Journal of Agricultural Science and Food Research

Bolanle-Ojo, et al., J Agri Sci Food Res 2018, 9:1

Research Article

Open Access

Morphological and Physiological Response of *Artocarpus heterophyllus* Lam. (Jackfruit) Seedlings to Selected Environmental Factors

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Rec date: Feb 22, 2018; **Acc date:** March 07, 2018; **Pub date:** March 15, 2018

Abstract

Artocarpus heterphylus Lam, which is commonly known as Jackfruit is the largest fruit in the world and valued for its heavy yields of nutritious fruits and durable timber. In Nigeria, its cultivation has not been encouraged, though it is found in the south-coastal parts of the country where it grows wild or semi-conserved. This study investigated the morphological and physiological response of *A. heterophyllus* to different light intensities and watering regimes. One hundred and sixty *A. heterophyllus* seedlings were used for this study. The light intensities used were 100%, 75%, 50% and 25%, and the watering regimes were watering every day, once in 3 days, once in 5 days and once in 7 days. Data were collected on plant height, collar diameter, number of leaves, root length, leaf dry weight, stem dry weight, root dry weight, total dry weight, shoot to root ratio (SRR), relative turgidity (RT%) and, chlorophyll a and b. Data were subjected to Analysis of Variance (ANOVA) and means were separated using Duncan Multiple Range test. After 4 months, ANOVA revealed that there was no significant difference in the seedling height, collar diameter, leaf production, leaf, stem and total dry weight, and root length but significantly affected the root dry weight. SRR increased with the age of the seedlings. RT% of the leaves of the seedlings was above 25%. Chlorophyll a and b content of the leaves of the seedlings were significantly affected by varying light intensities and watering regimes. The result from this study has shown that *A. heterophyllus* can be easily raised in the nursery under different light intensities and little moisture stress. Plants subjected to drought stress and under different light intensities, make changes in some of their physiological features.

Keywords: *Artocarpus heterophyllus*; Propagation; Growth Performance; Light intensity; Watering regimes

Introduction

Seedling survival and growth within a forest is determined to a large extent by the environmental conditions [1]. Plants are sensitive to light quality and quantity, which play a vital role in their physiological development [2]. The degree of shade created by the canopy is a key parameter that determines the amount of radiant energy available for photosynthesis in growing seedlings [3].

Soil water is also a key parameter in seedling survival and growth because of the sensitivity of photosynthesis to water availability. Water stress inhibits photosynthesis through both stomatal and non-stomatal (i.e., biochemical) effects [4]. In developing nations, numerous types of edible wild plants, which are not widely cultivated are exploited as sources of food; hence they provide an adequate level of nutrition to the inhabitants [5]. Recent studies on some lesser known Nigeria fruits indicated that these plant resources play a significant role in nutrition, food security and income generation [6]. In addition to the renewed interest in wild edible plant species as sources of food, there has been an increased awareness of their potential use in industries as a viable alternative to the non-renewable petroleum-based fuels and lubricants [7,8]. Most of these wild edible species are not widely cultivated and a good representative of such plant species is *Artocarpus heterophyllus* Lam.

Artocarpus heterophyllus Lam., which is commonly known as Jackfruit belongs to the family Moraceae. It is the largest fruit in the world and is one of the most significant trees in tropical home gardens and perhaps the most widespread and useful tree in the important genus *Artocarpus* [9]. Jackfruit is a tropical tree valued for its heavy yields of nutritious fruits and durable timber. It is one of the potential new crops that has attracted increased interest in the world [10]. The tree is reported native to India, Bangladesh and Nepal [11], spread and cultivated across the world. The tree is evergreen and monoecious. The compound or aggregate fruit is green to yellow when ripe with weight of 4.5-50 kg [12].

In Nigeria, its cultivation has not been encouraged, though it is found in the south-coastal parts of the country where it grows wild or semi-conserved [13] and in this area, the seeds are collected, boiled and eaten by children. However, this practice has stopped, and the seeds now substantially go to waste [14] and the species not widely cultivated [6]. Seed propagation techniques may greatly facilitate the process of domestication of fruit tree species by enabling the rapid multiplication of selected genotypes and the production of superior planting stock for farmers [15].

This study will aid the selection of the most appropriate light intensity and best watering regime that will facilitate the optimal seedling growth performance of the species. Due to the importance of this species, information on how to propagate this species could be of great value for reforestation effort in different parts of Nigeria.

Materials and Methods

Experimental site

The study was carried out at the Nursery site of the Department of Sustainable Forest Management (SFM), Forestry Research Institute of Nigeria (FRIN), Jericho Hill, Ibadan, Nigeria. FRIN is located on the longitude 07°23'18''N to 07°23'43''N and latitude 03°51'20''E to 03°51'43''E. The climate of the study area is the West African monsoon with dry and wet seasons. The dry season is usually from November through March and is characterized by dry cold wind of harmattan. The wet season usually starts from April to October with occasional strong winds and thunderstorms. Mean annual rainfall is about 1548.9 mm, falling within approximately 90 days. The mean maximum temperature is 31.9°C, minimum 24.2°C while the mean daily relative humidity is about 71.9% [16].

Fruit collection

Fruits of *Artocarpus heterophyllus* were collected from the mother trees in the botanical garden, University of Ibadan, Oyo State. Oyo State is in the South Western Region of Nigeria.

Seed extraction/Processing

A. heterophyllus fruits were cut opened with knife, seeds were separated from the fleshy sheaths that enclose the seeds. The thin, slimy coating around the seed (perianth lobe) was removed and the seeds thoroughly rinsed in water to remove any remaining pulp juice or sugary residue. Seeds were air-dried for about an hour for ease of handling.

Experimental Design

The Experimental Design used for this experiment was 4 × 4 Factorial experiment in Completely Randomized Design (CRD). Factor A is 4 light intensities and Factor B is 4 watering regimes which constituted the treatments. Each watering regime was replicated 10 times.

Experimental procedure

The study investigated the effects of different light intensities and watering regime on the seedling growth rate of *Artocarpus heterophyllus*. This was accomplished by applying four watering regimes during raising seedlings of *A. heterophyllus* in the nursery under four different light intensities. The four light intensities are as follows: a total of three screen chambers and direct sunlight (control).

The light screen chambers were constructed with varying penetrating layers followed by direct sunlight (control) respectively. The separation of light intensities was accomplished by synthetic green mesh net of 1 mm single (75%), double (50%) and triple layers (25%) [17] that allows the penetration of only certain amount of energy within the PAR (400 to 700 nm waveband) region of the electromagnetic spectrum. The penetration of light intensity entering each screen chamber was determined with the aid of a photo meter. Light intensities involved 100% (L1), 75% (L2), 50% (L3) and 25% (L4) while watering regimes involved watering very day (W1), once in three days (W2), once in five days (W3) and once in a week (W4) to pot capacity.

One hundred and sixty (160) *A. heterophyllus* seedlings of relatively uniform height were selected for this experiment. Seedlings selected for this experiment were transplanted into polythene pots (24 × 22 cm) containing 2 kg of topsoil. Each watering regime had 10 replicates from the 40 seedlings placed under each light intensity chamber. Growth variables assessment commenced at two weeks after transplanting.

Data Collection

Morphological response

Growth variables that were assessed are plant height (cm), collar diameter (mm) and leaves production. For biomass estimation, mean height of the seedlings of each potting media was calculated and one seedling whose height is closest to the mean height was selected for destructive sampling at every four weeks. The selected seedling from each treatment was carefully uprooted by separating the seedling from the soil, washed and section into root, stem and leaves. Estimations of stem length and root length of each seedling was obtained using meter tape and sensitive weighing balance was used to obtain the initial (fresh) weight of leaves, stem and root.

After that, seedling components (leave, stem and root) were taken to the analytical laboratory and placed in the oven to dry at 70°C until a constant weight is obtained. Since 100% of each component was dried in the oven, the dry weight of each component was taken as their biomass. Seedling total biomass was then obtained by summing the biomass of the various components.

Physiological response

Shoot/Root ratio: This is the ratio of root dry weight and shoot dry weight. This is used to measure the overall health of the plant.

SRR=Dry shoot weight/Dry root weight

Relative turgidity: The method was used to determine the relative turgidity [18]. A section of *A. heterophyllus* leaf 6 to 6 cm long was cut, immediately weighed and then floated on distilled water in Petri dish for 24 hours. The dishes were stacked so that evaporation is prevented. After turgid weight is obtained, the dry weight was determined by drying for 24 hours at 70°C. % Relative Turgidity was calculated as the original water content divided by the turgid water content × 100.

Chlorophyll content of leaves: The sample of leaves was collected from each treatment and prepared to determine their chlorophyll content [19]. 1.5 g was removed from the leaves collected from each treatment with the aid of a weighing balance. The leaf samples were grinded with 80% methanol [20] with the aid of pestle and mortar. The residue was removed from the liquid with the aid of a filter paper. The extract was collected into sample bottles and labelled. Before putting the extract into the spectrophotometer, 80% methanol was used to blank the meter after which the extract was introduced into the spectrophotometer. The readings from the meter was used to determine the chlorophyll concentrations using the following equations [19,20].

$Ca=12.7A663-2.69A645$.

$Cb=22.9A645-4.68A663$.

D645=Absorbance at 645 nm (chlorophyll a).

D663=Absorbance at 663 nm (chlorophyll b).

Data analysis

Data were subjected to descriptive and one-way Analysis of Variance. Mean found to be significantly different were subjected to follow-up test procedure using Duncan Multiple Range Test. Results were presented in tables and figures.

Results and Discussion

Seedling height

Analysis of Variance (ANOVA) indicated no significant differences (p>0.05) among light intensities, watering regimes and the interaction between light intensities and watering regimes (Table 1). Interactions of light intensities and watering regimes shows that seedlings under L2W3 had the highest mean height of 43.64 cm and seedlings under L4W4 had the least with 35.50 cm after 4 months (Table 1).

Seedling collar diameter

Interaction of light intensities with watering regimes showed that the highest mean diameter of 5.19 mm was recorded for seedlings in L1W3 while the least was recorded in L4W4 with 4.29 mm after 4 months. However, ANOVA for collar diameter revealed no significant differences (p>0.05) among the light intensities, watering regimes and the interaction between light intensities and watering regimes (Table 1).

Number of leaves

Leaf production increased with increase in age of the seedlings. Interaction of light intensity and watering regime showed that the highest leaf production of 7 was recorded in L1W3 and L1W4 while the seedlings in other treatments had 6 leaves each after 4 months. However, ANOVA for leaf production revealed no significant differences (p>0.05) among light intensities, watering regimes and the interaction between light intensities and watering regimes (Table 1).

Light intensity	Watering regime	Parameters assessed		
		Plant height	Number of leaves	Collar diameter
L1	W1	37.82	5.95	5.03
	W2	42.61	6.48	5.12
	W3	41.97	6.7	5.19
	W4	41.15	6.57	5.01
L2	W1	36.8	6.16	4.77
	W2	41.41	6.33	4.74
	W3	43.64	6.4	4.81
	W4	42.95	6.31	4.72
L3	W1	38.19	5.96	4.66
	W2	43.14	6.46	4.78
	W3	40.03	6.25	4.38
	W4	42.8	6.06	4.61
L4	W1	40.13	5.85	4.48
	W2	40.41	5.93	4.31
	W3	39.39	5.89	4.4
	W4	35.5	5.81	4.29
Sig.		1.00^{ns}	1.00^{ns}	1.00^{ns}

Table 1: Mean Plant height, Number of leaves and Collar diameter of *A. heterophyllus* seedlings. ns- not significant (p>0.05).

Biomass accumulation

Leaf Dry Weight (LDW): Mean values of LDW presented in Table 2 showed that at the end of four months, L1W3 had the highest value of leaf biomass 2.79 g while L4W4 had the lowest value 1.60 g. ANOVA indicated no significant differences (p>0.05) among the light intensities, watering regimes and the interaction between light intensities and watering regimes.

Stem Dry Weight (SDW): The result of the SDW presented in Table 2 showed that after four months, highest value of stem biomass was obtained from seedlings grown under L1W3 with the mean value 3.38 g while L4W4 gave the lowest SDW with mean value 1.60 g. ANOVA showed that the effect of light intensity, watering regime and the interaction of light intensities and watering regimes on the SDW of the seedlings during the period of four months were not significantly different (p>0.05).

Light intensity	Watering regime		Biomass			
		RL (cm)	LDW (g)	SDW (g)	RDW (g)	TDW (g)
L1	W1	33.27	2.34	3.05	2.15	7.53
	W2	32.95	2.4	2.59	1.91	6.91
	W3	35.03	2.79	3.38	1.94	8.1
	W4	30.4	2.19	2.51	1.58	6.27
L2	W1	27.85	2.37	2.59	1.75	6.69
	W2	37.08	2.25	2.64	1.62	6.51
	W3	36.85	2.14	2.4	1.5	6.03
	W4	25.03	2.19	2.71	1.46	6.36
L3	W1	27.78	1.94	2.31	1.4	5.64
	W2	30.08	2.24	2.58	1.23	6.05
	W3	40.4	1.68	2.07	1.11	4.85
	W4	32.58	2.03	2.23	1.29	5.54
L4	W1	25.83	1.85	2.1	1.09	5.03
	W2	26.3	1.81	1.99	0.98	4.77
	W3	29.85	1.8	1.99	1.1	4.88
	W4	26.78	1.6	1.6	1.06	4.26

Sig.	0.93^{ns}	1.00^{ns}	1.00^{ns}	1.00^{ns}	1.00^{ns}

Table 2: Mean Root Length and Biomass Accumulation of *A. heterophyllus* seedlings. ns-not significant (p>0.05).

Root Dry Weight (RDW): The mean seedlings RDW for light intensities ranged between 1.06 to 1.90 g with the highest value recorded in L1 and least in L4 (Table 3). Mean values of RDW of *A. heterophyllus* seedlings presented in Table 2 showed that at the end of fourth month of biomass estimation, RDW of seedlings under L1W1 gave the highest value (2.15 g) while L4W2 gave the lowest value of 0.98 g. ANOVA showed that RDW of seedlings subjected to different light intensities were significantly different ($p<0.05$) but not significantly different ($p>0.05$) in the effect of watering regimes and the interaction of light intensities and watering regimes, while mean separation result showed that the RDW of seedlings subjected to different light intensities were significantly different from each other (Table 3 and Figure 1).

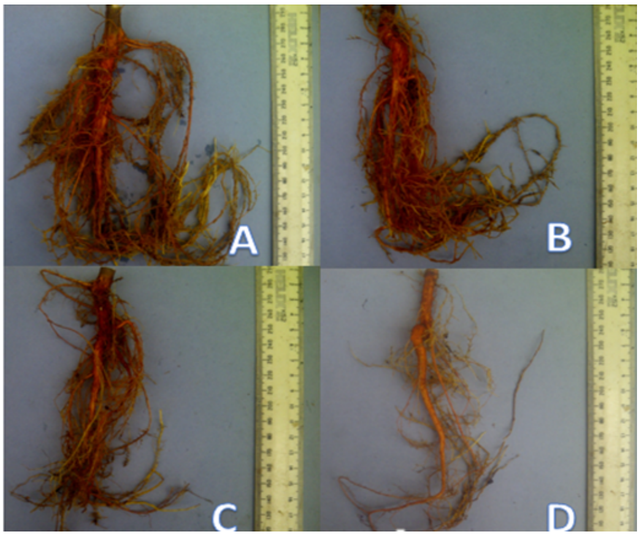

Figure 1: Sample of Root from *A. heterophyllus* seedlings under L1 (A), L2 (B), L3 (C) and L4 (D) after 4 months.

Light Intensity	Root Dry Weight (g)
L1	1.9
L2	1.58
L3	1.26
L4	1.06
Sig.	0.04^{*}

Table 3: Mean separation for the effect of light intensities on the Root Dry Weight. Means with different alphabet are significantly different from each other (p>0.05).

Total Dry Weight (TDW): The result of the TDW presented in Table 2 showed that after four months, highest value of TWD was obtained from seedlings grown under L1W3 with the mean value 8.10 g while L4W4 gave the lowest TDW with mean value 4.26 g. ANOVA for total biomass indicated that there were no significant difference ($p>0.05$) among the light intensities, watering regimes and the interaction between light intensities and watering regimes.

Root length: The result of root length presented in Table 2 showed that after four months, highest value of root length was obtained from seedlings grown under L3W3 with the mean value of 40.40 cm while L2W4 gave the lowest root length with mean value of 25.03 cm. ANOVA for root length indicated no significant difference ($p>0.05$) among the light intensities, watering regimes and the interaction between light intensities and watering regimes.

Shoot to Root Ratio (SRR): Shoot to root ratio of the seedlings ranged from 1:1 to 2:1 in the 1st month and the 2nd month of harvest. At the 3rd month of harvest, the ratio ranged from 2:1 to 5:1 while at the final harvest, the ratio range was between 1:1 and 5:1 with L3W2 and L3W4 having the highest SRR of 5:1 while L3W3 had the lowest value of 1:1. The result indicated that there was increase in SRR with increase in age of the seedlings of *A. heterophyllus* (Table 4).

L	W	1st month	2nd month	3rd month	4th month
L1	W1	01:01	02:01	03:01	02:01
	W2	01:01	02:01	03:01	02:01
	W3	01:01	02:01	05:01	02:01
	W4	01:01	01:01	03:01	04:01
L2	W1	01:01	02:01	02:01	03:01
	W2	01:01	02:01	03:01	02:01
	W3	01:01	01:01	02:01	03:01
	W4	02:01	02:01	03:01	04:01
L3	W1	01:01	02:01	04:01	04:01
	W2	01:01	02:01	03:01	05:01
	W3	01:01	01:01	03:01	01:01
	W4	01:01	01:01	02:01	05:01
L4	W1	02:01	02:01	02:01	04:01
	W2	02:01	02:01	03:01	03:01
	W3	01:01	02:01	02:01	04:01
	W4	01:01	01:01	02:01	03:01

Table 4: Effect of light intensity and watering regime on Shoot to Root Ratio of *A. heterophyllus* seedlings. Where; L=Light intensities; W=Watering regimes.

Relative Turgidity Percentage (RTP): Relative turgidity percentage of the seedling ranged from 40.9% to 80.0% at the termination of the experiment. Seedlings under L4W4 had the highest value (80.0%) of relative turgidity while the least value was recorded in L1W1 with 40.9%. The result showed that the relative turgidity of all the seedlings was above 25% (Figure 2).

Citation: Bolanle-Ojo OT, Akinyele AO, Aduradola AM (2018) Morphological and Physiological Response of *Artocarpus heterophyllus* Lam. (Jackfruit) Seedlings to Selected Environmental Factors. J Agri Sci Food Res 9: 211.

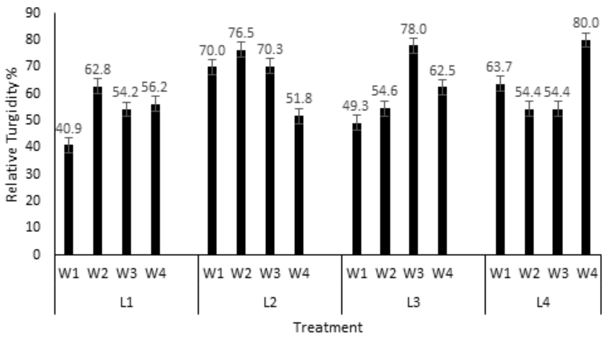

Figure 2: Effects of light intensities and watering regimes on Relative Turgidity.

Chlorophyll a and b: ANOVA revealed that light intensities (Table 5), watering regimes (Table 6), and interaction of light intensities with watering regimes (Table 7) had significant effect ($p<0.05$) on the chlorophyll a and b of *A. heterophyllus* seedlings. Table 5 showed L4 had the highest chlorophyll a and b (1.91 and 8.16 mg/m^2) while L1 had the lowest chlorophyll a and b (0.23 and 2.95 mg/m^2). Table 6 showed W1 had the highest chlorophyll a and b (1.49 and 4.72 mg/m^2). Table 7 showed that L4W1 had the highest amount of both chlorophyll a and b (1.98 and 8.91 mg/m^2) while L1W4 had the lowest amount of both chlorophyll a and b (0.2 and 2.92 mg/m^2).

Light intensity	Chlorophyll a (mg/m^2)	Chlorophyll b (mg/m^2)
L1	0.23 d	2.95 d
L2	1.78 c	3.56 c
L3	1.83 b	4.12 b
L4	1.91 a	8.16 a
Sig.	0.00*	0.00*

Table 5: Effect of Light intensities on the Chlorophyll a and b of *A. heterophyllus* leaves. *- Significant ($p \leq 0.05$).

Watering regime	Chlorophyll a (mg/m^2)	Chlorophyll b (mg/m^2)
W1	1.49 a	4.72 a
W2	1.46 b	4.70 b
W3	1.43 c	4.69 c
W4	1.37 d	4.66 d
Sig.	0.00*	0.00*

Table 6: Effect of Watering Regimes on the Chlorophyll a and b of *A. heterophyllus* leaves. *- Significant ($p \leq 0.05$).

Light intensity	Watering regime	Chlorophyll a (mg/m^2)	Chlorophyll b (mg/m^2)
L1	W1	0.26 e	2.97 d
	W2	0.24 e	2.96 d
	W3	0.23 e	2.94 d
	W4	0.20 e	2.92 d
L2	W1	1.86 b	3.59 c
	W2	1.83 bc	3.58 c
	W3	1.79 c	3.58 c
	W4	1.68 d	3.53 c
L3	W1	1.88 b	4.13 b
	W2	1.86 b	4.13 b
	W3	1.82 bc	4.12 b
	W4	1.79 c	4.10 b
L4	W1	1.98 ab	8.19 a
	W2	1.95 a	8.17 a
	W3	1.90 a	8.16 a
	W4	1.82 bc	8.12 a
Sig.		0.00*	0.00*

Table 7: Mean Values for Interaction Effect of Light intensities and Watering regimes on the Chlorophyll a and b of *A. heterophyllus* leaves. *- Significant ($p \leq 0.05$).

Discussion

Light is an important factor in plant growth and development because of its role in photosynthesis, development of leaves and shoot, flower initiation and fruit set [21].

The result from this study is in correlation with the findings reported no significant difference in height and leaf production of the seedlings of *Dialium guineense* subjected to different light intensities [22]. Thus, all the light intensities favored early growth rate of *A. heterophyllus*. The seedlings under all treatments gave higher height at the end of 16 weeks of growth compared with the height of seedlings reported for some tree species (e.g., *Buchholzia coriacea*, *Dialium guineense*, *Entandrophragma angolense* and *Kigelia africana*) [17,21-23].

The study of effect of light intensity on plant development is essential for a complete understanding of the processes of dry matter production and its partitioning [21]. The findings from this study showed that the seedlings of *A. heterophyllus* under each treatment were able to utilize the different light intensities for their biomass accumulation. The leaf, stem and total dry weight of the seedlings were not significantly affected by light intensities but significantly affected the root dry weight. The root hairs of the seedlings were also affected by light intensity. This is in correlation with the findings reported that light intensities do not affect the leaf, stem and total dry weight of the seedlings of *Buchholzia coriacea* but affected its root dry weight. This result on root length is in correlation with the findings stated that there was no significant difference in the root length of *K. africana* seedlings grown under different light intensities [21,23].

Water is a significant factor in tree growth and development in the tropics [24]. The result from this study shows that the seedlings were able to make use of the available soil moisture for its growth. The water stresses the seedlings were subjected to, did not affect the growth development. This agrees with the findings reported that irrigation frequencies did not affect the collar diameter and height of five tropical trees in the nursery (*Acacia tortilis* subspecies *raddiana*, and subspecies *spirocarpa*, *Acacia ehrenbergiana*, *Azadirachta indica* and *Eucalyptus microtheca*) [25]. The different watering regimes favored the growth development of the seedlings of *A. heterophyllus*.

The findings revealed that watering regimes did not have significant effect on the biomass accumulation of the seedlings of *A. heterophyllus*, which is in correlation with the work which reported no significant difference in the shoot dry weight of five tropical species subjected to different irrigation frequencies. The seedlings of *A. heterophyllus* were able to utilize the different watering regimes for biomass accumulation [25].

The shoot to root ratio (SRR) of the seedlings increased with increase in age of the seedlings. The SRR increased from the 2nd month to the 3rd month but the SRR of some seedlings reduced at the 4th month. The result of SRR did not follow any definite trend. The result showed that there is more growth in shoot than in root of the seedlings of *A. heterophyllus*. This shows that the species has a rapid shoot growth which can be referred to as a fast-growing species.

The interaction of light intensity and watering regime did not affect the relative turgidity of the seedlings of *A. heterophyllus*. The relativity turgidity of the seedlings was above 25% which shows that the seedlings will recover after re-watering. If the relative turgidity percentage was below 25%, the seedlings will not recover after re-watering [26].

Decrease in light intensity increased the amount of chlorophyll a and b in the seedlings of *A. heterophyllus* while decrease in watering regime decreased the amount of chlorophyll a and b. The restricted water supply during the entire experiment had a mild effect on these chlorophyll content. The effects of light intensities and watering regimes on the chlorophyll a/b ratio indicates that chlorophyll a is more sensitive to drought than chlorophyll b. Decrease in light intensity increased the chlorophyll content of the leaves of *A. heterophyllus*. Decrease in chlorophyll a and b due to water stress is in correlation, a significant decrease of chlorophyll a and b caused by water deficit in six *Triticum aestivum* cultivars [27].

Conclusion

Availability of high quality seedlings are essential characteristics desirable in tree species recommended for fruit trees plantation establishment such as *Artocarpus heterophyllus*. The result from this study has shown that *A. heterophyllus* can be easily raised in the nursery under different light intensities and little moisture stress, and it is a fast-growing species. The result revealed that height and other growth parameters as well as biomass accumulation do not depend on the amount of light intensities or moisture received at early growth stage. Plants subjected to drought stress and different light intensities that do not make changes in the morphological characteristics make changes in some of their physiological and biochemical features. Propagation and availability of this species will allow its sustainable use for food security, curing some diseases, thus improving human health status, generation of income (poverty alleviation) through sales of its products and could help in carbon sequestration in mitigation of global warming. Plantations of *A. heterophyllus* should be established to conserve this species in Nigeria.

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