EFFECTS OF SOURCES OF POTASSIUM AND WATERING REGIMES ON THE GROWTH OF AFRICAN STAR APPLE (*CHRYSOPHYLLUM ALBIDUM* G. DON) SEEDLINGS

D. O. ADELANI*

Federal College of Forestry Ibadan, P.M.B 5087, Dugbe, Ibadan, Nigeria

**Correspondence author's email address: adelani.olusegun@yahoo.com*

ABSTRACT

There is shortage of research-based facts on the performance of potassium-found plant foods on the improvement of *Chrysophyllum albidum*. To promote the gradual development of *Chrysophyllum albidum*, examination was carried out. A 3×3 split-plot experimental design accompanying three replications was chosen to determine the outcomes of origins of potassium and wetting periods on the enlargement of *Chrysophyllum albidum* plantlets. Three origins of nutrient specifically; muriate of potash (5g), potassium sulphate fertilizer (5g) and sheep manure (10g) made up the main plot treatments. The regular wetting (200ml), 3 days interval (200ml) and 5 days interval (200ml) formed sub plot treatment. The treatment comprised of three sources of potassium and three watering intervals copied three times. Twelve (12) seedlings stood for a replicate. Three hundred and twenty-four (324) seedlings were concerned. A month old *C. albidum* seedlings were transferred into pots with enhancers and exposed to 200ml watering at varying day's interval. Data gathered were submitted to two-way Analysis of Variance (ANOVA). The outcome disclosed that fountains of potassium and watering gaps considerably ($p < 0.05$) boosted the growing of *C. albidum.* Remarkable height (93.37cm), total fresh weight (26.55g), total dry weight (11.23g), leaf number (15.34), relative turgidity (81.35%) and relative growth rate ($0.446 gg^{-1}wk^{-1}$) were written down from seedlings cultivated in the soil enhanced with sheep manure and watered at day 1 and 3 interval comparable to other treatments. Administration of sheep manure and watered from day 1 to 3 interval upgrades the growing of *C. albidum* for multiplication in agroforestry systems.

Key words: Potassium, Moisture application rate, Propagation, Origin of potassium, Enhancers

Introduction

Forest is a source of diverse products that are of remarkable relevance to the people (Areo, 2018). Nigeria is well blessed with forest assets, but the excessive depletion of these forest resources is an inception of concern and threat to the economic, social and environmental importance (Chukwuemeka *et al.,* 2022). According to Popoola and Akinwumi (2003), available statistics in Nigeria specified that some 400, 000 hectares of forest is vanished yearly through shifting cultivation. World biodiversity is exhausting at a frightened rate, due to human encroachments and environmental degeneration, creating high risk of disappearance (Harun-ur-Rashid *et al.,* 2014). International Union for Conservation of Nature and Natural Resources (IUCN), Threatened Plants Unit approximated that about 60,000 plant species (25%) would come to be either extinct or rare by the year of 2050 (Uberoi, 2010). The extinction may affect vulnerable species as African star apple.

GJS is an Open Access Journal and distributed under the terms of Creative Commons (CC) License [CC by 4.0]

African star apple or White star apple known as *Chrysophyllum albidum* is a climax tree species of tropical rainforest that fits in to the family Sapotaceae (Olaoluwa *et al.,* 2012; Wole, 2013) which bring about nearly half of the order with 800 species (Ehiagbonare *et al.,* 2008). It is called "Osan Agbalumo," "Udara" or "Udala" and "Agwaluma or Agwaluba" in Yoruba, Igbo and Hausa languages respectively (Rahaman, 2012; Wole, 2013; Adelani *et al.,* 2018).The World Agroforestry Centre (ICRAF) has recognized *C. albidum* as one of the top five prime concern species for domestication in the African humid tropics (Tchounjeu *et al.,* 2002).The *C. albidum* has been acknowledged to be of reasonable economic (Onyekwelu *et al.,* 2011), nutritional and medicinal (Onyekwelu & Stimm, 2011) and industrial (Olaoluwa *et al.,* 2012) worths.

In spite of vast prospects of *C. albidum*, it has been substantially disregarded notably concerning its regeneration (Adelani *et al.,* 2016; Adelani *et al.,* 2017) and its generation has been restricted owing to slow growth (Adelani & Muhammed, 2017; Adelani, 2023). Oni and Ojo (2002) proved that the growth of many home-grown timber and fruit tree species in the tropics is slow-moving in spite of subjection to conventional edaphic and environmental surroundings. Tropical soil is low in fertility. Therefore, fertilizer supplication is called for to increase the advancement of plants. Sustaining of sufficient richness of nursery soil is principal to guarantee mass production of top class planting stocks (Hoque *et al.,* 2004) that grow fast. To enhance the soil fertility, categories of fertilizers to use are worth considering.

Lately, farmers incline to use synthetic fertilizers independently for appropriating the needs of plants nourishing components, owing to the facts that they are more economical, affordable, easy to use and quick in response; while natural fertilizer achieved gradual response on crop productivity, even though they are excellent in maintaining soil properties (Purbajanti *et al.,* 2019). Man-made booster can provide nourishments that are in scarce supply thereby, consequently, increasing the initial staying alive and /or increase rate of familiarized plants (Jafer and Gebresilasie, 2018). It is well confirmed that application of inorganic fertilizers energized the seedlings and considerable increases in biomass of many tree species (Bungard *et al.*, 2000; Ong *et al.,* 2004; Hoque *et al.,*2004; Uddin *et al.,* 2007);while the organic manure upgrades the physical and chemical features of the soils (Ojelabi *et al.,* 2018); upgrading soil water holding capacity and acts of soil organism (Mbah & Mbagwu, 2003); guaranteeing long time left over effects of nutrient (Makinde & Ayoola, 2008; Ogunade *et al.,* 2020) and as well draws low cost (Bayu *et al.,* 2006).

Evaluations on effect of natural and man-made origins of potassium on plants in nursery are vital. Prajapati and Modi (2012) announced that the use of fitted sources of potassium to handle the slow advancement as well as poor soil fertileness of the tropics soil is very important. Sources of potassium furnish potassium that is fundamental for plant growth. It upgrades nitrogen use efficiency (Prajapati & Modi, 2012). Potassium (K), known as a stress stabilizer plant nutrient, controls water disappearances from the plants (Farahani *et al.,* 2019), slows down leaf chlorosis and senescence (Weng *et al.,* 2007), and lessens the adverse repercussions of inadequacy of water distress by regulating, normalizing the physio-biochemical characteristics (Hafsi *et al.,* 2014) such as energizing enzymes needed for growth, which aids to prevent disease and control insects as well as assuring osmo-

regulation. Potassium incorporation escalated biomass partitioning to roots, boosted relative water content and leaf membrane stability, and remarkably enhanced plant seedling survival under water suffering (Anokye *et al.,* 2021). Anokye *et al.*(2021) stated that raising levels of employed K to plant incline to increase general biomass produce (root and shoot) and the amount of dry matter detached to roots.

Cakmak (2005) reported that under sufficient potassium nutrition, there is hindrance of the transmitting of photosynthetic electrons to molecular oxygen, thus reducing reactive oxygen species production (ROS). In plants furnished with suitable sufficient of soil potassium, leaf water relations were affected such that turgor potential, as a basis of relative water content, is soared and such plants are mostly discovered to have better watered tissues than potassium-stressed plants (Mengel & Kirkby, 2001). Under shortage of water stress, exogenous K fertilizer elevated the relative water content and lessened membrane damage, specifically the enzymatic antioxidants generated for self-defense as confirmed by the higher activities of superoxide dismutase., peroxidase., catalase., glutathione reductase and ascorbic peroxidase and the lower content of malondialdehyde (Aksu & Altay, 2020; Siddiqui *et al.,* 2021). Xu *et al.*(2021) expressed that potassium (K) diminishes the damaging consequences of drought stress on plants

External application of potassium to waterlessness-burdened plants influenced higher contents of soluble sugar, proline, and amino acid (Zhao *et al.,* 2019). Precisely, potassium administration reduced the proportion of diminish in the relative water content and chlorophyll content encouraged by drought stress, and simultaneously osmotically active solutes and ascorbic acid were exceptionally surged with K supply under waterlessness distress (Fang *et al.,* 2022). The K well-fed *Eucalyptus urophylla* × *camaldulensis* clone under critical water shortage sustained shoot biomass assemblage by stimulating the K-content in leaves and stems, gas exchange, water-use efficiency (WUE_I), leaf water potential (Ψw), and chlorophyll *a* fluorescence variables equated with *Eucalyptus urophylla* clone alone (Santos *et al.,* 2020). Samar *et al.*(2013) announced that under water shortage tension situations, productivity wastages can be diminished by the reasonable equip with K. In short, K administration could lighten water shortage pressure on the growth and development of plants by adjusting the architecture and exudations of roots and soil ecosystems (Xu *et al.,* 2021). Xu *et al.* (2021) established that potassium boosts water shortage suffering resilience in plants by modifying root morphology, root exudates, and microbial diversity.

The inappropriate supply of potassium to tree seedlings can lead to total loss for nursery operators, most especially during dry season that perennials plants has to undergo yearly. The normal quantity of watering becomes inadequate, in the presence of high temperature of the environment that associates with dry season. Ladikou *et al.* (2025) mentioned that K deficiency considerably changed the water content of scion stems and total scion biomass of Granny Smith' apple cultivar grafted onto M9 rootstock. Potassium inadequate crops grow steadily and have badly developed root systems (Prajapati & Modi, 2012). Under K inadequacy, sharp decline in photosynthesis has been observed (Zaied *et al.,* 2006). Xu *et al.*(2020) noted that improper K furnish would limit photosynthesis through stomatal limitations. The K insufficiency can

substantially give rise to losing of produce and standard of crops (Mustafa & Saleh, 2006). Peculiarly, K-inadequate plants showed a decreased shoot-to-root ratio of Granny Smith' apple cultivar grafted onto M9 rootstock chiefly due to the improved root biomass (Ladikou *et al.,* 2025). Attia *et al.*(2022) expressed that root and shoot increase in basil, *Ocimum basilicum* was reduced with diminishing K^+ concentration. This restraint was connected to a decrease in root elongation and leaf expansion, which was incorporated with a diminishing in chlorophyll and carotenoid constituents.

To fertilize with sources of potassium is as important as to use relevant watering regimes. In the tropics, water accessibility is the most paramount environmental factor impacting tree species richness composition, and distribution (Bongers *et al.,* 2004; Ter Steege *et al.,* 2006; Holmgren & Poorter, 2007). Gbadamosi (2014) disclosed that water is a substantial factor in the growth, development and productivity of plants. Water attainability notably influences plant growth and development, impacting traits such as flowering time, stomatal behavior, and moisturelessness resisting (Og Garden 2024). Gbadamosi (2014) mentioned that water is a major component of all living organisms, which is taking part in important biochemical processes involving photosynthesis, thus its obtainability in sufficient quantity and at naturally tolerable gaps affects produce of plant species.

Daba & Tadese (2017) stated that adequate quantity and quality of water is tremendously significant for the generation of tree seedlings at nursery site. Mng'omba *et al.* (2011) announced that for tree nurseries, constant watering is compulsory to bring out good quality seedlings. This is because any slowdown in seedling growth or following mortality converts into profitable loss to a nursery operator (Mhango *et al.,* 2008, Mng'omba *et al.,* 2011, Oboh & Igharo, 2017). A lack of soil moisture can generate nutritional inadequacies, even within the soil furnished with fertilizer (da Silva *et al.,* 2011). Water shortage has a consequence on the movement and disappearance of both nitrogen and phosphorus nutrients (Homyak *et al.,* 2017). Hartmann *et al.* (2005) disclosed that water stress due to water shortage is the most remarkable abiotic factor restricting plant growth and development. Water shortage is the most destructive abiotic stress factor, influencing growth and yield of various crops (Santos *et al.,* 2020). The threat of waterlessness gives rise to morphological and physiological modifications in advanced plants (Ghorbani *et al.,* 2019). Insufficient water can lead to the desiccation, browning, and final death of leaves, which can lead to suppressed growth (Og Garden 2024). Moisturelessness stress in plants takes place constantly all over the world (Fang *et al.,* 2022).

Water and fertilizer are crucial factors for growth and development of trees. Insufficient knowledge about water and nutrient need of our economic indigenous species has hindered their accomplished propagation. Paucity of practice to regenerate economic and indigenous tree species is a danger to biodiversity conservation (Adelani *et al.,* 2023). Investigations have been conducted on the effect of sources of potassium (Yousuf *et al.,* 2018; Farahani *et al.,* 2019; Khan & Nabi *et al.,* 2023) and watering levels (Sulok *et al.,* 2012; Mohamed *et al.,* 2013) on the plants, but remain unexplored for agroforestry species, *Chrysophyllum albidum.* Insufficient information is available on the effect of sources of potassium and watering regime on the growth of *Chrysophyllum albidum*

seedlings. In this light, this investigation was carried out to assess the effects of sources of potassium and watering regimes on the growth of *Chrysophyllum albidum* seedlings, with a view to enhance its growth as well as to encourage its propagation to meet population demand of its enormous potentials in Africa.

Experimental

Description of experimental site

The experimental site location was at the forest nursery of the Federal University of Agriculture, Abeokuta. It is positioned along Alabata Road, North-East of Abeokuta. It is found within latitudes 7°N and 7°55' N and longitudes 3° 20' E and 3° 37' E. The Federal University of Agriculture Abeokuta is located inside the rain forest zone of Southwestern Nigeria (Amujoyegbe *et al.,* 2008). It is nearest to Ogun-Osun River Basin Development Authority (OORBDA), along Osiele Abeokuta road, off Abeokuta-Ibadan road. It is in the North eastern end of Abeokuta and lies almost on latitude 7° 30 ' N and longitude 3° 54 ' E. It situated within the humid lowland rain forest region with two distinguishing seasons. The wet season stretches from March to October; while the dry season widens from November to February (Aiboni, 2001). The rainfall has a characteristic bimodal spread with peaks in July and September and breaks in August. Normally the rainfall could be heavy and erosive sometimes accompanied by lightning and thunderstorm at the beginning and end of rainy season.

Experimental design

The effect of sources of potassium and watering regimes on the growth of *Chrysophyllum albidum* seedling was investigated. A 3x3 split-plot experimental design accompanying three replications was chosen to determine the effect of sources of potassium and watering regimes on the advancement of *Chrysophyllum albidum* seedlings. Three sources of nutrient particularly; muriate of potash (5g), potassium sulphate fertilizer (5g) and sheep manure (10g) constituted the major plot treatment. The daily watering (200ml), 3 days interval (200ml) and 5 days interval (200ml) constituted minor plot treatment. The treatment comprised of three sources of potassium and three watering regimes copied three times. Twelve (12) seedlings categorized a replicate. Three hundred and twenty four (324) seedlings of the same measurements, nursed from seeds were concerned. The *C. albidum* seedlings of regular size at 2-4 leaf stages were transferred into 0.75 litre polypots size that encompassed acid saturated sand (750g) with plant foods and put through different watering regimes. After two weeks of seedling setting up, constants were taken biweekly for 12 months. Growth variables considered include; seedling height with the use of meter rule; girth with the use of venier caliper; collar diameter was detected by meter rule., the number of leaves were enumerated manually and Leaf area was acquired by linear measurement of leaf length and leaf width as described by Clifton-Brown and Lewandowski (2000).

LA=0.74xLxW (1) Where, LA =Leaf area is the combination of linear dimension of the length and width at the widest part of the leaf. The mean of the growth changeable for period of experiment was used for categorization. Total fresh weight (TFW), total dry weight (TDW), relative turgidity (RT), net assimilation rate (NAR), absolute growth rate (AGR), relative growth rate (RGR), chlorophyll a, b and a+b and nitrogen uptake were evaluated during and after 48 weeks.

Formula for AGR, RGR

$$\text{Absolute Growth Rate} = \frac{W2-W1}{T2-T1} gw \quad (2)$$

W_2 and W_1 are plant weight at corresponding time T_1 and T_2.
RGR=LAR*NAR

$$\text{Relative Growth Rate} = \frac{\log e\, W2 - \log e\, W1}{T2-T1} gg^{-1} wk^{-1} \quad (3)$$

T1=Initial time (Weeks)
T2= Final or second time (Weeks)
W_2= Total dry weight at T_2
W_1=Total dry weight at T_1

$$NAR = \frac{w2-w1}{t2-t1} \times \frac{\log e\, A2 - \log e\, A1}{A2-A1} gcm^{-2} wk^{-1} \quad (4)$$

Where W_2 and W_1 are plant dry weights at times t_1 and t_2, $\log_e A_2$ and $\log_e A_1$ are the natural logs of leaf areas A_1 and A_2 at times t_1 and t_2.

Relative turgidity, also known as relative water content was evaluated; by difference within fresh weight and dry weight fractionated by turgid weight minus dry weight times by 100. Turgid weight was determined by weight of the plant before and after soaking in water for 24hours. Seedling of high vigour was fractionated into three parts specifically; leaf, stem and root. Each part was weighed (fresh weight, FW), then left saturated in liquated water for twenty four (24hrs) (under normal room light and temperature) (Turgid Weight) and after soaked the samples were then dehydrated in an oven at 70°C for 48 hours and weighed (DW) (after being cool down in desiccators).

The RWC/RT is determined as follows:

$$\text{Relative turgidity} = \frac{Fw-Dw}{Tw-Dw} \times 100 \quad (5)$$

FW= Fresh weight
DW= Dry weight
TW= Turgid weight

Evaluations of Chlorophyll were formulated by straight forward calculations of the absorbance at different wavelengths, using Model 6405 uv/vis Spectrophotometer, serial number 1364. The concentrations were estimated by accumulating 20.2 A645, 8.02 A663 and fractionated by length of light path in cell (usually 1cm), fresh weight in grams and 1000. The outcome was accumulated by the volume of chlorophyll solution in mL. A645 and A663 is the absorbance at 645 and 663 nm.

Chlorophyll a (mgg^{-1}) [12.7(A663) - 2.69(A645) x VC/LLP x FW x 1000]

$$= \frac{12.7(A663) - 2.69(A645)x}{LLPXFWX1000} \quad (6)$$

Chlorophyll b (mgg^{-1}) [22.9(A645)- 4.86(A663) x VC/ LLP x FW x1000] =

$$\frac{22.9(A645) - 4.86(A663)x\ VC}{LLPXFWX1000} \quad (7)$$

Total Chlorophyll a+b (mgg^{-1}) [(20.2(A645) + 8.02(A663) x VC/LLP x FW x 1000]

$$= \frac{20.2\ A645 + 8.02\ A663x\ VC}{LLPxFWx1000} \quad (8)$$

Where:
A= absorbance at the given wavelength
C.C= Concentration of chlorophylls
VC = Volume of chlorophyll in mL
LLP = Length of light path usually 1cm
FW = Fresh Weight in grams

Tissue analyses were assessed for the whole plants of *C. albidum* seedlings to ascertain the nutrient uptake. Tissue analysis was also carried out for the sample of whole plants of *C. albidum* seedlings before transferring in the beginning and after transplanting at end of the investigation respectively to establish nutrient uptake. Potassium content was discovered by flame photometry method.

Nutrient Uptake was determined by Method of Sharma *et al.* (2012)

$$= \frac{\%N \times \%P \times \%K \times Dry\ matter\ kg\ ha-1}{100} \quad (7)$$

Actual nutrient uptake was detected by changes in nutrient uptake at the beginning and the end of the experiment. The part of formula relevant to potassium was used.

Data analysis

Data were assembled and exposed to analysis of variance (ANOVA) using SAS (2003). A comparison of significant means was achieved using Fishers' Least Difference LSD at 5% level of significance.

Results

Significant height (48.24cm), leaf area (230.34cm^2) relative growth rate (0.392gg^{-1}wk^{-1}) and were registered from seedlings deep-rooted in the soil improved with potassium sulphate. Outstanding girth (2.17cm), collar diameter (1.08cm) and net assimilation rate (0.219gcm^{-2}wk$^{-1)}$ were noted from seedlings situated in the soil amended with muriate of potash. Noteworthy height (47.19cm), leaf number (13.92), leaf area (206.23cm^2), total fresh weight (22.68g), total dry weight (8.74g), relative turgidity (70.66%), absolute growth rate (1.180gwk^{-1}) and relative growth rate (0.392gg^{-1}wk^{-1}) were entered from seedlings positioned in the soil advanced with sheep manure.

The minimum values of height (37.02cm), leaf number (12.46), leaf area (184.98cm^2), relative turgidity (57.43%) and relative growth rate (0.328gg^{-1}wk^{-1}) were written down from seedlings implanted in the soil boosted with muriate of potash. The lowest values of girth (1.85cm) and collar diameter (0.93cm) and relative growth rate (0.392gg^{-1}wk^{-1}) were registered from seedlings established in the soil influenced with sheep manure.

Remarkable height (58.13cm), leaf number (14.59cm), relative turgidity (70.53%) and relative growth rate (0.396gg^{-1}wk^{-1}) reported from seedlings drenched at 3 days' interval. Symbolic girth (2.18cm), leaf area (319.09cm^2), collar diameter (1.09cm) were marked from seedlings watered daily. The least value of height (24.40cm), leaf number (11.94), relative turgidity (58.30%) and relative growth rate (0.3382gg^{-1}wk^{-1}) were written down from seedlings watered at 5 days' interval. The meanest values of girth (1.85cm) and leaf area (113.62cm^2) were registered from seedlings moistened at 3 days interval.

The lowest values of height (24.40cm), leaf number (11.94), relative turgidity (58.30%) and relative growth rate (0.3382gg^{-1}wk$^{-1)}$, girth (1.85cm) and leaf area (113.62cm^2) were entered from seedlings dampened at 1 and 3 days interval respectively (Table 1).

TABLE 1

Effect of sources of potassium and watering regimes on the growth of C. albidum seedlings

S.O.P	H(cm)	G(cm)	LN	LA(cm^2)	CD (cm)	TF-W(g)	TDW(g)	RT(%)	NAR (gcm^{-2}wk^{-1})	AGR (gwk^{-1})	RGR (gg^{-1}wk^{-1})
M.O.P	37.02^b	2.17^a	12.46^c	184.98^b	1.08^a	11.18^b	4.84^b	57.43^b	0.219^a	0.658^b	0.378^b
K2S4	48.24^a	1.95^b	13.26^b	230.34^a	0.97^b	10.23^b	4.03^b	62.52^b	0.004^c	0.562^b	0.392^a
SM	47.19^a	1.85^c	13.92^a	206.23^a	0.93^b	22.68^a	8.74^a	70.66^a	0.007^b	1.180^a	0.392^a
SE±	1.62	0.03	0.21	12.18	0.02	1.22	0.48	2.90	0.001	0.10	0.02
WR											
1	49.91^b	2.18^a	13.11^b	319.09^a	1.09^a	13.03^a	6.29^a	61.78^b	0.018^a	0.764^{ab}	0.365^{ab}
3	58.13^a	1.85^c	14.59^a	113.62^c	0.92^b	13.03^a	5.06^a	70.53^a	0.006^a	0.652^b	0.396^a
5	24.40^c	1.94^b	11.94^c	188.83^b	0.97^b	16.19^a	6.26^a	58.30^b	0.006^a	0.985^a	0.338^b
SE±	1.62	0.03	0.21	13.16	0.02	1.22	0.48	2.90	0.001	0.10	0.02

Means on the same column having different superscripts are significantly different ($p<0.05$)

S.O.P = Sources of Potassium, H= Height, G=Girth, LN= Leaf Number, LA= Leaf area, CD=Collar Diameter, TFW=Total Fresh Weight, TDW=Total Dry Weight, R.T= Relative Turgidity, NAR=Net Assimilation Rate, AGR=Absolute Growth Rate, RGR= Relative Growth Rate, WR=Watering Regime Significant height (93.37cm), total fresh weight (26.55g) and total dry weight (11.23g) were written down from seedlings transplanted in the soil influenced with sheep manure and hydrated daily. Substantial girth (2.79cm), collar diameter (1.39cm) and net assimilation rate ($0.645gcm^{-2}wk^{-1}$) were filed from seedlings cultivated in the soil enhanced with muriate of potash and wetted daily. Outstanding leaf number (15.34), relative turgidity (81.35%) and relative growth rate ($0.446gg^{-1}wk^{-1}$) were reported from seedlings replanted in the soil amended with sheep manure and watered down at 3 days interval.

Considerable height (93.37cm), total fresh weight (26.55g) and total dry weight (11.23g), leaf number (15.34), relative turgidity (81.35%) and relative growth rate ($0.446gg^{-1}wk^{-1}$) were reported from seedlings placed in the soil enhanced with sheep manure and sprinkled day 1 and 3 interval respectively. The smallest value of leaf area ($88.07cm^2$) was marked from seedlings potted in sheep manure and watered at 3 days' interval. The lowest value of total fresh weight (8.18g), total dry weight (3.30g), relative turgidity (50.97%) , net assimilation rate ($0.002gcm^{-2}wk^{-1}$) and absolute growth rate ($0.395gwk^{-1}$) were recorded from seedlings cultivated in the soil enhanced with potassium sulphate and sprayed with water daily (Table 2).

TABLE 2

Interactive effect of sources of potassium and watering regimes on the growth of C. albidum seedlings

S.O.P	W.R	H(cm)	G(cm)	LN	LA(cm^2)	CD(cm)	TFW(g)	TDW(g)	RT(%)	NAR($g\text{-}cm^{-2}wk^{-1}$)	AGR(gwk^{-1})	RGR($gg^{-1}wk^{-1}$)
M.O.P	1	28.47^{d}	2.79^{a}	13.26^{b}	289.69^{ab}	1.39^{a}	9.83^{bc}	4.35^{b}	56.83^{c}	0.645^{a}	0.645^{b}	0.407^{a}
	3	72.04^{b}	1.70^{c}	14.51^{ab}	115.50^{c}	0.85^{c}	11.58^{bc}	5.18^{b}	58.76^{c}	0.006^{b}	0.641^{b}	0.363^{a}
	5	10.54^{f}	2.02^{b}	9.62^{c}	149.75^{bc}	1.01^{bc}	12.13^{bc}	5.00^{b}	56.70^{c}	0.005^{b}	0.686^{b}	0.364^{a}
K2S4	1	27.89^{d}	1.77^{c}	12.56^{b}	369.21^{a}	0.89^{c}	8.18^{c}	3.30^{b}	50.97^{f}	0.002^{b}	0.395^{b}	0.427^{a}
	3	74.61^{b}	2.09^{b}	12.91^{b}	137.29^{c}	1.04^{b}	10.90^{bc}	4.50^{b}	71.49^{c}	0.005^{b}	0.641^{b}	0.379^{a}
	5	42.23^{c}	1.99^{b}	13.30^{b}	184.51^{bc}	0.99^{bc}	11.60^{bc}	4.28^{b}	65.11^{d}	0.005^{b}	0.650^{b}	0.360^{ab}
SM	1	93.37^{a}	1.97^{ab}	13.53^{b}	298.38^{ab}	0.91^{c}	26.55^{a}	11.23^{a}	77.53^{b}	0.006^{b}	1.250^{ab}	0.251^{b}
	3	27.75^{de}	1.76^{c}	15.34^{a}	88.07^{c}	0.88^{c}	16.63^{b}	5.50^{b}	81.35^{a}	0.006^{b}	0.673^{b}	0.446^{a}
	5	20.45^{e}	1.83^{ab}	12.89^{b}	232.24^{b}	0.91^{c}	24.85^{a}	9.50^{ab}	53.10^{f}	0.001^{b}	1.618^{a}	0.291^{ab}
SE±		2.70	0.08	0.50	33.86	0.04	2.85	1.16	7.25	0.01	0.24	0.04

Means on the same column having different superscripts are significantly different ($p<0.05$)

S.O.P=Sources of Potassium, W.R=Watering Regimes, H= Height, G=Girth, LN= Leaf Number, LA= Leaf area, CD =Collar Diameter, TFW=Total Fresh Weight, TDW=Total Dry Weight, R.T= Relative Turgidity, NAR = Net Assimilation Rate, AGR = Absolute Growth Rate, RGR= Relative Growth Rate

Significant chlorophyll (a)(0.230mg/g) and total chlorophyll a+b (0.4791mg/g) were recorded from leaves of seedlings established in the soil enhanced with sheep manure and watered at 5 days interval. Meaningful chlorophyll (b) (0.2704mg/g) was recorded from leaves of seedlings transplanted in the soil enhanced with potassium sulphate and moistened at 3 days interval. Substantial potassium uptake (42.62%) was recorded from leaves of seedlings positioned in the soil enhanced with sheep manure and drenched daily and 3 days interval. The minimum value of 1.47% uptake was recorded from stem of seedlings cultivated in the soil influenced with potassium sulphate and saturated daily. The lowest values of 0.022mg/g (chlorophyll a) and 0.0199mg/g (chlorophyll b) were recorded from roots of seedlings implanted in the soil amended with potassium sulphate and irrigated at 3 and 1 day interval respectively (Table 3).

TABLE 3

Interactive effect of sources of potassium and watering regimes on the chlorophyll and potassium uptake of C. albidum seedlings

S.O.P	WR	PP	CL(a)(mg/g)	CL(b)(mg/g)	CL(a+b)(mg/g)	K(%)
M.O.P	1	Leaf	0.208^{a}	0.1424^{d}	0.3506^{c}	11.86^{d}
		Stem	0.092^{d}	0.0863^{d}	0.1783^{d}	2.67^{e}
		Root	0.029^{e}	0.0218^{e}	0.0512^{e}	9.12^{de}
	3	Leaf	0.203^{a}	0.1804^{bc}	0.3836^{bc}	18.03^{c}
		Stem	0.095^{d}	0.0885^{d}	0.1836^{d}	2.25^{e}
		Root	0.030^{e}	0.0215^{e}	0.0511^{e}	5.91^{e}
	5	Leaf	0.206^{a}	0.1944^{b}	0.4452^{b}	15.45^{cd}
		Stem	0.086^{d}	0.0883^{d}	0.1745^{d}	3.43^{e}
		Root	0.027^{e}	0.0210^{e}	0.0484^{e}	6.89^{de}
K2S4	1	Leaf	0.153^{c}	0.1548^{c}	0.3075^{c}	8.84^{de}
		Stem	0.086^{d}	0.0777^{d}	0.1640^{d}	1.47^{e}
		Root	0.026^{e}	0.0199^{e}	0.0454^{e}	5.97^{e}
	3	Leaf	0.199^{b}	0.2704^{a}	0.4293^{ab}	14.19^{cd}
		Stem	0.083^{d}	0.1014^{d}	0.1846^{d}	2.31^{e}
		Root	0.022^{e}	0.0223^{b}	0.0444^{e}	7.03^{de}
	5	Leaf	0.199^{b}	0.1451^{c}	0.342^{c}	15.69^{cd}
		Stem	0.093^{d}	0.0853^{d}	0.1786^{d}	2.52^{e}
		Root	0.024^{e}	0.0204^{e}	0.0441^{e}	4.36^{e}
SM	1	Leaf	0.205^{a}	0.2536^{a}	0.4185^{b}	42.62^{a}
		Stem	0.091^{d}	0.0964^{d}	0.1869^{d}	6.19^{de}
		Root	0.026^{e}	0.0249^{e}	0.0513^{e}	7.56^{de}
	3	Leaf	0.218^{a}	0.2231^{b}	0.4406^{b}	42.62^{a}
		Stem	0.093^{d}	0.0909^{d}	0.1839^{d}	1.48^{e}
		Root	0.028^{c}	0.0207^{e}	0.0489^{e}	9.84^{de}
	5	leaf	0.230^{a}	0.2545^{a}	0.4791^{a}	35.29^{b}
		Stem	0.096^{d}	0.1011^{d}	0.1977^{d}	5.47^{e}
		Root	0.028^{c}	0.0244^{e}	0.0523^{e}	8.87^{de}
SE±			0.01	0.01	0.02	2.02

Means on the same column having different superscript are significantly different ($p<0.05$). S.O.P=Sources of Potassium, W.R = Watering Regimes, P P=Plant Parts, CL (a) = Chlorophyll a, CL (b) = Chlorophyll b, CL (a+b) =Total Chlorophyll, K = Potassium

Discussion

Highest values of growth variables recorded in *C.albidum* seedlings planted in sheep manure are indications that it is the best source of potassium. Sources of potassium influences potassium supply. Similar observation has been made by Khan and Nabi (2023) who observed that KNO_3 was more efficacious in boosting leaf chlorophyll content (46.47 mgg-1 FW), leaf area shoot^{-1} (135.29 cm^2), fruit weight (85.64 g), number of fruits tree^{-1} (808.75) and fruit yield tree^{-1} (69.48 kg) of *Citrus limetta*. Yousuf *et al.* (2018) revealed that administration of potassium through Muriate of Potash(MOP) at 2500g/tree with two foliar applications of MOP at 1.5 % including vermicompost at 5kg/tree enhanced soil physical conditions nutrient obtainability fruit yield and quality of apple.

Potassium determines the growth of plants. Potassium is a critical essential constituent taken up by plants in numbers second only to nitrogen (Havlin *et al.,* 2005). Other vital roles of potassium include the activation of enzymes (Marschner, 2012; Mengel, 2001), the translocation of photosynthates, and the synthesis of cellulose, a key building structure of every plant cell wall (Havlin *et al.,* 2005; Wang *et al.,* 2013; Sardans & Penuelas, 2007), transfer of sugars from leaves to fruits, and production and assemblage of oils (Romheld & Kirkby, 2010).

Khan and Nabi (2023) reported that potassium administration mainly enhance the absorption of other nutrients which then present to the enzymes, which assist in the transfer of sugars to the growing sinks and maximizes yield and yield components. It is participated in several enzymatic of energy reactions as well as the combination of energy compounds (Epstein & Bloom, 2004; Anderson, 2015). Mengel and Kirkby (2001) announced that K upgrades physiological processes by the adjustment of turgor pressure and photosynthesis; translocation of cations and enzymes activation, while, Cakmak (2005) also discovered that plants suffering from water shortage stress required more internal K.

Researchers have shown that potassium enrichment results in a pronounced advancement in water use efficiency (Ashraf *et al.,* 2001). Sufficient potassium supply is essential to enhancing water shortage resistance by increasing root elongation and maintaining all membrane stability (Datnoff *et al.,* 2007; Wang *et al.,* 2013). An efficient potassium status may accelerate osmotic adjustment which sustains higher turgor pressure, relative water content and lower osmotic potential, thus enhancing the ability of plants to endure drought stress (Kant & Kafkafi, 2002; Egilla *et al.,* 2005). Potassium plays a fundamental role in turgor regulation within the guard cell during stomatal movement (Wang *et al.,* 2013). This element upgrades winter hardiness, the rigidity of young stems and advances diseases resistance. Higher K+ concentrations diminished the internal competition of pathogens for nutrients assets (Holzmneller *et al.,* 2007).

The potassium permits plants to administer more resources to evolving stronger cell walls for checking pathogen infection and insect attack and to acquire more nutrients to be utilized for plant defense and damage repair (Mengel, 2001). In a potassium abundant plant, the synthesis of high-molecular-weight compounds (such as proteins, starches and cellulose) was substantially escalated, thereby reducing the concentration of low-molecular-weight compounds, such as soluble sugar organic acids, amino acids and amides, in the plant tissues. These low-molecular-weight compounds are principal for the occurrence

of infections and insect infestations, so lower concentration, thereby, leave plants less susceptible to disease and pest strikes in potassium sufficient plants (Wang *et al.,* 2013). The meaningful growth constants recorded from seedlings planted in the soil amended with sheep manure could also be connected to its organic nature relative to others. Sheep manure is organic manure that enhances the growth of plants more than synthetic fertilizer, due to its ability to improve physical and chemical properties of soil. Osama and Amro (2016) stated that sheep manure employment improves soil possessions through improving physiochemical and biological situation of the soil, its increased soil organic matter and soil cation exchange capacity, and therefore the soil nutrient retention capacity was maximized . The improvement in tree growth and leaf mineral composition due to sheep manure administration may be clarified by the fact that sheep manure brings about positive effect on physical conditions of the soil; creates beneficial conditions for root growth and nutrient assimilation; supplies much nutrients and facilitates the sucking up of immovable nutrients by tree roots (Fayed, 2010; Abdel-Nasser & Harash, 2001; Shufu & Huairui, 2004). Moreover, Salama (2002) disclosed that sheep manure application enhanced tree growth, leaf surface area, total chlorophyll and leaf mineral content of Balady mandarin trees. Furthermore, Mosleh *et al.* (2014) recommended that sheep manure administration increased leaf area, and leaf total chlorophyll composition of apricot trees. Highest values of growth criterion recorded in *C. albidum* seedlings watered daily is traceable to adequate and regular supply of water. Regular supply of water is essential for the growth of plants. Water breaks down the soil nutrients and helps in transmitting of such nutrients from the soil to diverse parts of the plants (Aiyeloja & Azeez, 2010). Water is a paramount factor in the growth, development and productivity of plants (Gbadamosi, 2014). Water is needed by plants for manufacture of carbohydrate and as a means for conveyance of foods and mineral elements (Isah *et al.,* 2012). Og Garden (2024) stated that water accessibility is a critical abiotic factor, influencing all plant physiological operations including primary and secondary metabolism. It has a remarkable impact on plant growth and development in various crucial approaches including germination, water stress, and cell structural support.

Daily watering enhances the growth of *C. albidum* seedlings. Similar observation has been documented by Gbadamosi (2014) who approved daily watering for raising of *Picralima nitida* seedlings. The properly watered *Jatropha curcas* reacted by showing considerably ($p<0.05$) better height growth (Sulok *et al.*, 2012). *Adansonia digitata* and *Moringa oleifera* seedlings irrigated twice daily with 24 and 28 L/plot had highest values of growth criterions and biomass produce (Larwanou *et al.,* 2014). Bodunde & Ogunwole (2000) noted that *Lycopersicum esculentum* yield extending from 20-40 tha^{-1} properly watered condition and 10-13 tha^{-1} when the crops were starved. On the other hand, Mohamed *et al.,*(2013) reported that nine days irrigation frequency was established most acceptable for planting *of Acacia tortilis, Acacia enhrenbergiana, Azadirachta indica, Eucalyptus microtheca* in conventional nursery. Sufficient moisture is indispensable for effective potassium uptake; low water reduce K uptake by plant roots (Datnoff *et al.,* 2007).

The least growth limitations recorded from seedlings watered five days interval

revealed the insufficient supply of water. This result is in consonance with the report of Gbadamosi (2014) who stated that *Picralima nitida* seedlings which received the smallest water rate (10ml) at the lengthiest intervals of 5days had the least biomass value. This agreed with the discoveries of several authors who stated that water starves influence plant growth and limits outputs (Ky-Dembele *et al.,* 2010; Hsiao & Xu, 2000). This is in agreement with the findings of Vandoorne *et al*.(2012) that water distressed greatly decreased fresh and dry root weight, leaf number, total leaf area and stomatal conductance in *Cichorium mintybus* (var:sativum). Samar *et al.*(2013) specified that scarcity of water is the most overwhelming abiotic pressurized factor, influencing growth and yield of various plants. The *C. albidum* seedlings cultivated in sheep manure soil and watered daily and 3 days accorded the highest number of growth variables. It can be deduced that watering daily and 3 days space for *C. albidum* seedlings established in sheep manure influenced soil is the appropriate and accurate combination of source of potassium and watering frequency. Adequate combination of sources of potassium and watering regimes improves the growth of plants.

Highest leaf value of chlorophyll a and total chlorophyll a+b entered from *C. albidum* seedlings transplanted in sheep manure altered soil and watered at five days space is traceable to the correct integration of origins of potassium and watering frequencies that boosted the chlorophyll content of plants. Significant potassium uptake recorded from *C. albidum* seedlings established in sheep manure modified soil and watered at day I and 3 intervals, revealed the better accomplishment of regular and moderate supply of water relative to that of 5 day's gap. The lower potassium uptake recorded from the same source, but 5 days' watering regimes revealed effect of inadequate water supply. Inadequate water supply affects nutrient uptake. Samar *et al.*(2013) mentioned that the nutrients (N, P, K, Ca and Na) uptake in the plant was noticeably affected by the shortage of water stress.

Conclusion

The yearly loss of seedlings and saplings in the nursery as well as in the field due to drought is enormous. The adequate application of sources of potassium and watering regimes double the efforts to reduce the annual loss of the nursery operators, silviculturist as well as agroforesters. The role of sources of potassium and watering regimes cannot be over emphasized, as they reduce the loss of biodiversity of economic, priority indigenous species as *Chrysophyllum albidum,* which would have lost to ignorance. Investigation conducted to enhance the slow growth of multipurpose and endangered *C. albidum*, revealed that seedlings subjected to soil influenced with sheep manure and watered day 1 and 3 intervals respectively, gave the highest physiological and morphological growth variables. Administration of sheep manure and watered from day 1 to 3 interval enhances the growth of *C. albidum* seedlings for propagation in agroforestry systems.

References

ABDEL-NASSER, G.& HARASH, M. M. (2001). Studies on some plant growing media for olive cultivation in sandy soils under *Siwa oasis* conditions. *Journal of Advanced Agricultural Research,* **6**, 487-510.

ADELANI, D.O., ADURADOLA, M.A.& MAISAMARI, I.J. (2016). Storability and pre-sowing treatments of *Chrysophyllum albidum* seeds: A step towards biodiversity conservation. *In*: Borokini, I.T & Babalola,

F.D. (Eds); MDGS to SDGS: *Towards Biodiversity Sustainable Conservation in Nigeria. Proceedings of Joint Biodiversity Conservation Conference of Nigeria Tropical Biology Association (NTBA) and Nigeria Chapter of Society for Conservation Biology Conference*, Pp 80-86. (NSCB).

ADELANI, D. O., ADURADOLA, M. A. & AIYELAAGBE, I. O. O. (2017). Storability and pre-sowing treatments of African star apple (*Chrysophyllum albidum* G. Don) seeds. *Journal of Agricultural Science and Environment,* **17** (1), 91-102.

ADELANI, D.O.& MUHAMMED, R. (2017). Effect of organic seed pelleting and storage periods on the early seedling growth of *Chrysophyllum albidum* seedlings. *In:* V.A.J. Adekunle, O.Y. Ogunsanwo & A.O. Akinwole (Eds). *Harnessing the Uniqueness of Forests for Sustainable Development in a Diversifying Economy. Proceedings of the 39th Annual Conference of the Forestry Association of Nigeria* held in Ibadan, Oyo State between 20th 24th February. Pp126-140.

ADELANI, D.O., OGUNSANWO, J.A.& AWOBONA, T.A. (2018). Effect of seed weights on the germination and early seedling growth of African star apple (*Chrysophyllum albidum* G. Don). *Nigerian Journal of Forestry*, **48** (1), 33-38.

ADELANI, D.O. (2023). Improving growth of *Chrysophyllum albidum* G. Don seedlings using leaf litters of selected nitrogen fixing albizia trees. *Journal of Cameroon Academy of Sciences,* **18** (3), 60-76.

ADELANI, D.O., ADURADOLA, A.M., SULEIMAN, R.T. & OYELOWO, O.J. (2023). Effects of sources of nitrogen and watering regimes on the growth of African star apple (*Chrysophyllum albidum* G. don) seedlings. *Ethiopian Journal of Environmental Studies and Management* **16** (4), 454-473

AIBONI, V.U. (2001). Characteristics and classification of soil of a representative topographical location in University of Agriculture, Abeokuta.*Asset Series A,* **1** (1), 51- 61.

AIYELOJA, A.A.& AZEEZ, A.K. (2010). Growth response of *Sterculia setigera* Del. to different types of fertilizers and watering regimes in the nursery. *Journal of Agriculture and Social Research,* **10** (1), 127- 139.

AKSU, G.& ALTAY, H. (2020). The effects of potassium applications on drought stress in sugar beet. *Sugar Technology,***22** (6), 1092–1102. doi: 10.1007/s12355-020-00851-w

AMUJOYEGBE, B.J., BAMIRE, A.S.& ELEMO, K.O. (2008). Agronomic analysis of fertilizer effect on maize/ cowpea intercrop in Ile-Ife and Abeokuta, South-Western Nigeria. *Asset Series, A,* **8** (1): 62-72.

ANDERSON, P. (2015). N.P.K and Fe, what are they good for? www.limbwalker Tree Service. **1** (1), 1-4.

ANOKYE, E., LOWOR, S. T., DOGBATSE, J. A.&PADI, F. K. (2021). Potassium application positively modulates physiological responses of cocoa seedlings to drought stress. *Agronomy*, **11** (3), 563. https://doi.org/10.3390/agronomy11030563

AREO, O.S. (2018). Awareness of forestry as a career in secondary schools in Oyo State, Nigeria (A case study of Ido L.G.A of Oyo State), Nigeria. *Journal of Life Science,* **8** (2), 190-198.

ASHRAF, M., AHMAD, A. &MC NEILLY, T(2001). Growth and photosynthetic characteristics in pearl millet under water stress and different potassium supply. *Photosynthetica* **3**, 389-394.

ATTIA, H., REBAH, F., OUHIBI, C., SALEH, M.A., ALTHOBAITI, A. T., ALAMER, K.H., BEN NASRI, M. B. & LACHAÂL,

M. (2022). Effect of potassium deficiency on physiological responses and anatomical structure of Basil, *Ocimum basilicum* L. *Biology (Basel).* 2022, **11**(11), 1557. doi: 10.3390/biology11111557. PMID: 36358259; PMCID: PMC9688027.

BAYU, W., RETHMAN, N.F.G., HAMMERS, P.S.& ALEMU, G. (2006). Effects of farm yard manure and inorganic fertilizers on sorghum growth, yield and nitrogen use in a semiarid area of Ethiopia. *Journal of Plant Nutrition*, **29**, 391-407.

BODUNDE, J.G.&OGUNWOLE,J.O. (2000). Productivity of tomato (*Lycopersicon esculentum* Mill.) genotype grown on residual soil moisture. *Plant Science*, **1**, 115-125.

BONGERS, F., POORTER, L.& 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.

BUNGARD, R.A., PRESS, M.C. & SCHOLES, J.D. (2000). The influence of nitrogen on rain forest Dipterocarp seedlings exposed to large increase irradiance. *Plant Cell and Environment*, 23,1183-1194.

CAKMAK, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Soil Science,* **168**, 521– 530.

CHUKWUEMEKA, O.D., NWAJIOBI, B.& UWAGA, A.M. (2022). Depleting forest resources and quality of forest estates for sustainable development in Nigeria. *Securing the Nigeria's Forest Estates for Sustainable Development. In:* Ogunsanwo, O.Y, Adewole, N.A, Oni, P.I and Azeez, I.O (Eds). *The proceedings of the 43rd Annual Conference of the Forestry Association of Nigeria* held in Akure 14-18th March, 2022. Pp21-28.

CLIFTON-BROWN, J.C. & LEWANDOWSKI, I. (2000). Water use efficiency and biomass partitioning of three different Miscanthus genotypes with limited and unlimited water supply. *Annals of Botany,* **86**, 191- 200.

DABA, M. H. & TADESE, A. E. (2017). Estimation of optimum water requirement and frequency of watering for different tree seedlings at Bako Agricultural Research Center nursery site. *Journal of Health and Environmental Research*, **3** (6), 90-97.

DA SILVA, E. C., NOGUEIRA, R. J. M. C., DA SILVA, M. A.& DE ALBUQUERQUE, M. B. (2011). Drought stress and plant nutrition. *Plant stress,* **5**(1), 32-41.

DATNOFF, L.E., ELMER, W. & HUBER, D.M. (2007). *Mineral Nutrition and Plant Disease*. APS - The American Phytopathological Society. St. Paul Minnesota, 278pp.

EGILLA, J.N., DAVIES, J.F.T. & BOUTTON, T.W. (2005). Drought stress influences leaf water contain photosynthesis, and water use officially of Hibiscus rosa-sinensis at three potassium concentration. *Photosynthetica*, **43**, 135-140.

EHIAGBONARE, J.E., ONYIBE, H.I. & OKOEGWALE, E. (2008). Studies on the isolation of normal and abnormal seedlings of *Chrysophyllum albidum*: A step towards sustainable management of the Taxon in the 21st Century. *Scientific Research and Essay,***3** (12), 567-570.

EPSTEIN, E. & BLOOM, A. (2004). *Mineral Nutrition of Plants*. Sunderland M.A: Sinauer Associates. P.380.

FANG, S., YANG, H., WEI, G., SHEN, T., WAN, Z., WANG, M., WANG, X. & WU, Z. (2022). Potassium application enhances drought tolerance in sesame by mitigating oxidative damage and regulating osmotic adjustment. *Frontiers in Plant Science*, **13**, 1096606.doi: 10.3389/fpls.2022.1096606

FARAHANI, S., MAJIDI HERAVAN, E., SHIRANI RAD, A. H. & NOORMOHAMMADI, G. (2019). Effect of potassium sulfate on quantitative and qualitative characteristics of canola cultivars upon late-season drought stress conditions. *Journal of Plant Nutrition*,**42** (13), 1543–1555. doi: 10.1080/01904167.2019.1628987

FAYED, T.A. (2010). Response of four olive cultivars to common organic manures in Libya. *American-Eurasian Journal of Agricultural and Environmental Science,***8** (3), 275-291.

GBADAMOSI, A.E. (2014). Effect of watering regimes and water quantity on the early seedling growth of *Picralima nitida* (Stapf). *Sustainable Agricultural Research*, **3** (2), 35-42.

GHORBANI, P., ESHGHI, S., ERSHADI, A., SHEKAFANDEH, A.& RAZZAGHI, F. (2019).The possible role of foliar application of Manganese Sulfate on mitigating adverse effects of water stress in grapevine. *Communications in Soil Science and Plant Analysis*, **50** (13), 1550-1562. https://doi.org/10.1080/00103624.2019.1 626873

HAFSI, C., DEBEZ, A. & ABDELLY, C. (2014). Potassium deficiency in plants: effects and signaling cascades. *Acta Physiologiae Plantarum*, **36** (5), 1055–1070. doi: 10.1007/s11738-014-1491-2

HARTMANN, T., COLLEGE, M.& LUMSDEN, P. (2005). Responses of different varieties of *Lolium perenne* to salinity. *Annual Conference of the Society for Experimental Biology*, Lancashire. unpaginated

HARUN-UR-RASHID, M., RASHID, M.E. & RAHMAN, M.A. (2014). Inventory of threatened plants of Bangladesh and their conservation management. *International Journal of Environment,* **3** (1), 141-167.

HAVLIN, J.L., TISDALE, S.L., BEATON, J.D. & NELSON, W.L. (2005).*Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Pearson Education, Inc, Upper Saddle River, New Jersey* 07458. Pp. 244-254.

HOLMGREN, M . & POORTER, L. (2007). Does a ruderal strategy dominate the endemic flora of the West African forests? *Journal of Biogeography*, **34***,* 1100-1111.

HOLZMUELLER, E. J., JOSE, S. & JENKINS, M.A. (2007). Influence of calcium, potassium and magnesium on *Cornus florida* L. density and resistance to dogwood, *Plant Soil*, **290**,189-199.

HOMYAK, M., ALLISON, D., HUXMAN, E., GOULDEN, L.& TRESEDER, K. (2017). Effects of drought manipulation on soil nitrogen cycling: A meta-analysis. *Journal of Geophysical Research:Biogeosciences,* **122** (12), 3260-3272. https://doi.org10.1002/2017JG004146

HOQUE, A.T.M.R., HOSSIAN, M. K., MOHIUDDIN, M. & HOQUE, M.M. (2004). Effect of inorganic fertilizers on initial growth performance of *Michelia champaca* Linn. seedling in nursery. *Journal of Biological Sciences,***4**(4), 489-497.

HSIAO, T.C.& XU, L. (2000). Sensitivity of growth of roots versus leaves to water stress biophysical analysis and relation to water transport. *Journal of Experimental Botany,***51** (350), 1595-1616.

ISAH, A.D; BELLO, A.G., MAISHANU, H.M.& ABDULLAHI, S. (2012). Effect of watering regime on the early growth of *Acacia senegal* (Linn) wild provenance. *International Journal of Plant, Animal and Environmental Sciences,* **1**, 2231-4490.

JAFER, D. & GEBRESILASIE, H. (2018). Inorganic fertilizer requirement of coffee (*Coffea arabica* L) – Review. *Journal of Biology, Agriculture and Health Care,* **8** (21), 1-11.

KANT, S. & KAFKAFI, U. (2000). Potassium and abiotic stresses in plants. *In Potassium for Sustainable Crops Production;* Pastricha, N.S; Bansal, S.K ; Eds , Potash Institute of India: Gurgaan, India. Pp 233-251.

KHAN, M.N.&NABI, G. (2023). Potassium fertilizer source and timing regulate growth, flowering and yield in trees of sweet lime (*Citrus limetta* L). *Sarhad Journal of Agriculture,39* (3), 655-664. DOI | https://dx.doi.org/10.17582/journal.sja/2023/39.3.655.664

KY-DEMBELE, C, BAYALA, J., SAVADOGO, P., TIGABU, M., ODEN, P.C.& BOUSSIM, I.J. (2010). Comparison of growth responses of *Khaya senegalensis* seedlings and stecklings to four irrigation regimes. *Silva Fennica,* **44** (5), 787-798.

LADIKOU, E.-V., DARAS, G., LANDI, M., CHATZISTATHIS, T., SOTIROPOULOS, T., RIGAS, S. & PAPADAKIS, I.E. (2025). Physiological and biochemical effects of potassium deficiency on apple tree growth. *Horticulturae11*, **42**, 1-19. https://doi.org/10.3390 /horticulturae11010042

LARWANOU, M., ADAMOU, M. M. & ABASSE, T. (2014). Effects of fertilization and watering regimes on early growth and leaf biomass production for two food tree species in the Sahel: *Moringa oleifera* Lam. and *Adansonia digitata* L. *Journal of Agricultural Science and Applications,* **3** (4), 82-88. doi:10.14511/jasa.2014.030401

MAKINDE, E.A. & AYOOLA, A.A. (2008). Residual influence of early season crop fertilization and cropping system on growth and yield of cassava. *American Journal of Agricultural and Biological Sciences,* **3** (4), 712-715. DOI:10.3844/ajabssp.2008.712.715, http://www.scipub.org/full text.AJAB/AJAB 34712-715pdf.

MARSCHNER, P. (2012). Marschner's Mineral Nutrition of Higher Plants , 3rded; Academic Press: London, UK, PP.178-189.

MBAH, C.N. & MBAGWU, J.C.C. (2003). Studies on decomposition, mineralogical rate and biochemical oxygen demand of organic wastes. *International Journal of Agriculture and Biological Services,* **2**, 51-54.

MENGEL K. (2001). *Principles of Plant Nutrition. 5th ed. Kluwer Academic Publishers; Dordrecht, the Netherlands:* **2001**. pp. 481–509. [Google Scholar]

MENGEL, K.& KIRKBY, E.A. (2001). Principles of Plant Nutrition, 5th edn. pp. 864, Kluwer Academic Publishers Dordrecht, The Netherlands.

MHANGO, J., AKINNIFESI, F.K, MNG'OMBA, S.A. & SILESHI, G. (2008). Effect of growing medium on early growth and survival of *Uapaca kirkiana* Müell Arg. seedlings in Malawi. *African Journal of Biotechnology,***7** (13), 2197-2202.

MNG'OMBA, S. A., AKINNIFESI, F. K., SILESHI, G., AJAYI, O. C., NYOKA, B. I.& JAMNADASS, R. (2011). Water application rate and frequency affect seedling survival and growth of *Vangueria infausta* and *Persea americana*. *African Journal of Biotechnology*, **10** (9), 1593-1599.

MOHAMED, A.E., KHALIDA, A.E.& TALAAT, D.A. (2013). Effect of different watering regimes on growth performance of five tropical trees in the Nursery. *Jonares,* **1**,14-18.

MOSLEH, M . S . D., AL-AA'REJI, J. M ., A.& HAJI KHALIFA, G. F.(2014). Effect of sheep manure, ascorbic acid and sulphur on some growth characteristics of apricot (*Prunus armeniaca*, L.) cv.Royal. *Journal of Research in Agriculture and Animal Science,***2** (8), 06-18.

MUSTAFA, E.A.M.& SALEH,M.M.S. (2006). Response of Balady mandarin trees to girdling and potassium sprays under sandy soil conditions. *Research Journal of*

Agriculture and Biological Sciences, **2** (3), 137-141.

OBOHO, E. G.& IGHARO, B. (2017). Effect of pre germination treatments on germination and watering regimes on the early growth of *Pycnanthus angolensis* (Welw) Warb. *Journal of Agriculture and Veterinary Science,* **10** (3), 62-68.

OLAOLUWA, T.A., MUHAMMAD, N.O.& OLADIJI, A.T. (2012). Biochemical assessment of the mineral and some antinutritional constituents *Aspergillus niger* of fermented *Chrysophyllum albidum* seed meal. *African Journal of Food Science,* **6** (1), 20-28.

ONI, O.& OJO, I.O. (2002). Germination, growth and cloning of the popular West African chewing stick (*Massularia acuminata* G. Don) Bullock Ex. Hoyle. *Nigeria Journal of Ecology*, **4**, 8-12.

ONYEKWELU, J.C.& STIMM, B. (2011). *Chrysophyllum albidum.* In: Roloff, Eds): A; Weisgerber, H; Lang, U; Stimm, B. Enzyklopadie Holzgewachse, Willey der VCH, Weinheim, 59. Erg.Lfg.10/11, 12pp.

ONYEKWELU, J.C., STIMM, B., MOSANDI, R.& OLUSOLA, J.A. (2011). Domestication of *Chrysophyllum albidum* from rainforest and derived savannah ecosystem – Phenotype variation and selection of elite trees. *Conference on International Research on Food Security, Natural Resource Management and Rural Development*. Tropentage, pp. 7.

OG GARDEN (2024). The impact of water availability on plant Development. file:///C:/Users/USER/Downloads/How%20Water%20Availability%20Affects%20Plant%20Grow. Accessed on 11/03/24. Pp9.

OGUNADE, J.O., GBADEBO, J.O., AJEKIGBE, J.M., BANJO, T.A.& BOLANLE-OJO, O.T. (2020). Early growth performance of *Parkia biglobosa* (Jacq) Benth on plantation as influenced by fertilizer application. *Forestry Development in Nigeria: Fifty years of Interventions and Advocacy*. *In*: Ogunsanwo, O.Y., Adewole, N.A., Oni, P.I and Idumah, F (Eds). *The proceedings of the 42nd Annual Conference of the Forestry Association of Nigeria* held in Ibadan, 23-28th November, **2020**. Pp555-563.

OJELABI, O.K., MUSA, F.B., AKINLEYE, F.O.& OYEWUMI, R.V. (2018). Effects of different organic manure on the growth of *Pterocarpus erinaceous* Poir. *Emerging issues in Forest Management: Experiences and Lessons for Nigeria. In*: Akinwole, A.O., Adekunle, V.A.J & Ogunsanwo, O.Y (Eds). *The proceedings of the 40th Annual Conference of the Forestry Association of Nigeria* held in Lagos, Lagos State, 12-16th March, **2018**. Pp 614-624.

ONG, K., LIM, M.T.& LABIT, S. (2004). Growth and photosynthetic response of *Shorea platyclados* seedlings to nitrogen application. *In*: H. Aminah., S. Ani, H.C. Sim and B. Krishnapillay, Eds. *Proceedings of the seventh round table conference on Dipterocarps, Asia Pacific Association of Forestry Research Institutions,* Kuala Lumpur, **2004**, pp. 89-100.

OSAMA, H.M. EL G. & AMRO, S.M. S. (2016). Effect of sheep manure application rate and method on growth, fruiting and fruit quality of Balady guava trees grown under Mid-Sinai conditions. *IOSR Journal of Agriculture and Veterinary Science* (IOSR-JAVS) **9** (1): 59-72.

POPOOLA, L. & AKINWUMI (2003). Economics considerations for management and utilization of biodiversity in Nigeria. In Biodiversity update Ed. L.O.Ojo and A.O. Adeola, *Proceedings of a Symposium by FMWENV-UNAAB Linkage for Forest, Conservation and Biodiversity*, pp 181-196.

PRAJAPATI, K. & MODI, H.A.(2012). The importance of potassium in plant growth – a

review. *Indian Journal of Plant Sciences*, **1** (2-3), 177-186,

PURBAJANTI, E.D., SLAMET, W., FUSKHAH, E. & ROSYIDA.(2019). Effects of organic and inorganic fertilizers on growth, activity of nitrate reductase and chlorophyll contents of peanuts (*Arachis hypogaea* L*). IOP Conf. Series: Earth and Environmental Science, 250 (2019) 012048. IOP Publishing*. pp1-8.

RAHAMAN, O. (2012). A review of medicinal value of *Chrysophyllum albidum* (African star apple). *African Traditional Medicine,***1** (1), 1-3.

ROMHELD, V.& KIRKBY, E.A. (2010). Research on potassium in agriculture: needs and prospects. *Plant Soil,* **335**, 155-180.

SALAMA, A.S.M.(2002). Response of Some Fruit Species Transplants and Trees to Organic

Fertilization. *Thesis, Fac.of Agric., Moshtohor, Zagazig University, BenhaBranh Egypt. Ph.D.* unpaginated.

SANTOS, E. F., MATEUS, N.S., ROSÁRIO, M. O., GARCEZ,T. B., MAZZAFERA, P. & LAVRES, J.(2020). Enhancing potassium content in leaves and stems improves drought tolerance of eucalyptus clones. *Physiologia Plantarum,* **172** (2), 552-563.

SAMAR, R. M. A., FARRUKH, S.M., MUSTAFA, S. G., JAMIL, M. & HAIDER, K. I. (2013). Potassium applied under drought improves physiological and nutrient uptake performances of wheat (*Triticum aestivum* L.). *Journal of Soil Science and Plant Nutrition,* **13** (1), 175-185.

SARDANS, J. & PEÑUELAS, J. (2007) Drought changes phosphorus and potassium accumulation patterns in an evergreen Mediterranean forest. *Functional Ecology,* **21**, 191-201.

SAS (2003). Statistical analysis system. SAS release 9. 1 for windows, SAS Institute Inc. cary, NC, US

SHARMA, N.K., SINGH, R.J.& KUMAR, K. (2012). Dry matter accumulation and nutrient uptake by wheat (*Triticum aestivum* L) under poplar (*Populus deltoides*) based agroforestry system. *International Scholarly Research Notices,* **12**, 1-9.

SHUFU, D. & HUAIRUI, S.(2004). Sheep manure improves the nutrient retention capacity of apple orchard soils. *Acta Horticulturae,* **638**, 151-155.

SIDDIQUI, M. H., KHAN, M. N., MUKHERJEE, S., ALAMRI, S., BASAHI, R. A., AL-AMRI, A. A., ALSUBAIE, Q. D., AL-MUNQEDHI, B.M.A., ALI, H. & ALMOHISEN, I.A.A.(2021). Hydrogen sulfide (H_2S) and potassium (K+) synergistically induce drought stress tolerance through regulation of h+-ATPase activity, sugar metabolism in tomato seedlings. *Plant Cell Reports,* **40** (8), 1543-1564. https://doi.org/10.1007/s00299-021-02731-3

SULOK, K.M.T., ZAINUDIN, S.R., HASSIM, M.I. & SUHAILI, S. (2012). Effects of different watering regimes on foliar spectral reflectance and chlorophyll content of *Jatropha curcas* Linn. *Journal of Tropical Plant Physiology,* **4**, 41-51.

TER STEEGE, H., PITMAN, N.C., PHILLIPS, O.L., CHAVE, J., SABATIER, D., DUQUE, A., MOLINO, J.F., PREVOST, M.F., SPICHIGER, R. & CASTELLANOS, H. (2006). Continental-scale patterns of canopy tree composition and function across Amazonia. *Nature,* **443**, 444-447.

TCHOUNJEU, Z., KENGUE, J.& LEAKEY, R.R.(2002) Domestication of *Dacryodes edulis* state-of-the-art. for trees. *Livelihoods2002*, 12, 3-13.

UBEROI, N. K. (2010). Environmental Studies (2nd edition). Excel Books Pvt. Ltd, New Delhi, India. Pp. 1-202.

UDDIN, M. B., MUKUL, S.A., KHAN, M.A.S.A. & HOSSAIN, M.K. (2007). Effects of phosphorous fertilizer on seedlings growth and nodulation capabilities of some popular agroforestry tree species of Bangladesh. *Journal of Forestry Research*, **18** (4), 283-286. DOI: 10.1007/s11676-007-0054-4

VANDOORNE, B., MATHIEU, .S., VAN DEN ENDE, W., VERGAUWEN, R., PERILLEUX, C., JAVAUX, M.& LUTT, S. (2012). Water stress drastically reduces root growth and insulin yield in *Cichorium intybus* (var. sativum) independently of photosynthesis. *Journal of Experimentally Botany*, **63** (12), 4359-4373.

WANG, M., ZHENG, Q., SHEN, Q & GUO, S. (2013). The critical role of potassium in plant stress response. *International Journal of Molecular Science,* **14**, 7370-7390.

WENG, X. Y., ZHENG, C. J., XU, H. X. & SUN, J. Y. (2007). Characteristics of photosynthesis and functions of the water–water cycle in rice (*Oryza sativa* l.) leaves in response to potassium deficiency. *Physiologia Plantarum,* **131** (4), 614–621. doi: 10.1111/j.1399-3054.2007.00978.x

WOLE, O. (2013). Unlimited nutritional benefits of African star apple. *Natural Health,1*(1): 1-4.

ZAIED, N.S., KHAFEGY, S.A.A. & SALEH,M.A. (2006). Effect of nitrogen and potassium fertilization on vegetative growth, fruit set and quality of Washington Navel orange tree. *Journal of Applied Research*, **2**, 851-857.

ZHAO, W., DONG, H., ZAHOOR, R., ZHOU, Z., SNIDER, J. L., CHEN, Y., SIDDIQUE, K.H.M. & WANGA, Y. (2019). Ameliorative effects of potassium on drought-induced decreases in fiber length of cotton (*Gossypium hirsutum* l.) are associated with osmolyte dynamics during fiber development. *Crop Journal,* **7** (5), 619–634. doi: 10.1016/j.cj.2019.03.008

XU, X., DU, X., WANG, F., SHA, J., CHEN, Q., TIAN,G., ZHU, Z., Ge, S. & JIANG, Y.(2020). Effects of potassium levels on plant growth, accumulation and distribution of carbon, and nitrate metabolism in apple dwarf rootstock seedlings. *Frontiers in Plant Science,***11** (904), 1-13.

XU, Q., FU, H., ZHU, B., HUSSAIN, H.A., ZHANG, K., TIAN, X., DUAN, M., XIE, X. & WANG, L.(2021). Potassium improves drought stress tolerance in plants by affecting root morphology, root exudates, and microbial diversity. *Metabolites 2021,* 11, 131. https://doi.org/10.3390/ metabo11030131

YOUSUF, S., SHEIKH, M. A., CHAND, S. & ANJUM, J. (2018). Effect of different sources of potassium on yield and quality of apple (cv. Red Delicious) in temperate conditions. *Journal of Applied and Natural Science*, **10** (4), 1332-1340. https://doi.org/10.31018/jans.v10i4.1945

Received 13 Sept. 25; revised 29 Jul. 26.