Nigerian Journal of Ecology (2012) 12:71-76.

ISSN: 1116-753X

Drought stress on early growth of *Diospyros mespiliformis* Hochst ex A. Rich in Jega, Northern Nigeria

Olajuyigbe S. O.[*1], Jimoh S. O.[1], Adegeye A. O.[1], Mukhtar R. B.[2]

[1]Department of Forest Resources Management, University of Ibadan, Ibadan, Oyo state, Nigeria
[2]Department of Forestry and Fisheries, Kebbi State University of Science and Technology, Jega, Kebbi State, Nigeria.
*Corresponding author email: lekito2001@yahoo.com

(Accepted 5 August 2013)

ABSTRACT

Trees face rising drought stress and mortality with global warming and it is vital that adequate information is available on the tolerance levels of tree species. In 2012, seedlings of Diospyros mespiliformis Hochst ex A. Rich were evaluated for response to varied levels of water availability at the Aliero Teaching and Research Farm, Kebbi State University of Science and Technology, Jega, Kebbi State, Nigeria. Twelve uniformly growing potted seedlings were selected and exposed to four watering frequencies (daily, once in three days, weekly and fortnightly) in a screen house. For each watering event, 200 ml of water was administered to the soil of each potted seedling. Seedling height and collar diameter were measured, while number of leaves were counted fortnightly for 16 weeks. The data were analysed using descriptive statistics and analysis of variance, at $p<0.05$ level of significance.

A hundred percent survival rate was observed in all treatments. Seedlings that were watered daily had the highest height (13.53 ± 2.66 cm) and collar diameter (3.41 ± 0.44 mm). The treatments resulted in 283%, 133%, 98% and 125% increase in height, as well as 100%, 89%, 57% and 40% increase in collar diameter of seedlings watered daily, once in 3 days, weekly and fortnightly, respectively. Time of experiment had a significant influence on the height and collar diameter growth of seedlings in the four treatments while watering frequency only had a significant effect on collar diameter of the seedlings, after 16 weeks. However, posthoc analysis showed that only the collar diameter of daily watered seedlings differed from other treatments. Although, delayed watering reduced the rate of growth, it did not hinder it. The least watered seedlings had the lowest number of leaves (6) after 16 weeks.

The study showed that fortnight supply of water was sufficient for the early growth and development of D. mespiliformis seedlings. The apparent drought tolerance of the species may be an indication of a good candidate species for plantation establishment under dry and warm conditions which are imminent in the event of climate change.

Keywords: leaf abscission, climate change, drought tolerance, seedling survival

INTRODUCTION

Increased tree mortality and die-offs triggered by drought and/or high temperatures suggest that amplified forest mortality may already be occurring in some locations in response to global climate change (Allen *et al*., 2010). In the tropics, water availability is the most important environmental factor influencing tree species richness, composition and distribution (Bongers *et al.*, 2004; Ter Steege *et al.*, 2006; Holmgren and Poorter, 2007). Water supply in ecosystems is greatly influenced by the seasonality of its distribution and the length of the dry period may vary from a dry spell of a few days in humid wet forests, to a dry season of up to 8 months, in dry monsoon forests (Walsh and Newbery, 1999; Poorter and Markesteijn, 2008).

In recent times, tropical and savanna forests have experienced a dramatic decrease in annual rainfall, and an increase in dry season length and rainfall variability (Veenendaal and Swaine, 1998; Malhi and Wright, 2004). Therefore, insights into the mechanism of drought-tolerance are necessary, in order to understand, predict species responses to climatic change and gain insights into potential species for afforestation programmes in the nearest future.

Low water availability affects seedlings and saplings growth through a reduction in their leaf water potential and gas exchange, resulting in a reduction in growth and survival (Cao, 2000; Engelbrecht and Kursar, 2003). The seedling stage is generally considered to be the most important bottleneck for successful regeneration in dry areas, as seedlings with their limited root systems are most vulnerable to drought (Burslem *et al.*, 1996; Sack, 2004).

Diospyros mespiliformis Hochst ex A. Rich is a tall, evergreen tree (15-50 m high), with dense, rounded and buttressed stem. It grows in woodlands, savannas and along river banks. It prefers areas with continuous water supply and this enhances natural regeneration. It is a multipurpose tree and the fruits are edible with a variety of uses such as fodder for animals, fermented beverages for humans, forage for bees, fuel wood and timber. It also has antibiotic properties and other medicinal uses (Orwa *et al.*, 2009). There is a need to determine how this species will respond to drought stress in the event of climate change.

In order to understand how *Diospyros mespiliformis* will respond to drought, seedlings were exposed to fixed treatments of varied levels of water availability for 16 weeks, to determine if the species is able to survive an extended period with little water supply.

Materials and Methods

The study was carried out in the screen house at Aliero Teaching and Research farm, Kebbi State University of Science and Technology, Jega, Nigeria (12° 17' N, 4° 29' E and altitude of 282 m). Mean annual rainfall ranges from 800 mm in the north to 1000 mm in the south, while mean annual temperature is 26°C. The natural vegetation in Kebbi State varies, from Sahel shrubs in the extreme north, to thick shrubs and dense wood land in the south. Some common species found in the study area included *Azadirachta indica* A. Juss., *Eucalyptus camaldulensis* Dehnh., *Parkia biglobosa* (Jacq.) Benth., *Vitex doniana* Sweet, and *Vitellaria paradoxa* G. Don.

Experimental Procedure

Twelve uniformly growing, potted seedlings were randomly selected for this study. Four watering frequencies (daily, once in three days, weekly and fortnightly) were applied in a completely randomised experimental layout. For each watering event, 200 ml of water was administered to the soil in each pot, early in the morning. The seedling height, collar diameters were measured and number of leaves counted at the commencement of the experiment and every fortnight for 16 weeks after which the experiment was terminated. A vernier mini caliper was used to measure collar diameter, while a measuring tape was used to measure height.

Data Analysis

Statistical analyses were conducted using SigmaStat 11 for Windows (Systat Software Inc. UK). Data were analysed using descriptive statistics and Analysis of Variance at $p<0.05$ level of significance. Data were normalized using square root transformation and the two-way ANOVA was used to determine the main and interaction effects of time and watering frequency on the growth parameters. Pairwise multiple comparison procedures (Holm-Sidak method) were used to separate significant differences among treatments.

RESULTS

Seedlings in all treatments survived, with daily watering resulting in the highest height growth (13.53 ± 2.66 cm), while fortnight watering resulted in the lowest (8.93 ± 2.56 cm) at 16 Weeks After Transplanting (WAT) (Fig. 1). Only the main effect of time had a significant influence on height growth of seedlings ($p = <0.001$) (see Table 1). However, there was no significant difference in the main effect of watering frequency ($p = 0.107$) and its interaction effect ($p = 0.935$) with time on seedling height.

Similarly, the highest collar diameter was recorded for seedlings watered daily (3.41 ± 0.44 mm), while the lowest was recorded for seedlings that were watered fortnightly (2.56 ± 0.18mm) at 16 WAT (Fig. 2). There were significant differences in the main effects of watering frequency (p = <0.001) and time (p = <0.001) on collar diameter of seedlings, while there was no significant difference in their interaction effect (p = 0.549). The post hoc analysis showed that only the collar diameter of seedlings watered daily differed from the other treatments (Table 1).

At 16 WAT, the mean number of leaves (Fig. 3) from the seedlings watered daily was highest (14.33 ± 1.20), while seedlings that were watered fortnightly had the lowest (6.33 ± 3.05).

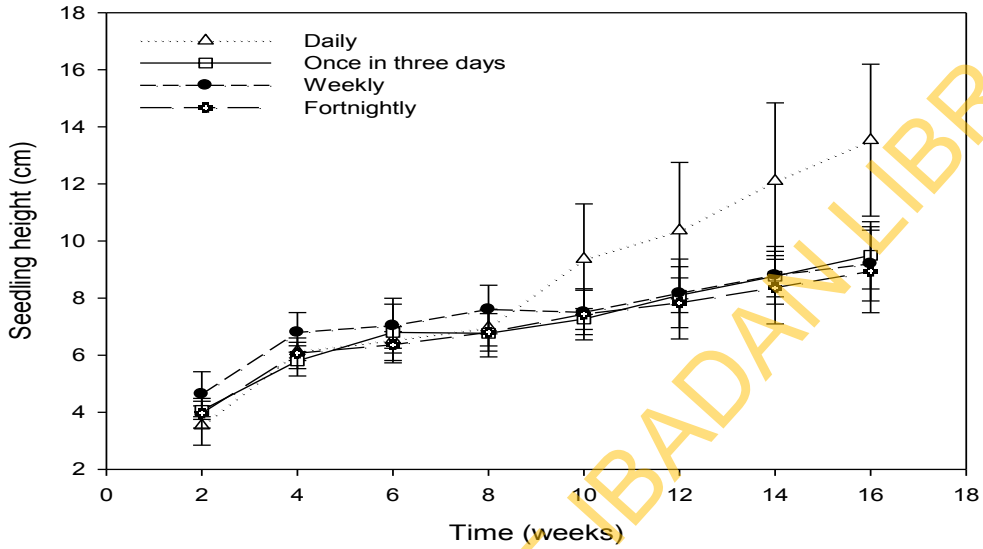

Figure 1: **Effect of different watering frequencies on height growth of *D. mespiliformis* seedlings (mean ± S.E. bars)**

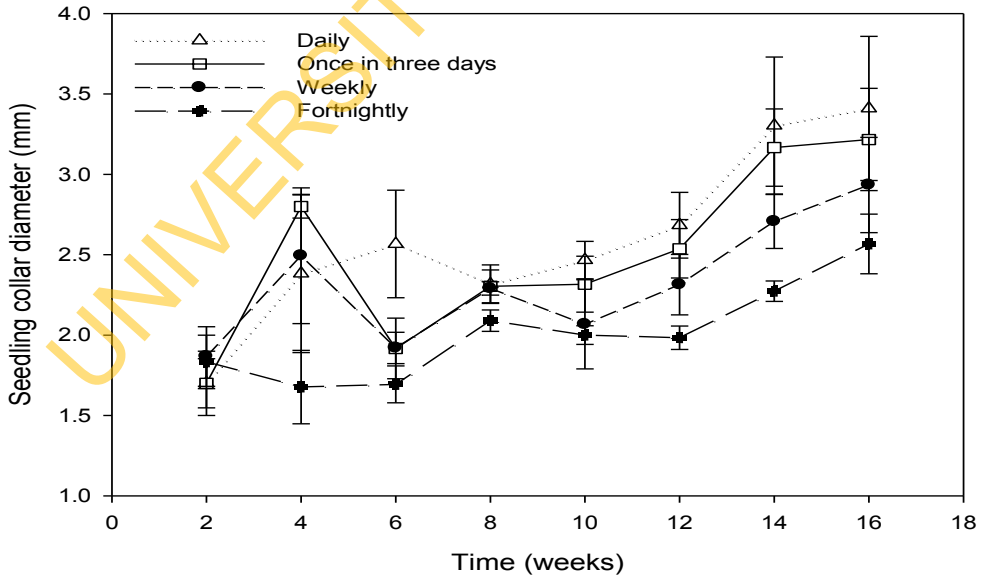

Figure 2: **Effect of different watering frequencies on collar diameter growth of *D. mespiliformis* seedlings (mean ± S.E. bars)**

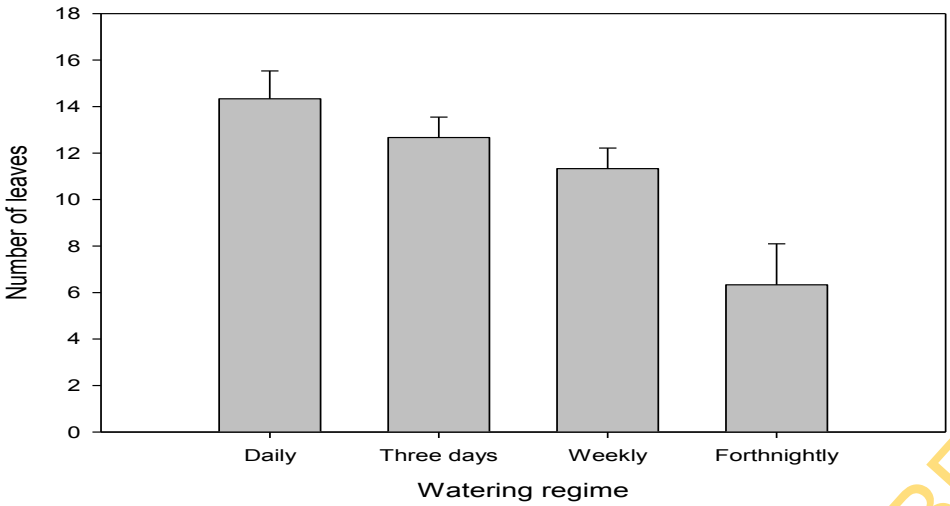

Figure 3: **Number of leaves on seedlings subjected to different watering frequencies at 16 WAT (each bar represents the mean + S.E.)**

Table 1: **Least square mean values for growth variables of *D. mespiliformis* seedlings based on Holm-Sidak multiple comparison tests for mean separation of two-way ANOVA (main effects: time and watering frequency)**

Watering frequency	**Height (cm)**	**Collar diameter (mm)**
Daily	8.57a	2.60a
Once in three days	7.13a	2.49b
Weekly	7.47a	2.32b
Fortnightly	6.97a	2.02b
Time (weeks)		
2	4.05a	1.78a
4	6.20ab	2.34b
6	6.68b	2.02ab
8	7.03b	2.25ab
10	7.89bc	2.21ab
12	8.62bc	2.38b
14	9.51c	2.86c
16	10.29c	3.03c

Note: means with the same alphabet are not significantly different at $p<0.05$

DISCUSSION

Growth and biomass production is directly proportional to the supply and use of water in plants (Cao, 2000), but *D. mespiliformis was* able to tolerate low water availability, because no significant differences were observed among the watering frequencies, except for the collar diameter of seedlings treated with daily watering. Deciduousness is an important component of the drought-tolerance strategy of plant species. The plant had a physiological response by de-emphasizing leaf production under low water supply as the number of leaves reduced with decrease in frequency of watering. Poorter and Markesteijn (2008) had reported similar observation in *Spondias mombin, Amburana cearensis, Chorisia speciosa* in Bolivian forest.

In this experiment, potted seedlings restricted to a limited volume of soil were exposed to

relative drought. This sudden dry spell has been shown to affect seedling survival in the field within a few days (Engelbrecht *et al.*, 2006). In this study, the seedlings survived a drought period of 2 weeks, which indicate that *D. mespiliformis* is a drought-tolerant species as the plant thrived well, even at low watering frequencies. The treatments resulted in 283%, 133%, 98% and 125% increase in height of seedlings watered daily, once in 3 days, weekly and fortnightly, respectively. In addition, collar diameter increased by 100%, 89%, 57% and 40% in seedlings watered daily, once in 3 days, weekly and fortnightly, respectively. Though the growth rate decreased with decreasing watering frequency, it was not significantly hindered (Figs. 1 and 2).

These suggest that the species may be able to adapt to drought stress that may be created by the impacts of climate change. In addition, this partly explains why the species thrives well in savanna regions where there is limited rainfall. However, it has been reported that drought-induced seedling mortality may occur after 2 weeks (Splunder *et al.*, 1995; Engelbrecht *et al.* 2006).

CONCLUSION

Drought as a consequence of climate change poses a great danger to the survival of tree species, especially in the savanna regions of Northern Nigeria. Therefore, it is vital that adequate information is available on the drought tolerance levels of savanna species. This information will enhance the adaptation strategies required for sustainable forest management. In anticipation of the potential effects of climate change on tree species, forest managers must begin to consider the response of tropical tree species to the impacts of global warming. *Diospyros mespiliformis* responded to varying low water availability, with stable growth at a watering frequency of 2 weeks. Reduced leaf production was implicated as a physiological response of the seedlings to drought stress. Further research is required to determine the influence of water stress on biomass allocation, plant morphology and phenology of *D. mespiliformis*.

REFERENCES

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hogg, 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 overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* **259:** 660-684.

Bongers, F., Poorter, L. and Hawthorne, W.D., (2004). The forests of Upper Guinea: gradients in large species composition. In: Poorter, L. (Ed.) *Biodiversity of West African forests: An ecological atlas of woody plant species*. CABI Wallingford, United Kingdom, pp 41-52.

Burslem, D.F.R.P., Grubb, P.J. and Turner, I.M. (1996). Responses to simulated drought and elevated nutrient supply among shade-tolerant tree seedlings of lowland tropical forest in Singapore. *Biotropica* **28:** 636-648.

Cao, K.F. (2000). Water relations and gas exchange of tropical saplings during a prolonged drought in a Bornean heath forest, with reference to root architecture. *Journal of Tropical Ecology* **16:** 101-116.

Engelbrecht, B.M.J., Dalling, J.W., Pearson, T.R.H., Wolf, R.L., Gálvez, D.A., Koehler, T., Tyree, M.T. and Kursar, T.A. (2006). Short dry spells in the wet season increase mortality of tropical pioneer seedlings. *Oecologia* **14:** 258-269.

Engelbrecht, B.M.J and Kursar, T.A. (2003). Comparative drought-resistance of seedlings of 28 species of co-occurring tropical woody plants. *Oecologia* **136:** 383-393.

Holmgren, M. and Poorter, L. (2007). Does a ruderal strategy dominate the endemic flora of the West African forests? *Journal of Biogeography* **34:** 1100-1111.

Malhi, Y. and Wright, J. (2004). Spatial patterns and recent trends in the climate of tropical rainforest

regions. *Philosophical Transactions: Biological Sciences* **359:** 311-329.

Orwa C., Mutua A. , Kindt R , Jamnadass R, Simons A., (2009). Agroforestree Database: a tree reference and selection guide version 4.0. http://www.worldagroforestry.org/af/treedb/ Accessed on 11th October 2012.

Poorter, L. and Markesteijn, L. (2008). Seedling traits determine drought-tolerance of tropical tree species. *Biotropica* **40:** 321-331.

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

Splunder, I., Van-Voesenek, L.A.C.J., Coops, H., Vries, X.J.A. and de Blom, C.W.P.M. (1995). Morphological responses of seedlings of four species of *Salicacea* to drought. *Canadian Journal of Botany* **74:** 1988-1995.

Ter Steege, H., Pitman, N.C., Phillips, O.L., Chave, J., Sabatier, D., Duque, A., Molino, J.F., Prevost, M.F., Spichiger, R. and Castellanos, H. (2006). Continental-scale patterns of canopy tree composition and function across Amazonia. *Nature* **443:** 444-447.

Veenendaal, E., Swaine, M. (1998). Limits to tree species distribution in lowland tropical rainforests. In: Newbery, D., Prins, H. and Brown, N. (Eds.). *Dynamics of tropical forest communities.* Thirty-seventh Symposium of the British Ecological Society.

Walsh, R.P.D. and Newbery, D.M., 1999. The eco-climatology of Danum, Sabah, in the context of the World's Rainforest Regions, with particular reference to dry periods and their impact. *Philosophical Transactions: Biological Sciences* **354:** 1869-1883.