growth rate by plant height (AGR_{PH} cm day^{-1}), relative growth rate by dry weight (RGR_{DW} cm day^{-1}) and absolute growth rate by dry matter (AGR_{DM} mg g^{-1} day^{-1}) were assessed. SD, CD, NL and RL varied significantly among seed sources. CD and SD were highest in Dumsai with each recording 4.91 and 60.82, respectively. NL ranged from 166.60 (Mashi) to 104.70 (Gamawa), RL increased from 34.01±6.46 (Baure) to 46.71±20.18 (Mashi). Seedlings of Dumsai origin demonstrated better growth characteristics compared to other sources and could serve as a good source of seed for domestication and improvement of the species.

Keywords: Desert date; Domestication; Improvement; Seedlings diameter; Seedlings height

Citation: Wakawa, L.D., Akinyele, A.O., Abdulhamid, A.S., & Ali, B. (2025). Variation In Seedling Growth of *Balanites aegyptiaca* (l.) Delile from Different Seed Sources in Arid and Semi-Arid Nigeria. *Sahel Journal of Life Sciences FUDMA*, 3(3): 112-119. DOI: *https://doi.org/10.33003/sajols-2025-0303-14*

INTRODUCTION

Genetic variation in forest tree species at provenances (population) level is usually high, and understanding the level and pattern of this variation is crucial for production of forest reproductive material (Ivetić *et al.,* 2016). The production of forest reproductive material usually starts from seed collection. Adequate sampling during seed collection will ensure the preservation of genetic material, while narrow sampling can lead to the loss of genetic material (Ivetić *et al.,* 2016). Provenance study was originally designed for the selection of appropriate seed material (Morgenstern, 1996) but other objectives such as seed transfer and utilization schemes and developing adaptation capacity of trees to withstand climate have been the recent application of provenance study (Rehfeldt *et al*., 1999; St. Clair, 2006; McLachlan *et al*., 2007; Ukrainetz *et al*., 2011).

Seed source or provenances affect growth characteristics in forest tree. This has been documented by several researchers. For example, significant variation in seedling height and diameter of *Eucalyptus pellita* among provenances in Columbia was observed (Nieto *et al*., 2016). Variation in growth variable of *Pinus wallichiana* and *Celtis australis* among provenances was reported in India (Rawat and Bakshi 2011; Kumar *et al*. 2018). Akinyele and Adegeye (2012) also observed significant variation among different sources in many growth characteristics such as leaf area, root dry weight, collar diameter, leaf production, and seedlings height of *Buchholzia coriacea* in Nigeria. A similar trend was reported by Fredrick *et al*. (2015) who observed a significant variation in leave number and seedlings collar diameter of *Faidherbia albida* within and among provenances in Niger republic. However, absence of significant variation in the growth characteristics of *Acacia senegal* among 12 provenances in Sudan was report (Mohammed *et al.,* 2022). Shu *et al*. (2012) also reported an absence of significant difference in relative growth rates and net assimilation rates of *Magnolia officinalis* from different provenance in China.

Growth response of trees among provenances depends on the type of species, different species response differently. For example, a significant difference in stem height and diameter increment in *Quillaja saponaria* species among provenances was observed but a dearth of significant difference in stem height and diameter increment in *Cryptocarya alba* among provenances was also observed when the two species were grown under similar condition (Espinoza *et al*., 2021). Tree species usually have wide distribution range which exposed them to diverse environmental conditions leading to modification in morphology and ability to adapt to site conditions and changes in climatic conditions (Kapeller *et al*. 2013). Tree species variations among provenances are essentially control by genetic factor more especially at nursery stage (Sneizko and Stewart, 1989). Provenance (seed sources) studies give us an insight on the level of variation in species among location and the ability to identify seed sources or population with superior characteristics for the purpose of mass production of forest reproductive material, breeding and/or tree improvement programme.

Balanites aegyptiaca (L) Del is an important wild fruit species distributed across the arid and semi-arid zones of Africa, Asia, and the Middle East (Orwa *et al*., 2009). The fruit and leaf of *Balanites aegyptiaca* are edible and provides the much-needed nutrients supplements particularly in time of famine or poor harvest (Lockett *et al*., 2005). However, the species is undomesticated and its population is dwindling at an alarming rate due to overexploitation and land clearing for arable crops farming. This called for research that will encourage its propagation. Studies conducted on the growth response of *Balanites aegyptiaca* from diverse seed origins have yielded conflicting outcomes (Weber *et al*., 2019; Hounsou-Dindin *et al*., 2021). Therefore, this study is aim at determining the effect of seed sources on the growth characteristics of *Balanites aegyptiaca* among its natural distribution range so as to identify sources with superior growth and adaptive traits which will serve as a guide to future programme on domestication, breeding and/or improvement

MATERIALS AND METHODS

Study area

The experiment was setup in the seedling's nursery of the Department of Forestry and Wildlife Management, Federal University Gashua. The site is located on approximately Latitude 12°51'.723''- 12°54'.723'' N and longitude 11°00'.024'' - 11°03'.475'' E. The climate is characterized by the wet and dry seasons with a minimum temperature that ranges from 23-28°C and a maximum temperature of between 38-40°C. Average annual rainfall falls between 500 and 1000 mm (Wakawa and Suleiman, 2022).

Seed collections

Eight locations (sources): Baure, Bauchi, Buratai, Dumsai, Gamawa, Gashua, Guri and Kirikasama (Table 1) were identified for seed collection based on the availability of *Balanites aegyptiaca* species. Ten (10) mature trees randomly selected from the natural population of *Balanites aegyptiaca* in each location as described by Pacalaj *et al*. (2011) and Ivetić *et al*. (2016). A minimum distance of 100m was maintained between each species in order to reduce the effect of inbreeding as suggested by Abasse (2011). The preserved samples of the tree species were duly certified as *Balanites aegyptiaca* species and accessioned with the voucher identity number: BUKHAN 0359 in the Herbarium unit, Department of Plant Biology, Bayero University Kano, Nigeria.

Table 1. Geographic characteristic of *B. aegyptiaca* source(s)

Source (s)	Longitudes	Latitudes	Elevation (m)	Ecological zone
Baure	008°43.496	12°50.407	403.7	Sudan Savanna
Buratai	012°02.535	11°01.488	537.8	Sudan Savanna
Dumsai	010°33.325	12°51.615	344	Sahel Savanna
Gamawa	010°35.661	12°11.397	355.5	Northern Guinea Savanna
Gashua	011°00.770	12°52.496	334.1	Sahel Savanna
Guri	010°24.755	12°45.313	347.9	Sahel Savanna
Kirikasama	010°20.296	12°40.213	387.2	Sudan Savanna
Mashi	007°56.316	12°57.681	507.2	Sudan Savanna

Source: Wakawa and Akinyele 2024

Growth study

Polythene bags of 15 × 8.5 cm size were filled with topsoil and cow dung, mixed in a ratio of 5:1 respectively. A total of 100 seedlings of even growth from each source were transplanted from the germination beds into polythene bags. The experiment was arranged in a CRD and replicated 5 times. After twenty weeks, the seedlings were transferred to another polythene bags measuring 28 × 12.4 cm in size. This was done to avoid growth restriction because the seedlings were found to have outgrown the polythene bags they were earlier transplanted into. Seedlings were watered once daily during the 12 months the study lasted.

Growth characteristics assessed

Stem diameter (mm): Digital vernier caliper was used to determine stem diameter. The diameter was measured at the collar

Stem height (cm): The centimeter rule was used to assess the stem height. Measurement was taken from the soil level to the apex.

Number of leaves: The number of leaves was counted by physical observation.

Root length: The root length was measured using the centimeter rule at the termination of the experiment.

Root: shoot ratio: The shoot and root of each seedling sampled for analysis were collected and washed with water to remove soil particles. The shoots and roots were then packaged in a separate envelope and dry to constant weight at 70^0C in the oven for 24 hours. Root: shoot ratio was then calculated as shown below

$$\frac{\text{Dry weight of the root}}{\text{Dry weight of the shoot}} \qquad \text{eq. (1)}$$

Absolute growth rate by plant height (AGR_{PH}) (cm day^{-1})

AGR_{PH} was calculated according to the formula used by Redford (1969) given below:

$$AGR_{PH} = \frac{H2-H1}{t2-t1} \qquad \text{eq. (2)}$$

H_1 = Initial plant height, H_2 = final plant height, t_1= initial time, t_2 = final time

Biomass assessment

The fresh and dry weight of leaves, stems and roots was determined separately. The samples were then oven-dried to constant weight for twenty-four hours at 70^0C to ascertain their dry weight. Plant total fresh and dry weight was the summation of the fresh weight of roots, stems, and leaves.

Relative growth rate by dry weight (RGR_{DW}) (mg g^{-1} day^{-1})

RGR_{DW} was determined using the formula below (Gbadamosi 2014)

$$RGR = \frac{\text{In (final dry weight)} - \text{In (initial dry weight)}}{\text{Duration of the experiment (Days)}} \qquad \text{eq. (3)}$$

Absolute growth rate by dry matter* (AGR_{DM}) *(g day^{-1})

AGR_{DM} was calculated based on the formula of Redford (1969) as shown below

$$AGR_{DM} = \frac{W2-W1}{t2-t1} \qquad \text{eq. (4)}$$

W_1 = Plant dry matter weight at the start of the experiment, W_2 = Plant dry matter weight at end of the experiment, t_1= Time at beginning of the experiment, t_2 = Time at end of the experiment

Data Analysis

Analysis of variance (ANOVA) at $p<0.05$ level of significance was used while Duncan multiple range test was used for mean separation where applicable.

RESULTS AND DISCUSSIONS

Seedling height growth

Significant variation in seedlings height growth was observed among the sources of *B. aegyptiaca* seedlings. Seedlings from Dumsai had the highest mean stem height of 60.82 cm and differed significantly from the other sources except for Baure and Guri sources which had 54.30 cm and 57.24 cm respectively. Seedlings from Mashi had the least mean stem height of 43.57 cm (Figure 2).

Relative growth rate by dry weight (RGR_{DW} mg g^{-1} day^{-1})

The relative growth rate by dry weight of *Balanites aegyptiaca* seedlings among sources did not vary significantly. However, seedlings from Mashi had a higher RGR_{DW} of 0.004 mg g^{-1} day^{-1} in comparison with the other sources which had a similar RGR_{DW} value of 0.003 mg g^{-1} day^{-} each (Table 3).

Absolute growth rate by plant height (AGR_{PH} cm day^{-1})

The source of a selection of *Balanites aegyptiaca* seeds did not significantly affect the seedling's absolute growth rate. However, seedlings from Dumsai recorded the highest mean absolute growth rate by plant height of 0.11±0.04 cm day^{-1}. Seedlings from Buratai, Gamawa, and Gashua had the least seedling mean absolute growth rate with each recording 0.07±0.03 cm day^{-1} (Table 3).

Absolute growth rate by plant dry weight (AGR_{DW} g day^{-1})

Seedlings of *Balanites aegyptiaca* from different sources show significant variation in their absolute growth rate by plant dry weight. Seedlings from Dumsai, Guri, and Mashi recorded the highest mean AGR_{DW} value of 0.028±0.010 g day^{-1} each while seedlings from Buratai, Gashua, and Kirikasama recorded the least mean AGR_{DW} value of 0.017±0.007g day^{-1} each (Table 3).

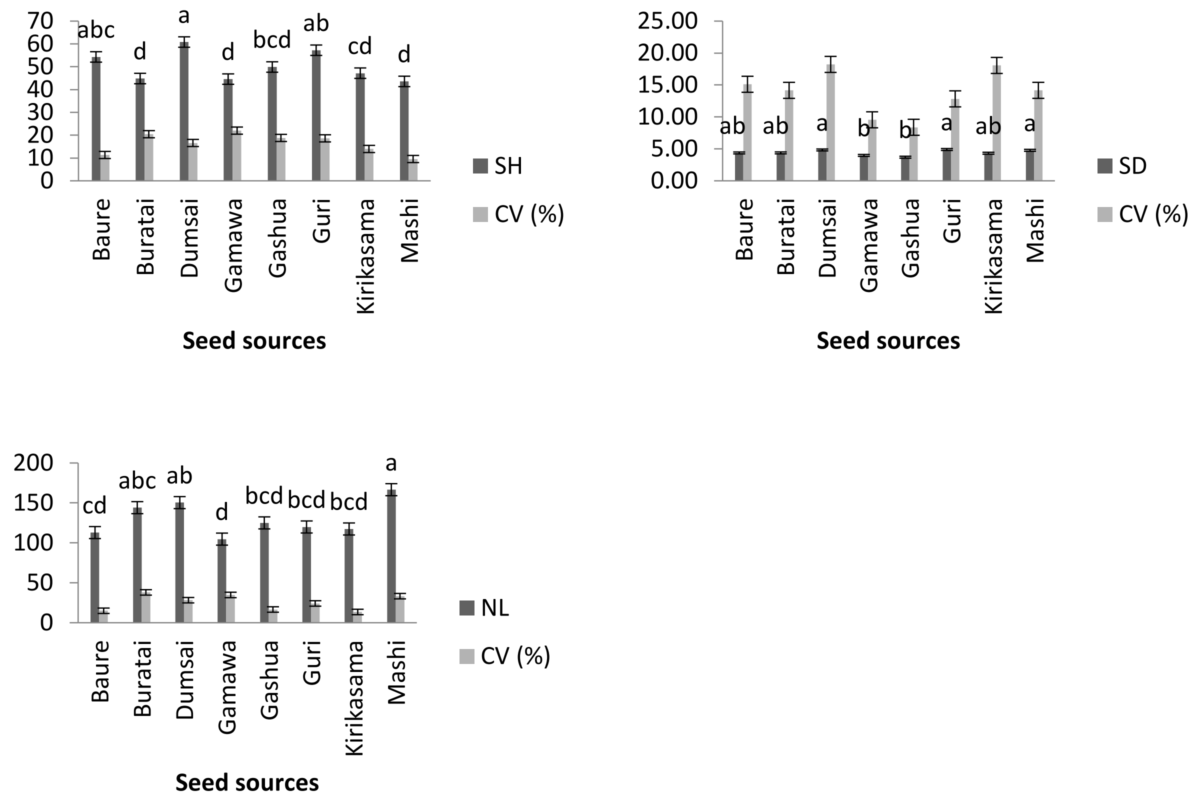

Figure 1. Effect of seed sources on seedlings height (SH), seedlings diameter (SD) and number of leaf (NL)
Note: CV = Coefficient of variation, different letters indicate significant differences among provenances at a significant level of $p \leq 0.05$ (Duncan test). The error bars indicate the standard error.

Table 2. Root length, root: shoot ratio, and dry biomass of *Balanites aegyptiaca* seedlings among seed sources

Source	RL	RSR_{DW}	LDW	SDW	RDW	TDW
Baure	34.01±6.46^{c}	3.58±1.87^{a}	1.62±0.70^{c}	2.18±0.77^{bcd}	6.73±2.00^{ab}	10.52±2.06^{bc}
Buratai	45.69±7.83^{ab}	3.47±1.60^{a}	1.67±0.70^{bc}	1.70±0.97^{cd}	4.92±1.74^{bc}	8.28±2.88^{c}
Dumsai	34.63±9.67^{bc}	2.26±0.79^{a}	2.25±0.92^{abc}	3.52±1.08^{a}	7.66±2.52^{a}	13.44±3.84^{a}
Gamawa	35.22±7.83^{bc}	3.67±1.04^{a}	1.85±0.82^{bc}	1.66±0.43^{d}	5.94±1.80^{abc}	9.44±2.49^{c}
Gashua	43.56±9.45^{abc}	3.03±1.41^{a}	1.54±0.73^{c}	1.88±0.54^{cd}	5.43±2.27^{bc}	8.85±2.13^{c}
Guri	45.54±8.87^{ab}	2.81±1.23^{a}	2.65±0.78^{a}	2.91±0.88^{ab}	7.43±1.70^{a}	12.99±2.13^{ab}
Kirikasama	43.24±12.14^{abc}	2.36±0.77^{a}	1.69±0.47^{bc}	1.98±0.59^{cd}	4.55±1.54^{c}	8.21±2.20^{c}
Mashi	46.71±20.18^{a}	3.77±2.03^{a}	2.39±0.80^{ab}	2.50±1.09^{bc}	7.86±2.64^{a}	12.75±3.82^{ab}
CV (%)	24.84	42.30	38.72	35.17	33.55	25.82
F-stat.	2.443	1.780	3.090	6.264	3.912	5.949
Sig	0.026 *	0.105**ns**	0.007 *	0.000 *	0.001 *	0.000 *

Note: Mean carrying the same alphabet did not vary significantly $\alpha_{0.05\%}$. Mean values are followed by the standard deviation. RL = Root length (cm), RSR_{DW} = Root: Shoot ratio by dry weight, LDW = Leave dry weight (g), SDW = Stem dry weight (g), TDW = Total dry weight (g) RDW = Root dry weight (g)

Table 3. Relative growth rate and absolute growth rate by dry weight and plant height of *Balanites aegyptiaca* among seed sources

Source	RGR_{DW} (mg g^{-1} day^{-1})	AGR_{PH} (cm day^{-1})	AGR_{DW} (g day^{-1})
Baure	0.003±0.000^{a}	0.088±0.027^{a}	0.022±0.005^{ab}
Buratai	0.003±0.001^{a}	0.070±0.027^{a}	0.017±0.007^{b}
Dumsai	0.003±0.001^{a}	0.109±0.036^{a}	0.028±0.009^{a}
Gamawa	0.003±0.001^{a}	0.071±0.046^{a}	0.019±0.006^{b}
Gashua	0.003±0.000^{a}	0.073±0.035^{a}	0.017±0.007^{b}
Guri	0.003±0.000^{a}	0.096±0.031^{a}	0.028±0.005^{a}
Kirikasama	0.003±0.001^{a}	0.073±0.024^{a}	0.017±0.005^{b}
Mashi	0.004±0.000^{a}	0.098±0.034^{a}	0.028±0.010^{a}
CV (%)	33.33	39.74	31.47
F-stat.	2.400	2.017	5.604
Sig	0.219**n**	0.064**ns**	0.000 *

Note: Mean carrying the same alphabet did not vary significantly $\alpha_{0.05\%}$. Mean values are followed by the standard deviation. RGR_{DW} = Relative growth rate by dry weight (mg g^{-1} day^{-1}), AGR_{PH} = Absolute growth weight by plant height (cm day^{-1}), AGR_{DW} = Absolute growth rate by plant dry weight (g day^{-})

DISCUSSION

Variation in growth characteristics of *Balanites aegyptiaca*

Genetic variability within and among species is the basis for any tree improvement programme and play an important role in the ability a species to adapt to changes in the environment. Therefore, an understanding of the level and pattern of variation in growth pattern of plant species is crucial. In this study significant variation in growth characteristics of *B. aegyptiaca* species from different locations was observed. This could be attributed to genetic or environmental factors. According to Jayasankar *et al*. (1999), Andersen (2010), Ivetić *et al*. (2016) seedlings with better initial height growth are likely to maintain their performance over time. This implies that seedlings from Dumsai which had superior height performance may outperform seedlings from other sources in terms of height growth when transplanted on the field and may have a better chance of survival on the field. However, according to Grossnickle and MacDonald (2018) seedling diameter at the time of planting is regarded as better predictors of field performance. This is however is not always true, for example initial stem height and diameter did not influence growth and survival of *Quillaja saponaria* and *Cryptocarya alba* on the field (Espinoza *et al*., 2021). This variation could be attributed to differences in environmental factors. According to Loha *et al*. (2006), collar diameter increment is easily affected by environmental conditions.

Seedlings from Mashi which have more leaves would be expected to have a high photosynthetic ability since the leaf is the major organ that facilitates carbon fixation in plants (Bojović and Stojanović, 2006). However, seedlings of Mashi origin did not have a better performance with respect to collar diameter, and height growth when compared with other sources. Leave production unlike other growth variables can increase and decrease during the course of the experiment. Raw data collected during the early months (1-7) of assessments shows Dumsai source performing better in terms of leaf production compared to Mashi.

The number of resources acquired by the plant can be determined indirectly by RGR (Didon 2002) and determine the competitive ability of the plant (Lowry and Smith 2018). This means seedlings from Mashi may have a better competitive edge over others on the field since it has better RGR. This was further elucidated by the longer root system recorded in Mashi. Plants with longer root system have better access to water and nutrients. This implies that seedlings of Mashi origin would be expected to have a better supply of water and nutrients in comparison with others. However, since all the plants were subjected to similar conditions, water, and nutrient supply may not be necessary be an issue at the seedling stage. Seedlings from Mashi may have a better chance of survival on the field, in the long run, especially when water and nutrient supply become scarce. Plants with developed root systems have a better chance of survival (St-Denis *et al*., 2013) and resistance to fire (Hoffmann and Sgro, 2011) which is very important in the savannah region.

The RSR_{DW} relationship is a good measure of the ability of a plant to cope with limited resources required for growth and development in the environment (Maskova and Herben 2018). Our result contradicts that of Jayasankar *et al*. (1999), Saklani *et al*. (2012), Qi *et al*.

(2019) who reported significant among variation in RSR_{DW} in other tree species. Species differences may be responsible for this contradiction. Seedlings from the Mashi source have higher RSR_{DW} in comparison with other sources even though the variation as earlier stated was not significant. This implies that seedlings from Mashi may have a better ability to cope with limited resources such as nutrients and water on the field.

Seedlings from Mashi had better RGR_{DW} even though the variation was not significant. This finding was in agreement with that of Jayasankar *et al*. (1999) in a study done to evaluate the role of provenance in the growth characteristics of *Tectona grandis*. However, a contrary result was obtained by Bognounou *et al*. (2010) in *Anogeissus leiocarpa* and *Combretum aculeatum* species from different provenance. It should however be noted that RGR_{DW} was calculated based on percentage in the work of Bognounou *et al*. (2010), a different approach from what was used in this study. This could be responsible for the contradictory result. This is not ruling out the effect of genetic attributes of individual species and environmental factors. The AGR_{PH} is the rate of increase of total plant height per plant (Hunt 1990) and it is regarded as the simplest possible measure of plant growth. Seedlings from Dumsai had the highest rate of increase per plant just as what was observed in the result of seedlings height implying the similarity of both AGR_{PH} and SH in assessing growth in plant seedlings. Seedlings from Dumsai, Guri, and Mashi gain more dry weight per plant. This was similar to what was observed in seedlings' total dry weight where seedlings from Dumsai, Guri, and Mashi had better dry weight in comparison with others. This implies that both AGR_{DW} and TDW might be serving the same purpose in the growth assessment of *Balanites aegyptiaca* seedlings.

CONCLUSION

The study was carried out a study to assess variation in growth characteristics of *Balanites aegyptiaca* seedlings from different locations for 12 months (1 year) in order to identify source(s) with better or superior germination and growth characteristics that could be used for afforestation, domestication and improvement programmes. Seeds sourced from Dumsai origin outperformed the other sources in height growth variable assessed and may do well on the field after transplanting. However, seedlings from Mashi had better root shoot ratio by dry weight and relative growth rate by dry weight, which give it a competitive advantage to tolerate or withstand harsh condition on the field over seedlings from the other sources. This is very important because *B. aegyptiaca* species is predominantly found in the arid/semi-arid region where water stress and fire are a common phenomenon. The ability to withstand water stress is an important survival strategy. Guri, Dumsai and Mashi sources should be prioritized for seed collection when designing afforestation, improvement and/breeding programme.

ACKNOWLEDGEMENTS

We acknowledge the valuable assistance rendered by Gambo Abah, Mustapha Umar, Mohammed Auwal Abdulmumini, Baba Audu and Abakar Mohammed of the Department of Forestry and Wildlife Management, Federal University, Gashua during stand identification and seed collection across Nigeria.

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