Ethiopian Journal of Environmental Studies & Management 18(2): 215 – 227, 2025
ISSN:1998-0507 doi: https://ejesm.org/doi/v18i2.7
Submitted: April 01, 2025 Accepted: June 02, 2025

GROWTH PERFORMANCE OF *Adansonia digitata* L. IN WATER STRESSED CONDITION

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Abstract
Water is a fundamental requirement for plant growth, playing a crucial role in food production and nutrient transportation. This study evaluates the effects of water stress on the germination and growth performance of Adansonia digitata seedlings. The experiment was carried out at the Forestry Research Institute of Nigeria, Ibadan, using mature fruits sourced from Federal Department of Forestry, Ibadan. Germination trials were conducted with twenty seeds per treatment, replicated three times. Fifty robust two-month-old seedlings were transplanted into polythene pots, with 10 replicates per treatment. The watering treatments consisted of five watering regime, arranged in CRD. Seedling height, collar diameter, leaf area, and number of leaves were recorded fortnightly over a twelve-week. Biomass measurements were taken at weeks six and twelve, with calculations for RGR, NAR and AGR. Data were analyzed using ANOVA, and mean differences were determined using LSD. The results revealed that seeds subjected to daily watering achieved the highest germination percentage (75.4%), whereas the lowest germination rate (10.0%) was observed under the seven-day watering interval. Although no statistically significant differences ($p > 0.05$) were detected among treatments for growth parameters, seedlings under daily watering consistently exhibited the highest values for height, collar diameter, leaf area, and leaf production, while those subjected to the longest watering interval (T5) showed the lowest values. Water stress negatively affected biomass production and other physiological parameters. The study underscores the importance of adequate water availability during the nursery stage to promote the successful establishment of healthy A. digitata seedlings.

Key Words: *Water stress, Growth performance, Adansonia digitata, Seed germination*

Introduction

The global climatic change has created different reactions in plants and animals, even among microorganisms due to changes in environmental conditions. This condition has influence on the weather elements like rainfall pattern giving rise to unpredictable flooding and drought conditions all over the world which have created a new way of regenerating forest species of economic importance (Gbadamosi, 2006). Water plays an important role in plant survival, growth and productivity either sourced naturally or artificially. Plants require water to manufacture their own food (carbohydrates) and useful in movement of foods including mineral elements within their systems; however, variation in food and water availability makes seedlings rely on photosynthesis for continuous existence. The availability of sufficient water in plants supports important physiological processes such as cell elongation, cell division, stem and leaf enlargement, including chlorophyll formation (Shao *et al*., 2008). Any change in all processes may lead to death due to water deficiency in the plants below the critical level. Similarly, water available above critical levels in plants could cause reduction in the physiological performances. It has been reported that soil-water balance affects stomata and xylem pressure (Buckley, 2000). One of the problems faced in the establishment and management of forest nursery is the permanent water supply availability and determination of the exact period of watering for the survival and growth of nursery seedlings (Adelani, 2019) which include *Adansonia digitata*.

A. digitata L. is a tropical tree with important uses across the African continent (Rashford, 2015). It has global prominence especially in the food, cosmetic and pharmaceutical industries worldwide (Gruenwald and Galizia 2005). The demand for *A. digitata* as agricultural products is rising daily. Baobab helps subsistence and commercial objectives such as improving nutrition, food security, fostering rural development and supporting sustainable landscape management (Gebauer *et al*., 2016 and Jäckering *et al*., 2019). It is increasingly threatened by habitat loss and ecosystem degradation as a result of climate change and population growth-related land-use changes (De Smedt *et al.,* 2012 and Venter, and Witkowski 2013). Despite its importance, the tree remains in the wild undomesticated. As a result of its status, there is a growing interest in domesticating it (Jensen *et al*., 2011). It is considered one of the most important underutilized crops for domestication (Gebauer *et al*., 2016). One of the contributing factors to the underutilization of *A. digitata* is its undomesticated state. Its availability is not controlled by man. *A. digitata* is especially vulnerable due to its low cultivation status and low natural regeneration as well as the 'scattered' dispersal of the species resulting in many *A. digitata* populations consisting of old individuals and/or decreasing in number (Venter and Witkowski, 2013). Overexploitation of natural stands is a pressing issue for conservation of the species' genetic resources, as human *A. digitata* propagation is uncommon and conservation strategies have not been widely implemented so far (Gebauer *et al*., 2016). As anthropogenic pressure on the tree is expected to increase with the international approval of *A. digitata* fruit pulp as a food ingredient, the tree has become a priority species for domestication. Widespread decline of *A. digitata* populations would have negative effects on African societies with locals losing nutritional, pharmaceutical and income-generating resources. While *A. digitata* and its products have the potential to become a 1bn USD industry that could generate significant foreign exchange reserves for African countries, exploitation of the species might not be sustainable in the long run in absence of sustainable harvesting and propagation practices as well as of targeted breeding operations to maintain *A. digitata* populations. Solving these problems would secure a continued supply of *A. digitata* products to foreign and domestic markets (Jenya *et al*., 2016). Despite the usefulness of the species, it remained undomesticated because its silvicultural requirements are not well documented, hence, the study investigated the growth performance of *A. digitata* in water stress conditions with a view to enhance its regeneration and promote its conservation.

Study Area

The experiment was conducted at the Forestry Research Institute of Nigeria, Ibadan, Nigeria. Mature fruits of A. digitata collected from Federal Department of Forestry nursery beside Federal College of Forestry, Jericho, Ibadan. They were depulped to extract the seeds at the Tree Physiology nursery, Sustainable Forest Management department, Forestry Research Institute of Nigeria (FRIN), Jericho, Ibadan. The Forestry Research Institute of Nigeria is located between 07023'18"N to 07023'43"N longitude and 03051'20"E to 03051'43"E latitude. The climate of the area is the West African monsoon with distinct dry and wet seasons. The dry season usually starts in November and run through March and is generally characterized by dry wind of harmattan. The wet season, on the other hand, generally runs through April to October with strong winds and thunderstorms occasionally. Mean annual rainfall falls around 1548.9 mm approximately, within 90 days. The temperature ranges from 31.9^{o}C maximum to 24.2^{o}C minimum, while the relative humidity is about 71.9% daily (FRIN, 2015).

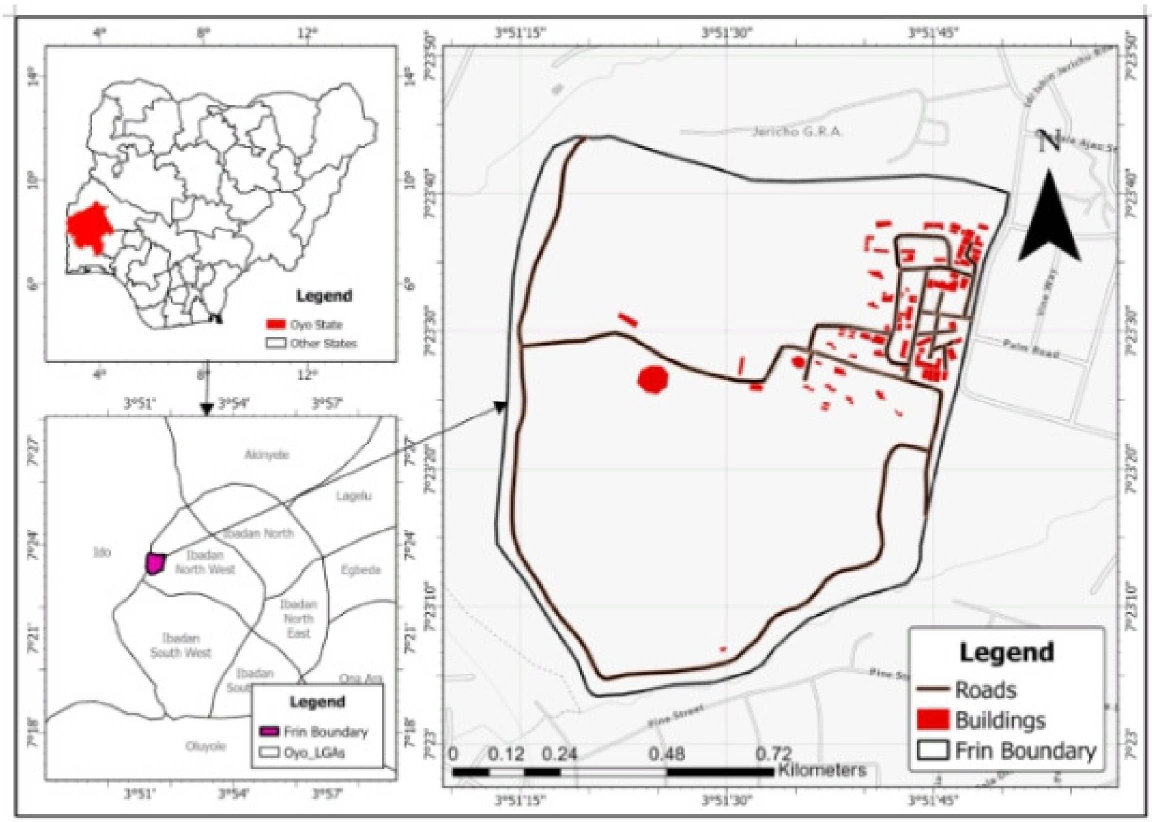

Fig. 1: Map of study area

Materials and Methods

Experimental Design

Twenty (20) seeds were sown in germination tray containing topsoil and watered with 200ml of water. Daily (T1) (Control), 2-day interval (T2), 3-day interval (T3), - day interval (T4) and 7-day interval (T5). The 5 treatments were replicated 3 times and arranged in a Completely Randomized Design. 300 seeds were used for the experiment. Observations were made on seed emergence every day. Fifty (50) 2-month-old of A. digitata seedlings with good vigor and relatively uniform growth were randomly selected from germinated seeds raised with topsoil. They were pricked into poly pots (16x14x12cm) 2kg filled with forest topsoil at 8 weeks after germination and placed under the following treatment with 200ml using measuring cylinder of Daily watering (T1), 2-day interval (T2), 3-day interval (T3), 5-day interval (T4) and 7-day interval (T5).

The experiment was laid in a Completely Randomized Design (CRD) with 10 replicates. The following variables: Seedlings height (Meter rule), Collar diameter (veneer caliper), leaf area (Area meter) and Number of Leaves (by counting) were assessed fortnightly for twelve weeks. The experiment was monitored for a period of 12 weeks. Biomass (root, stem and leaves dry weights) was determined at the 6th and 12th weeks of the study by destructive method. Fresh weight of root, stem and leaves were taken with weighing balance before oven dried to constant weight. The dry weight and leaf area were used to calculate the relative growth rate, net assimilation rate and absolute growth rate. Data collected on dry weights and leaf areas were used to calculate Relative Growth Rate (RGR), Absolute Growth Rate (AGR) and Net Assimilation Rate (NAR).

Data Analysis

Data collected on other growth parameters were subjected to Analysis of Variance (ANOVA). LSD test was used to separate the means at 5% level of probability. According to Adewusi (1997), Relative Growth Rate (RGR), Absolute Growth Rate (AGR) and Net Assimilation Rate (NAR) were calculated as shown below:

$$RGR\ (\text{g/g/wk}) = \frac{lnTDW_2 - lnTDW_1}{t_2 - t_1} \quad \text{.............................. (i)}$$

$$AGR\ (\text{g/g/wk}) = \frac{TDW_2 - TDW_1}{t_2 - t_1} \quad \text{.................................. (ii)}$$

$$NAR(\text{g/cm}^2/\text{wk}) = \frac{\text{TDW}_2 - \text{TDW}_1}{\text{LA}_2 - \text{LA}_1} \times \frac{\ln\text{LA}_2 - \ln\text{LA}_1}{\text{t}_2 - \text{t}_1} \quad \text{............................. (iii)}$$

Where

TDW_1 = Initial total dry weight (g)

TDW_2 = Final total dry weight (g)

t_1 = Initial time

t_2 = Final time

LA_1 = Initial leaf area (cm^2)

LA_2 = Final leaf area (cm^2)

ln = Natural Logarithm

Data collected were subjected to Analysis of Variance (ANOVA).

Results

Germination Performance

Analysis of variance Table 1 shows that there is significant difference among the treatments at 5% level of probability which implies that different water stress used had influence on germination of *A. digitata*.

The highest germination rate (75.4%) was recorded under daily watering (T1), while the lowest (10.0%) occurred in the seven-day watering interval (T5) (Table 2). Germination percentage declined progressively with increased water stress. The trend suggests that water scarcity adversely affects the metabolic processes involved in seed germination, likely limiting enzymatic activities and delaying radical emergence.

Table 1: Analysis of Variance Table for Germination of Adansonia digitata

SV	df	SS	MS	F	P-value
Treatments	4	336.67	84.17	29.36 *	0.001
Error	10	28.67	2.87		
Total	14	365.33			

* Significant at a level of 5% of probability (.01 =< p < .05)

Table 2: Means Separation of A. digitata seeds Percentage germination with DMRT

Treatments	Percentage (%)	Mean
T_1	75.4	15.00[a]
T_2	55.0	11.00[b]
T_3	31.5	6.33[c]
T_4	20.0	4.00[cd]
T_5	10.0	2.00[d]

Note: Means with the same letter are not significantly different from each other

Growth Performance

Although statistical analysis indicated no significant differences ($p > 0.05$) among treatments (Table 3), seedlings subjected to daily watering (T1) exhibited superior growth performance across all measured parameters, including height, collar diameter, leaf area, and leaf production. In contrast, seedlings under the seven-day interval (T5) displayed the lowest values. A notable trend observed was that seedlings in intermediate watering treatments (T2 and T3) showed moderate growth, indicating a potential threshold beyond which water stress significantly impacts physiological development (Table 4).

The analysis of variance (ANOVA) above shows that there was no significant difference among the water stress (treatments) applied at the 5% probability level (Table 3). This means that water stress has no influence on the height, collar diameter, leaf area and leaf production of *A. digitata* seedlings. However, seedlings watered daily have the best performance. Seedlings watered daily had highest means in stem height (15.20cm), leaf area (32.51cm^2), collar diameter (3.58mm) and number of leaves (6.5) followed by the seedlings that watered at 2 days interval with stem height, leaf area, collar diameter and number of leaves having 14.85cm, 32.51 cm^2, 3.47mm and 6.3 respectively and the least were found in seedlings treated with water at 7days interval having 14.50cm, 31.3 cm^2, 3.15mm and 6.2, stem height, leaf area, collar diameter and number of leaves respectively (Table 4).

Table 3: ANOVA for the Effect of Water stress on the Growth variables of *A. digitata* Seedlings

Variables	SV	df	SS	MSS	F.cal	F.tab
Seedling Height (cm)	Treatment	4	4.70	1.18	0.52	2.60ns
	Error	45	101.84	2.25		
	Total	49	106.54			
Collar Diameter (mm)	Treatment	4	6.20	1.55	0.68	2.60ns
	Error	45	102.96	2.29		
	Total	49	109.16			
Number of Leaf	Treatment	4	47.68	11.92	0.89	2.60ns
	Error	45	603.72	13.42		
	Total	49	651.40			
Leaf Area	Treatment	4	85.42	21.36	0.46	2.60ns
	Error	45	2089.35	46.43		
	Total	49	2174.77			

Table 4: Mean Values of Growth parameters of *Adansonia digitata* seedlings under water stress

Treatment	No of leaf	Collar diameter (mm)	Seedling height (cm)	Leaf area (cm^2)
T1	6.5	3.58	15.20	32.51
T2	6.3	3.47	14.85	32.50
T3	6.2	3.38	14.65	31.85
T4	6.3	3.36	14.62	31.60
T5	6.2	3.15	14.50	31.3

Biomass Production

Water stress had a detrimental effect on biomass accumulation, with biomass production decreasing from T1 to T5. Seedlings in T1 had the highest dry weight, while those in T5 had significantly reduced biomass, indicating limited photosynthetic activity under prolonged water deficit. The reduction in biomass with increasing water stress suggests that limited moisture availability constrains carbon assimilation and nutrient uptake, ultimately affecting overall plant productivity (Table 5).

Table 5: Effect of water stress on seedling biomass production (g) of *Adansonia digitata*

Treatment	**Root**	**Stem**	**Leave**	**Total**
T1	4.24	15.26	6.85	26.35
T2	2.18	8.32	3.61	14.11
T3	2.01	6.83	2.85	11.69
T4	1.16	4.57	0.66	6.39
T5	0.36	1.41	0.52	2.29

Leaves Dry Weight (LDW)

Water stress has significant effect on biomass production of *A. digitata* seedlings and followed downward trend from T1 – T5. Seedlings watered daily had LDW of 6.85g as the highest closely followed by seedlings water at 2-day interval (3.61g) while the least was found in seedlings watered at 7 days interval (Table 5).

Stem Dry Weight (SDW)

Water stress had significant influence on SDW where seedlings that treated with water once daily had the highest SDW (15.26g), followed by seedlings watered in 2-day interval having 8.32g while the least was found in 7-day interval with 1.41g (Table 5)

Root Dry Weight (RDW)

Table 4 shows that mean RDW of seedlings exposed to water stress were affected significantly. The seedlings watered daily had the highest RDW (4.24g) followed by those watered in 2-day interval (2.18g) and the least was in 7-day interval watering (0.36g).

Total Dry Weight (TDW)

Water stress had significant influence on TDW where seedlings that treated with water once daily had the highest TDW (26.35g), followed by seedlings watered in 2-day interval having 14.11g while the least was found in 7-day interval (2.29g) (Table 5)

Physiological Parameters

The seedlings that received daily watering demonstrated the highest performance in terms of NAR, RGR, and AGR, with values of 0.00428 g/cm²/week, 0.03130 g/g/week, and 0.16802 g/g/week, respectively. Following them, seedlings watered every two days had moderate results, with NAR, RGR, and AGR values of 0.00286 g/cm²/week, 0.02110 g/g/week, and 0.08510 g/g/week, respectively. The lowest performance was observed in seedlings watered every seven days, with NAR, RGR, and AGR values of 0.00068 g/cm²/week, 0.00148 g/g/week, and 0.00624 g/g/week, respectively (Table 6).

Table 6 above shows the effect of water stress on Net assimilation rate (NAR), Relative growth rate (RGR) and Absolute growth rate (AGR) of *A. digitata* seedlings

Table 6: Effect of water stress on Physiological Parameter (AGR, RGR and NAR) of *A. digitata*

Treatment	AGR (g/g/wk)	RGR (g/g/wk)	NAR (g/cm^2/wk
T1	0.16802	0.03130	0.00428
T2	0.08510	0.02110	0.00286
T3	0.02680	0.00652	0.00147
T4	0.01520	0.00345	0.00052
T5	0.00624	0.00148	0.00068

Discussion

Water stress on seed germination

A significant difference was observed among the treatments at the 5% level of probability, indicating that varying water stress levels affected the germination of *A. digitata*. The highest germination percentage was recorded for seeds watered daily, while the lowest percentage occurred in seeds watered only once every seven days. This highlights the critical role of water availability in seed germination. This finding aligns with Yigit *et al*. (2016), who observed a decline in germination percentages for *Sophora japonica*, *Ailanthus altissima*, *Cupressus arizonica*, *Pinus nigra*, *Cupressus sempervirens*, and *Pinus brutia* under increased water stress. A similar trend was reported by Khera and Shing (2005) for the germination of *Acacia catechu*, *Acacia nilotica*, *Albizia lebbek*, *Dalbergia sissoo*, and *Tectona grandis* under various water stress conditions.

Water stress and growth variables

No significant differences were observed among the treatments at the 5% probability level, indicating that water stress did not influence the height, collar diameter, leaf area, or leaf production of *A. digitata* seedlings. However, seedlings that were watered daily performed the best. Awodola and Nwoboshi (1993) emphasized that water is a critical factor in forest ecosystems, influencing seedling growth and development. As water stress increases, seedling growth and development tend to decrease. Daily watering had the most significant impact on all the assessed growth variables, likely because water was readily available, allowing seedlings to absorb nutrients from the soil more efficiently. Water stress did affect the early growth of *A. digitata*, with daily watering and the two-day interval treatment showing better growth than the other treatments.

Despite water stress, *A. digitata* is considered a drought-tolerant species, as evidenced by the survival of seedlings watered only once every seven days, albeit with slow growth. This supports the findings of De Smith *et al*. (2011) and Larwanou *et al*. (2014), who found that *A. digitata* seedlings can retain water well in drought conditions and avoid xylem cavitation, thus surviving water stress. Relative turgidity positively influences physiological traits such as leaf production, leaf area, and shoot height. In contrast, Iroko *et al*. (2020) reported that reduced relative water content negatively affected plant growth and morphological processes in *E. angolensis* seedlings. Water plays a vital role in plant survival, growth, and productivity, whether sourced naturally or artificially. Daily watering yielded the best growth results in all variables assessed, which contrasts with the findings of Isah *et al*. (2013), who reported that *Acacia senegal* seedlings watered every three days showed better growth than those watered daily, twice a day, or every two days.

Seedlings watered daily exhibited the highest growth in stem height, collar diameter, leaf production, leaf area, and biomass, although no statistical differences were found compared to other treatments. Seedlings watered once every seven days survived the experiment but exhibited stress. This supports Olajuyigbe *et al*. (2012), who noted that deciduous species are drought-tolerant and tend to delay leaf flushing in low-water environments. It also aligns with Sale (2015), who stated that water stress affects a tree species' physiological functions, thus influencing growth and yield. Additionally, Jajarmi (2009) highlighted that soil water conditions can significantly affect a plant's morphological and physiological processes. Nutrient uptake from soil water is closely tied to root and soil water status, as well as the species and genotype of the plant. Growth variables in forest seedlings depend on the water needs of the seedlings and their developmental stage (Mng'omba *et al*., 2011).

Akinyele (2007) also observed the highest growth in *Buchholzia coreacea* seedlings watered once a day. This is consistent with Larwanou (2014), who found that water favored the growth of *Moringa oleifera* seedlings. However, Suberu (2014) and Oyun *et al*. (2010) reported that *Acacia senegal* seedlings watered twice a week exhibited the best growth, suggesting that water conservation capacity could be a determining factor. This study confirms that while *A. digitata* can tolerate water stress, the best growth performance was observed in seedlings watered daily, although those watered every seven days still survived throughout the experimental period.

Biomass Accumulation

Water stress has significant effect on biomass production of *A. digitata* seedlings and followed downward trend from T1 – T5. Generally, plant species grown in drier condition may increase water capture by increase in root biomass and in production of adventitious roots with high specific root length (SRL) and more root length per unit plant mass (RLPM) in the whole plant level (Poorter and Markesteijn, 2008). De Smedt, (2012) reported that the seedlings of Baobab provenances from drier conditions had developed root mass fraction, so as to store more water in their systems, and resulted in higher conductance and photosynthetic rates during drought. The increased biomass in leaves under shade was not only at the expense of stem biomass reduction, but also at the expense of root biomass reduction (Amissah *et al.* 2015).

Physiological Variables (AGR, RGR and NAR)

The results for relative growth rate (RGR) did not show a clear trend, but seedlings watered daily performed the best, while those watered every seven days showed the lowest performance. Similarly, the net assimilation rate (NAR) did not follow a distinct pattern, but seedlings watered daily performed the best, indicating they had more photosynthesizing tissues than those watered every seven days. The absolute growth rate (AGR) also lacked a consistent trend, but seedlings watered daily showed the best performance, with the least growth observed in seedlings watered at seven-day intervals. These findings are consistent with the results of Oyedeji and Akinyele (2016), who found no specific trend in RGR, NAR, and AGR when studying the effect of light intensity on *Dialium guineense* seedlings. However, these results contrast with those of Amadi *et al*. (2022), who observed an increase in RGR, NAR, and AGR with higher light intensity in African walnut seedling growth.

RGR was significantly reduced under wet conditions compared to dry conditions, which is inconsistent with the observations of Sack and Grubb (2002) and Sack (2004), who reported a proportional reduction in RGR under varying conditions. It has been noted that water deficiency can lower leaf water potential and stomatal conductance (Amissah *et al*., 2015), resulting in a reduced assimilation rate (Aranda *et al*., 2005), which explains the slower growth of water-stressed plants (Amissah *et al*., 2015). Stomata responses to drought range from water avoidance, where stomata close at a critical water potential to minimize leaf transpiration and prevent cavitation, to water tolerance, where stomata control is less restrictive, allowing higher transpiration rates (Allen *et al*., 2010; McDowell et al., 2008). High stomata conductance supports higher assimilation rates, thus facilitating faster growth in plants exposed to high light compared to those in shaded conditions (Amissah *et al*., 2015).

Conclusion and Recommendations

This study demonstrates that water stress adversely affects the germination and growth performance of *A. digitata*. While statistical differences were not observed, trends indicate that daily watering supports optimal seedling development. The results suggest that for successful domestication and conservation of *A. digitata*, adequate water supply during the nursery phase is crucial. The decline in biomass accumulation under water-stressed conditions further underscores the importance of proper watering regimes to ensure seedling vigor and survival. Given the economic and ecological significance of *A. digitata*, conservation efforts should focus on developing adaptive irrigation strategies to improve seedling establishment in water-limited environments. Future research should explore the physiological mechanisms underpinning water stress tolerance in *A. digitata*, such as osmotic adjustment, root morphology adaptation, and stress-related gene expression, to develop more resilient cultivation strategies. Additionally, investigating the long-term effects of varying watering regimes on field establishment and productivity will provide further insights into the domestication potential of this species.

References

Adelani D.O. (2019). Effect of watering regimes on the growth and nutrient uptake of *Citrus tangelo* J. W. Seedling grown in a mixture of sand and pulverized *Jacaranda mimosifolia* D. don leaves. *J. Res. For Wildl. Environ.,* 11: 172-9.

Adewusi, H.G. (1997). Variations in Nigeria provenances of *Millettia thonnigii* (Schur and Thonn) Baker. Ph.D Thesis, University of Ibadan. 198pp.

Akinyele, A.O. (2007). Silvicultural requirement of seedlings of *Buchholzia coriacea* Engler. Unpublished PhD theses, submitted to the Dept. of Forest Resources Management, University of Ibadan, 20-34.

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hoff, E.H.T., Gonzalez, P., Fensham, R., Zhangm, Z., Castro, J., Demidova, N., Lim, J.H., Allard, G., Running, S.W., Semerci, A. and Cobb, N. (2010). A global review of drought and heat induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management*, 259(1): 660-684.

Amadi, J.O., Alaje, V.I., Iroko, O.A., Williams, O.A. and Oyedeji, O.F. (2022). Light intensity effect on seed emergence and seedling growth of African walnut (*Plukenetia conophora* Mull Arg.). *Australian Journal of Science and Technology,*.6(2): 100 – 106. ISSN No 2208-6404

Amissah, L., Mohren, G.M.J., Kyereh, B., Poorter, L. (2015). The Effects of Drought and Shade on the Performance, Morphology and Physiology of Ghanaian Tree Species. PLoSONE 10(4): e0121004.doi:10.1371/journal.pone .0121004

Aranda, I., Castro, L., Pardos, M., Gil, L. and Pardos, J.A. (2005). Effects of the interaction between drought and shade on water relations, gas exchange and morphological traits in cork oak (*Quercus suber* L.) seedlings. *Forest Ecology and Management*, 210: 117–129.

Awodola A.M. and Nwoboshi, L.C. (1993). Effect of source of potassium and frequency of moisture application on growth and macronutrient distribution in seedlings of *Parkia biglobosa* (R. Br. ex. G. Don). *Niger. J. For.,* 23: 98-108.

Buckley, N.T. (2000). The control of stomata by water balance. New *Phytol,* 168: 275-92.

De Smedt, S. (2012). Morphological and ecophysiological adaptations of African baobab (*Adansonia digitata* L.) to drought. PhD Dissertation, Universiteit Antwerpen (Belgium). http://gradworks. umi.com/35/10/3510887.html.

FRIN, (2015). Forestry Research Institute of Nigeria, Annual Meteorological Report.

Gbadamosi, A.E. (2006). Fertilizer response in seedlings of medicinal *Enantia chlorantha* oliv. Trop Subtrop Agroecosyst 2006; 6 111-5.

Gebauer J., Adam Y.O., Sanchez A.C., Darr D., *et al*. (2016). Africa's wooden elephant: the baobab tree (*Adansonia digitata* L.) in Sudan and Kenya: a review. *Genet Resource Crop Evol*., 63: 377–399.

Gruenwald, J. and Galizia, M. (2005). Market brief in the European Union for selected natural ingredients derived from native species *Adansonia digitata* L. United Nations conference on trade and development. UNCTAD/DITC/TED/2005

Iroko, O.A., Aduradola, A.M. and Oladoye, A.O. (2020). Evaluation of watering frequencies and water volume on seedlings growth performance of *Entandrophragma angolense*. *FUDMA J. Agric. Technol*., 6: 200-3

Isah, A.D., A.G. Bello, Maishanu, H.M. and Abdullahi, S. (2013): Effect of watering regime on the early growth of *Acacia senegal* (Linn) wild provenances. *International Journal of Plant, Animal and Environmental Sciences*, 3(1): 52-56.

Jäckering, L., Fischer, S. & Kehlenbeck, K. (2019). A value chain analysis of baobab (*Adansonia digitata* L.) products in Eastern and Coastal Kenya. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*,120(1): 91–104.

Jajarmi, (2009). Effect of water stress on germination indices in seven Wheat cultivars. World Academic Science England Tech 49: 105 – 106.

Jensen J.S., Bayala J., Sanou H., Korbo A., Raebid A., Kambou S., Tougiani A., Bouda H., Larsen A.S and Parkouda C. (2011). A research approach supporting the domestication of baobab (*Adansonia digitata* L) in West Africa. *New Forest*., 41: 317–335.

Jenya, H., Munthali, C.R.Y. and Mhango, J. (2016). Amenability of African baobab (*Adansonia digitata* L.) to vegetative propagation techniques. *Journal of Sustainable Forestry*, 37(6): 632–644.

Khera, N. and Shing, R.P. (2005). Germination of some multipurpose tree species in five provenances in response to variation in light temperature, substrate and water stress. *Tropical Ecology*, 46(2): 203–217.

Larwanou, M., Adamu, M.M. and Abasse, T. (2014). Effect of fertilization and watering regimes on early growth and leaf production of two food tree species in the Sahel: *Moringa oleifera* and *Adansonia digitata*. *Journal of Agricultural Science and Applications*, 3(1): 82-88.

McDowell, N., Pockman, W.T., Allen, C.D., Breshears, D.D., Cobb, N. and Kolb, T. (2008). Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought? New Phytologist 178:719–739. doi:10.1111/j.1469-8137.2008.02436.xPMID: http://www.ncbi.nlm.nih.gov/pubmed/18422905.

Mng'omba, S.A., Akinnifesi, F.K., Sileshi, G., Ajayi, O.C., Nyoka, B.I. and Jamnadass, R. (2011). Water application rate and frequency affect seedling growth of *Vangueria infusta* and *Persea americana*. *Afr. J. Biotechnol.,* 10:1593-9.

Olajuyigbe, S.O., Jimoh, S.O., Adegeye, A.O. and Mukhtar, R.B. (2012).

Drought stress on early growth of *Diospyros mespiliformis* Hochst ex. A. in Jega, Northern Nigeria. *Nigerian Journal of Ecology*, 12(1): 71-76.

Oyedeji, O.F. and A.O. Akinyele (2016): Effects of Light Intensity on Growth of *Dialium guineense* Willd Seedlings. Environtropica - *An international Journal of Tropical Environment*. 12&13: 53 – 60. www.environtropica.com/publications/volume-12&13

Oyun, M.B., Adedunfan, S.A. and Suberu, S.A. (2010); Influence of watering regime and mycorrhizae inoculations on the physiology and early growth of *Acacia senegal* (L.) wild. *African Journal of Plant Science*, 4(7): 210-216.

Rashford, J. (2015). The uses of the baobab flower (*Adansonia digitata* L). *Ethnobotany Research and Applications*, 14: 211-229.

Sack, L. (2004). Responses of temperate woody seedlings to shade and drought: do trade-offs limit potential niche differentiation? *Oikos*, 107: 110–127.

Sack, L. and Grubb, P.J. (2002). The combined impacts of deep shade and drought on the growth and biomass allocation of shade-tolerant woody seedlings. *Oecologia,* 131: 175–185.

Shao, H.B., Chu, L.Y., Jaleel, C.A. and Zhao, C.X. (2008). Water-deficit stress-induced anatomical changes in higher plant. *CR Biol*., 331: 215-25.

Suberu, S.U. (2014). Determination of watering regimes and mycorrhizae inoculation required for the establishment of seedlings of *Acacia senegal* (L) wild in the nursery. *International Journal of Biological Research*, 6(1): 83-94.

Venter, S.M. and Witkowski, E.T.F. (2013) Where are the young baobabs? Factors affecting regeneration of *Adansonia digitata* L. in a communally managed region of southern Africa. *Journal of Arid Environments*, 92: 1-13.

Yigit, N., Sevik, H., Cetin, M. and Kaya, N. (2016). Determination of the Effect of Drought Stress on the Seed Germination in Some Plant Species. Water Stress in Plants. INTECH. Pp 43 – 62. http://dx.doi.org/10.5772/63197