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RESEARCH PAPER

Effect of Different Irrigation Periods and Mulching on Growth of *Paulownia tomentosa* (Thunb.) Steud. Seedlings.

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A B S T R A C T:
To obtain high quality and quantity forest seedlings, silvicultural practices have been implemented in the nursery. Watering and mulching are two the most important silvicultural treatments that must be managed carefully in forest nursery in order to obtain healthy seedlings. The aim of the present study was to evaluate the effect of irrigation periods, mulching treatments and their interactions on the growth and development of *Paulownia tomentosa* seedlings. A factorial completely randomized design (CRD) with two factors was applied. The first factor was four irrigation periods which were once daily (D1), once every two days (D2), once every three days (D3), and once every four days (D4). The second factor was two mulching treatments which were mulching (M1) and non-mulching (M2). Each treatment was replicated five times. Morphological and physiological parameters of identified seedlings were studied. It is found that the irrigation periods significantly effect on the studied parameters, where the highest value of stem height increment (45.5 cm), stem diameter increment (4.74 cm), leaf number increment (10.3), stem dry weight (28.78 g), leaf dry weight (18.21 g), root dry weight (63.04 g), total dry weight (110.01 g), stem mass ratio (0.27), Dickson quality index (1.84), leaf area (3656.78 cm^2) and specific leaf area (200.18 $cm^2\ g^{-1}$) were recorded from the seedlings that watered daily(D1), while the lowest value of these parameters were obtained from the seedlings that watered once every four days(D4). Moreover, most of the biomass and physiological parameters were significantly affected by mulching treatments and the maximum value of them were found in the seedlings that mulched with hay. Thus, the study suggested that to enhance growth and development of Paulownia seedlings, the seedlings should be watered daily and mulched with an organic material.

KEY WORDS: Dickson quality index, Fast growing species, Mulching, Seedling production Silvicultural treatments, Water interval.
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1. INTRODUCTION:

Paulownia which is generally known royal paulownia is a genus belonging to Paulowniaceae, native to China and it has more than 20 species (Barton *et al.*, 2007). They are deciduous trees and fast-growing wood species. Under optimum conditions, it grows to 10–20 m in height and 30–40 cm in diameter at breast height, and each tree could produce 1 m^3 of wood at the age of 5–7 years (Caparrós *et al.*, 2008). At the mature stage its stem height can reach 20 - 30 m, and its diameter can reach 2 m, which makes it an excellent source of timber (Alagawany *et al.*, 2020).

Paulownia tomentosa (Thunb.) Steud. can be used as soil cleaner because it can absorb heavy metals such as zinc from soils (Azzarello *et al.*, 2012). It is possible to cultivate Paulownia with other crops (intercropping) such as wheat, corn, soybeans, peas, beans, barley, cotton, vegetables and herbs that can be farmed between the rows of *Paulownia* (Barton *et al.*, 2007). The wood is highly valued throughout the world as a source material for a wide range of products: construction materials, furniture, boats, musical instruments, etc (EL-Showk and EL-Showk, 2003). Paulownia leaves are also a good source of carbohydrates and protein and it can be compared to legume family crops in terms of the nutritional

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value of the leaves. Therefore, it is used as feed for livestock, green fertilizer, or peat moss manufacturing (Al Taher *et al*., 2020).

Given the potential of the aforementioned species, nurserymen should produce it for afforestation and reforestation operations. Several silvicultural treatments have been used in the nursery to produce good quality forest seedlings. Watering and mulching are two the most important abiotic factors that must be managed carefully in nursery in order to obtain healthy seedlings.

Water availability is a significant concern, particularly in forestry and nursery produced seedlings in dry regions. Water is a main component of all living creatures and plays a significant role in metabolic processes (Oboho and Igharo, 2017). Water is vital to plant growth because it regulates the rate of transpiration, which has an impact on the influx of nutritional solutions (Aderounmu *et al*., 2017). Water availability and consumption in plants are directly proportional to plant growth and biomass output (Olajuyigbe *et al*., 2012), as well as it has a crucial role in plant growth, development, and production (Emmanuel, 2014; Ogidan *et al*., 2018).

Mulches can be used efficiently in the field and nursery production as well (Chalker-Scott, 2007). Moisture content, soil temperature, and the availability of nutrients are all directly impacted by mulching. When mulch is applied into the topsoil, the rate of evaporation declines, maintaining a higher moisture content for a longer period of time (Gill and Jalota 1996; Sharma *et al*. 1998). Plants can access this moisture, which can reduce water requirement. The metabolic activity of the soil microorganisms that recycle and release nutrients necessary for a healthy floral community depends on proper moisture levels (Couteaux *et al*. 1995). Soil organisms and plants are killed at extremely high and low soil temperatures (Grinstein *et al*. 1995; Athy *et al*., 2006). The temperature of soil can also be modified by a covering of mulch (Athy *et al*., 2006). Gonzalez-Sosa *et al*. (2001) discovered that mulched with plant residuals had the power to cool the underlying soil and reduce the seasonal temperature range when compared to non-mulched plots. Mulching results in a positive adjustment of soil properties that has a noticeable impact on plant survival, growth and development (Tomlinson *et al*., 1997; Haywood, 1999). Mulch also significantly reduced weed germination and growth as well as plant disease, subsequently enhanced root establishment and upgraded overall plant growth performance (Chalker-Scott, 2007).

Therefore, the main aim of the study was to determine the water requirement and mulching effect at the nursery for rising and producing *Paulownia tomentosa* seedlings. The specific objectives of the study were to evaluate the effect of irrigation periods, mulching treatments and their interactions on the growth and development of the studied species.

2. MATERIALS AND METHODS

2.1. Study Location

The study was conducted from the early June to the late October 2021 on *Paulownia tomentosa* seedlings under an arched house that covered by a layer of plastic green net that allows 50% of full sunlight at Girdarasha field (Altitude: 415 meters above sea level, Longitude: 4401 00′ 45.5 ″ E, Latitude: 360 06′ 48.9 ″ N) that follows to the College of Agricultural Engineering Sciences, Salahaddin University-Erbil.

The required numbers of new sprouted *Paulownia tomentosa* seedlings (from root cutting) were provided and supported by a private company named Hawargay Hawkary for Paulownia tree in Erbil city. The average stem height and diameter of the seedlings were approximately 29.11 ± 0.96 cm and 7.69 ± 0.16 mm respectively. The seedlings were grown in the pot (7L) that filled with 8 kg of sandy clay loamy soil.

2.2 The Experimental Design

The experiment was conducted based on a factorial completely randomized design (CRD) with two factors. The first factor was considered was four irrigation periods which were; once daily (D1), once every two days (D2), once every three days (D3), and once every four days (D4). The water field capacity of the potted soil was found as proceed by Qadir *et al.* (2016). On this base (1.5 L) water added as full capacity for each irrigation periods. The second factor was two mulching treatments which were mulching (M1) with an organic matter which was hay and non-mulching (M2). Each treatment was replicated five times. So, that the total number of experimental units was 40 and for each one contained one seedling.

2.3 Seedling Measurements

2.3.1 Seedlings Survival

At the end of the experiment; survival percentage of the seedlings was calculated by the following formula (Engelbrecht *et al*., 2005):

$$\text{Survival percentage (\%)} = \frac{\text{Number of remained seedlings}}{\text{Number of total used seedlings}} \text{ x } 100$$

2.3.2 Morphological Growth Parameters

At the beginning of the experiment (July), growth parameters which were stem height (cm), stem diameter (mm) and leaf number for all seedlings were measured, and the average of these parameters were 25.40cm, 6.82mm, and 10.37 respectively. Tape in centimeter units was used to measure the stem height from the edge of the containers to the uppermost living apical shoot. A digital vernier caliper in millimeter units (Digimatic caliper Mitutoyo-Japan) was used to calculate the stem diameter at the edge level of the containers. Number of leaves for each seedling was calculated manually. Furthermore, the above-mentioned parameters re-calculated at the end of the trial (October) to discover increments of stem height (cm), stem diameter (mm) and leaf number.

2.3.3 Biomass Measurements

2.3.3.1 Biomass Allocation

From each treatment three seedlings were randomly selected and destructed at the end of the experiment. The roots were cleaned carefully from the soil by washing. The seedlings were parted into their contents (stem, leaf, and root) and dried by oven at 80 ºC until a constant dry weights were established (Sherzad *et al*., 2017). Parts of seedlings were then weighted by a sensitive digital balance to calculate stem dry weight, leaf dry weight, root dry weight and total seedling dry weight.

2.3.3.2 Biomass Ratio and Dickson Quality Index

Parameters of biomass ratio were calculated from the parameters of biomass allocation(Sherzad *et al*., 2017). The biomass ratios involved stem mass ratio (SMR) (stem dry weight / total dry weight of the seedling), leaf mass ratio (LMR) (leaf dry weight / total dry weight of the seedling), root mass ratio (RMR) (root dry weight / total dry weight of the seedling), root to shoot ratio (R:S) (root dry weight / shoot dry weight).

Dickson Quality Index (DQI) was measured to evaluate seedling quality index using the following equation (Dickson *et al*., 1960):

$$\boldsymbol{DQI} = \frac{\boldsymbol{TDW\ (g)}}{\frac{\boldsymbol{SH(cm)}}{\boldsymbol{SD(cm)}} + \frac{\boldsymbol{SDW(g)}}{\boldsymbol{RDW(g)}}}$$

Where:
TDW: total dry weight (g).
SH: stem height (cm).
SD: stem diameter (cm).
SDW: shoot dry weight (g).
RDW: root dry weight (g).

2.3.4 Morphological and Physiological Parameters of the Leaf

The parameters included leaf area (LA), specific leaf area (SLA) (leaf area/leaf dry weight), leaf water content (LWC) and chlorophyll content. To estimate leaf area (cm^2), three seedlings were randomly chosen from each treatment, then their leaves were separately collected, afterward, the leaves were sited on a white paper and their pictures were taken by the camera. The pictures were transferred to the laptop and leaf area measured using Image J software as described by Ahmad *et al*. (2015). To calculate leaf water content (LWC), the fresh leaves of each seedlings were weighed and recorded as leaf fresh weight (LFW), then oven dried at 80◦C until constant dry weights were obtained. The dry leaves were weighed and recorded as leaf dry weight (LDW). Then LWC was measured based on the following formula (Jin *et al*., 2017):

$$\boldsymbol{LWC}(\%) = \frac{\boldsymbol{LFW - LDR}}{\textbf{LFW}} \text{ X } 100$$

The measurement of chlorophyll content was achieved for all seedlings under the study using a portable chlorophyll meter SPAD-502 (Minolta Co. Ltd. Japan). Moreover, the mean of three chlorophyll content readings was obtained from the three leaves in three positions (top, middle and bottom) per plant (Sherzad *et al.,* 2015).

2.4 Data Analysis

All data of the studied parameters were analyzed according to the Analysis of Variance (ANOVA) using SPSS Version 26. The significant differences between treatment means were compared by Duncan Multiple Rang Test at $p \leq 0.05$.

3. RESULTS AND DISCUSSIONS

Results in Table 1, showed that survival percentage of *Paulownia tomentosa* seedlings was not significantly differed ($P > 0.05$) under different irrigation periods. On the other hand, increments of stem height, stem diameter and leaf number were significantly ($P < 0.05$) affected by different irrigation intervals, where the highest significant value of stem height increment (45.50 cm), stem diameter increment (4.74 mm) and leaf number increment (10.30) were obtained from the seedlings watered daily (D1), while the value of these growth parameters decreased by increasing irrigation intervals as the lowest increments of them were 11.76 cm, 1.47 mm and 3.60 respectively in the seedlings irrigated once every four days (D4). These results demonstrated that *Paulownia tomentosa* potted seedlings grew very well when they were irrigated daily. However, drought stress had negative impact on the growth of the studied species. The decrease in stem height and diameter may be linked to the stunted growth and increased leaf drop of plants under water stress. Water stress may have a negative impact on growth due to alterations in a number of physiological processes. Due to the reduction in turgor pressure, the formation of cells is thought to be one of the physiological processes that is most vulnerable to dryness (Rostami and Rahemi, 2013). Moreover, Plants grown under drought conditions tend to have lower stomatal conductance, thus helping water conservation and maintenance of an adequate leaf water status, but at the same time reducing leaf internal CO_2 concentration and photosynthesis and subsequently decreasing growth (Chaves *et al*., 2002). Reduction in stem diameter under water stress in the present study may be due to decreased water availability which causes shrinking of xylem vessels and decreased circular growth of stem (Rostami and Rahemi, 2013). These findings are in accordance with the study of Deligoz *et al*. (2016) who documented that the growth of *Cedrus libani* seedlings significantly reduced under drought stress condition compared with well-watered seedlings. Khan *et al*. (1996) also reported that *Pseudotsuga menziesii* seedlings' height and diameter reduced as soil water content declined. In addition, decreasing growth rate of two types of oak tree seedlings (*Quercus cerris* and *Quercus robur*) under drought stress was observed in a study by Deligoz and Bayar (2018). Bian *et al.* (2021) showed that stem height and stem diameter of *Cunninghamia lanceolata* significantly reduced when the seedlings grown under low water content condition compared with well-watered condition.

Table (1): Effect of irrigation periods on survival percentage, stem height increment, stem diameter increment, and leaf number increment of *Paulownia tomentosa* seedlings

Irrigation periods	Survival percentage (%)	Stem height increment (cm)	Stem diameter increment (mm)	Leaf number increment
Once daily (D1)	100 a	45.50 a	4.74 a	10.30 a
Once every two days (D2)	90 a	20.35 b	2.82 b	6.20 b
Once every three days (D3)	90 a	17.60 b	2.32 b	6.13 b
Once every four days (D4)	90 a	11.76 c	1.47 c	3.60 b
P- value	*0.801*	*0.000*	*0.000*	*0.000*

Means with the same letter in a column are not significantly different by Duncan at $p \leq 0.05$.

Nonsignificant effects with applying mulching treatments (P > 0.05) was observed on the survival percentage, increments of stem height, stem diameter and leaf number (Table 2). Even though several prior studies appeared the significant role of mulching in enrichment the survival and growth of the plants (Gupta, 1991; Mishra *et al*., 1996; Calkins *et al*., 1996; Foshee *et al*., 1996; Singh and Singh,1999; Cahill *et al*., 2005, Athy *et al*., 2006; Hjelm *et al*.,2018), some others revealed that mulching treatment did not have any significant improvement on the survival and growth of other plants (Adams, 1997; Ugese *et al*.,2010; Blanco-García *et al*., 2011). These differences probably due to used various mulching types, different plant species, and applied in different environmental conditions and different duration the experiments.

Table (2): Effect of mulching treatments on survival percentage, stem height increment, stem diameter increment, and leaf number increment of *Paulownia tomentosa* seedlings

Mulching treatments	Survival percentage (%)	Stem height increment (cm)	Stem diameter increment (mm)	Leaf number increment
Mulching (M1)	100 a	24.80 a	3.02 a	6.75 a
Non mulching (M2)	85 a	22.81 a	2.65 a	6.36 a
P- value	*0.093*	*0.287*	*0.230*	*0.641*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Significant interaction effect of irrigation periods and mulching treatments observed only on the leaf number increment (Table 3), as the seedlings watered daily and non-mulched (D1M2) recorded higher leaf number (12.20) compared with other combination treatments, whereas the minimum leaf number increment (2) was found in the seedlings watered once every four days and non-mulched (D4M2). It means that when the seedlings irrigated daily, mulching treatment did not need to increase the leaf number because at that situation soil moisture content might be over full capacity which negatively impact on this growth parameter. In contrary, when watering interval increased, mulching treatment should be applied to conserve soil moisture for a longer time.

Table (3): Interaction effect of irrigation periods and mulching treatments on survival percentage, stem height increment, stem diameter increment, and leaf number increment of *Paulownia tomentosa* seedlings

Combination treatments	Survival percentage (%)	Stem height increment (cm)	Stem diameter increment (mm)	Leaf number increment
D1+M1	100 a	45.40 a	4.64 a	8.40 b
D1+M2	100 a	45.60 a	4.84 a	12.20 a
D2+M1	100 a	22.20 a	2.93 a	6.40 b
D2+M2	80 a	18.50 a	2.71 a	6.00 b
D3+M1	100 a	19.20 a	2.94 a	7.00 b
D3+M2	80 a	16.00 a	1.70 a	5.25 bc
D4+M1	100 a	12.40 a	1.58 a	5.20 bc
D4+M2	80 a	11.13 a	1.36 a	2.00 c
P- value	*0.801*	*0.863*	*0.391*	*0.027*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Results in Table 4 illustrated that biomass dry weight of *Paulownia tomentosa* seedlings which included stem dry weight, leaf dry weight, root dry weight and total seedling dry weight dramatically (P< 0.05) influenced by various irrigation periods. Moreover, comparison means among irrigation treatments demonstrated that the greatest dry weight of different parts of the seedlings and total dry weight were found in the seedlings well-watered (D1). However, when the seedlings faced drought stress their partial dry weight were critically reduced with increased watering intervals, as the lowest value of stem dry weight, leaf dry weight, root dry weight and total seedling dry weight were occurred in the seedlings irrigated once every four days (D4). In addition, dry weight of stem (28.76 g), leaf (18.21 g), root (63.04 g) and total seedling parts (110.01 g) that watered every day were more than three times weightier than those watered every four days (7.12 g, 4.94 g, 19.18 g and 31.24 g respectively). These results indicated that water is an important factor in the growth, development and productivity of plants. Water is a major constituent of all living organisms which is involved in important biochemical processes including photosynthesis thus its availability in adequate quantity and at biologically tolerable interval affects productivity of plant species (Emmanuel, 2014). The regular watering allows nutrient to dissolve and transport to appropriate area for leaf expansion for photosynthesis, hence the higher biomass under the well-watered condition (Olubode *et al*., 2016). Hartmann *et al.* (2005) reported that water stress due to drought is the most significant abiotic factor limiting plant growth and development. Water stress drastically decreased plant fresh and dry weight, leaf number, total leaf area and stomatal conductance (Vandoorne *et al*., 2012). The limitation in biomass allocation due to water stress is basically caused by decrease in carbon balance depending on the balance between photosynthesis and respiration in the plant (Flexas *et al*., 2006).

Many researchers were observed the same finding such as, Emmanuel, (2014) stated that seedlings of *Picralima nitida* which received the lowest water rate (10 ml) at the longest intervals of 5 days had the lowest biomass value. González *et al*. (2009) also displayed that drought stress negatively influenced on biomass allocation of *Chenopodium quinoa.* Deligoz *et al*. (2016) who reported that the drought stress had caused significant reductions in dried weight of shoot, root and needle of *Cedrus libani* seedlings. I addition, *Ptach et al.* (2017) found tha sprinkler irrigation significantly increased stem height, stem diameter and leaf number which resulted in an increase in biomass yield of *Paulownia* trees at the first-year cultivation compared with non-irrigated trees.

Table (4): Effect of irrigation periods on stem dry weight, leaf dry weight, root dry weight, and total seedling dry weight of *Paulownia tomentosa* seedlings

Irrigation periods	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Total seedling dry weight (g)
Once daily (D1)	28.76 a	18.21 a	63.04 a	110.01 a
Once every two days (D2)	11.12 b	11.13 b	38.69 b	60.93 b
Once every three days (D3)	9.58 b	6.75 c	25.13 c	41.45 c
Once every four days (D4)	7.12 b	4.94 d	19.18 c	31.24 c
P- value	*0.000*	*0.000*	*0.000*	*0.000*

Means with the same letter in a column are not significantly different by Duncan at $p \leq 0.05$.

Results of mulching treatments in Table 5 exposed that all biomass parameters except of leaf dry weight were significantly ($P < 0.05$) impacted by mulching treatments. In addition, the seedlings were grown under mulching treatment with hay significantly increased in stem dry weight (15.75 g), root dry weight (42.34 g) and total plant dry weight (68.63 g) as compare to those non mulched. These results were in agreement with Gupta (1991) who stated that mulching treatment (coir pith) significantly increased stem dry weight, leaf dry weight, root dry weight and total plant dry weight of *Eucalyptus camaldulensis*, *Acacia nilotica*, *Acacia planifrons* and *Peltophorum pterocarpum* compared to the control treatment. The significant effect of mulching treatment on the seedling biomass in the present study may be due to an important role of mulching which decreases the evaporation rate from soil surface, thus increases moisture content keeps greater moisture, protects soils from extreme temperatures and reduces weed growth (Athy *et al*., 2006 and Chalker-Scott, 2007). Appropriate moisture and temperature are important for metabolic activity of the soil microbes that recycle and release nutrients that are essential for enhancing plant biomass. Beside above-mentioned benefits mulch residue affects the dynamics of soil organic matter (SOM), such as an increase in mulch residues can increase dissolved organic carbon (C) and nitrogen (N) by the decomposition of plant materials and leaching (Chantigny, 2003).

Table (5): Effect of mulching treatments on stem dry weight, leaf dry weight, root dry weight, and total seedling dry weight of *Paulownia tomentosa* seedlings

Mulching treatments	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Total seedling dry weight (g)
Mulching (M1)	15.75 a	10.53 a	42.34 a	68.63 a
Non mulching (M2)	12.53 b	9.98 a	30.68 b	53.19 b
P- value	*0.042*	*0.332*	*0.016*	*0.021*

Means with the same letter in a column are not significantly different by Duncan at $p \leq 0.05$.

There were interaction effect of irrigation periods and mulching treatments only on the leaf dry weight, where the seedlings that irrigated daily and either mulched (19.15 g) or non-mulched (17.28 g) were significantly better than other treatment combinations (Table 6). This result confirmed the prior results in Table 4 and 5 that appeared irrigation periods were more effective than mulching treatments in terms of the leaf dry weight.

Table (6): Interaction effect of irrigation periods and mulching treatments on stem dry weight, leaf dry weight, root dry weight, and total seedling dry weight of *Paulownia tomentosa* seedlings

Combination treatments	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Total seedling dry weight (g)
D1+M1	32.25 a	19.15 a	77.42 a	128.82 a
D1+M2	25.26 a	17.28 a	48.66 a	91.20 a
D2+M1	11.37 a	10.46 b	44.99 a	66.81 a
D2+M2	10.87 a	11.80 b	32.39 a	55.06 a
D3+M1	12.03 a	8.09 c	26.02 a	46.13 a
D3+M2	7.14 a	5.41 d	24.24 a	36.78 a
D4+M1	7.37 a	4.45 d	20.94 a	32.76 a
D4+M2	6.87 a	5.43 d	17.43 a	29.73 a
P- value	*0.324*	*0.047*	*0.151*	*0. 229*

Means with the same letter in a column are not significantly different by Duncan at $p \leq 0.05$.

Table 7 elucidated that the watering periods had high significant ($P < 0.05$) influence on all biomass ratio parameters and Dickson quality index of the seedlings except leaf mass ratio. The seedlings that watered once every day (D1, well-watered), significantly allocated more dry mass in stem part comparted to other irrigation periods. In contrast, when the seedlings were exposed to watered once every two (D2), three (D3) or four (D4) days significantly allocated more dry mass in root system and root to shoot ratio also increased. This phenomenon is a mechanism of the species to acclimate with drought stress condition. Similar results were reported by the previous researchers. For instance, Susiluoto and Berninger (2007) revealed that under drought stress, root to shoot ratio significantly increased in *Eucalyptus microtheca* species. Zang *et al.*, (2014) also noted that, in *Fagus sylvatica* seedlings, root:shoot ratio increased with increasing drought stress. Deligoz *et al*. (2016) showed that *Cedrus libani* seedlings had increased their root to shoot ratio in response to drought stress. Deligoz and Bayar (2018) investigated that the root to shoot ratio in *Quercus robur* increased in water stress condition. In fact, increase in root growth or decrease in shoot / root ratio is considered to be a general response against water stress (Dickson and Tomlinson, 1996) Because seedlings may maximize their water intake from soil with a strong root systems in order to ensure their growth and survival (Chaves *et al*., 2003 and Wu *et al*., 2013).

In addition, based on Dickson quality index, quality of the seedlings enhanced significantly when the seedlings irrigated once daily (1.84). However, for the rest of seedlings this measurement was gradually decreased with increased periods of irrigation (1.32, 0.79 and 0.67 respectively). Thus, result of Dickson Quality Index approved that regular watering is a key factor for improving quality of *Paulownia tomentosa* seedlings.

Table (7): Effect of irrigation periods on stem mass ratio, leaf mass ratio, root mass ratio, root to shoot ratio and Dickson quality index of *Paulownia tomentosa* seedlings

Irrigation periods	Stem mass ratio	Leaf mass ratio	Root mass ratio	Root to Shoot ratio	Dickson quality index
Once daily (D1)	0.27 a	0.173 a	0.56 b	1.31 b	1.84 a
Once every two days (D2)	0.18 c	0.185 a	0.63 a	1.76 a	1.32 b
Once every three days (D3)	0.23 b	0.162 a	0.61 a	1.62 a	0.79 c
Once every four days (D4)	0.23 b	0.160 a	0.61 a	1.60 a	0.67 c
P- value	*0.000*	*0.108*	*0.002*	*0.000*	*0.000*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Table 8 showed that mulching treatments had not any significant (P > 0.05) effect on the stem mass ratio and Dickson quality index. On the other hand, mulching treatments had significant impact on the leaf mass ratio, root mass ratio and root to shoot ratio. Furthermore, leaf mass ratio was significantly higher in the seedlings that non-mulched compared with those mulched, this indicated that the seedlings were not mulched had higher leaf mass than those mulched due to increased leaf thickness and density as general trend to reduce water lose through transpiration in the seedlings grown on non-mulched growing media where soil moisture lower than mulched growing media (Chalker-Scott, 2007). In contrast, root mass ratio and root to shoot ratio were significantly developed in the seedlings that mulched compared with those non-mulched. Several studies have proved that enhanced water preservation and weed competition decreased as happened in mulched positions are correlated with improved root growth by desirable plants (Fausett and Rom., 2001; Wood *et al*., 1994). Mulches permit roots of plant to spread and establish far beyond the stem compared to non-mulched (bare) soil (Burgess *et al*., 1997) and consequently become gradually stabilized.

Table (8): Effect of mulching treatments on stem mass ratio, leaf mass ratio, root mass ratio, root to shoot ratio and Dickson quality index of *Paulownia tomentosa* seedlings

Mulching treatments	Stem mass ratio	Leaf mass ratio	Root mass ratio	Root to Shoot ratio	Dickson quality index
Mulching (M1)	0.23 a	0.16 b	0.62 a	1.66 a	1.25 a
Non mulching (M2)	0.22 a	0.18 a	0.59 b	1.49 b	1.06 a
P- value	*0.512*	*0.003*	*0.043*	*0.048*	*0.173*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

There were significant combination effects of irrigation periods and mulching treatments on stem mass ratio, leaf mass ratio, root mass ratio and root to shoot ratio (Table 9). In addition, the highest and lowest mean values of stem mass ratio were recorded in D1M2 and D2M1 respectively. Table 9, also appeared that to improve stem mass ratio the seedlings did not require mulching when they watered once every day or every two days, while the positive effect of mulching appeared when the seedlings irrigated once every three days. The maximum and minimum mean values of leaf mass ratio were obtained from the seedlings that watered once every two days and non-mulched (D2M2) and the seedlings that watered once every four days and mulched (D4M1) respectively. Moreover, the greatest mean values of both the root mass ratio and root to shoot mass ratio were found in the seedlings that treated with D2M1, while the smallest value of these two parameters were observed in the seedlings that treated with D1M2.

Table (9): Interaction effect of irrigation periods and mulching treatments on stem mass ratio, leaf mass ratio, root mass ratio, root to shoot ratio and Dickson quality index of *Paulownia tomentosa* seedlings

Combination treatments	Stem mass ratio	Leaf mass ratio	Root mass ratio	Root to Shoot ratio	Dickson quality index
D1+M1	0.25 b	0.16 bcd	0.59 b	1.47 bc	2.13 a
D1+M2	0.28 a	0.19 ab	0.53 c	1.15 c	1.55 a
D2+M1	0.17 e	0.16 bcd	0.67 a	2.09 a	1.41 a
D2+M2	0.20 d	0.21 a	0.59 b	1.43 bc	1.22 a
D3+M1	0.26 b	0.18 ab	0.56 bc	1.29 c	0.83 a
D3+M2	0.19 d	0.15 ab	0.66 a	1.95 a	0.75 a
D4+M1	0.22 c	0.14 d	0.64 a	1.77 ab	0.62 a
D4+M2	0.23 c	0.18 ab	0.59 b	1.44 bc	0.72 a
P- value	*0.000*	*0.004*	*0.000*	*0.000*	*0.354*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Results in Table 10 revealed that the mean values of leaf area (LA) and specific leaf area (SLA) were significantly influenced ($P < 0.05$) by different irrigation periods. However, leaf water content (LWC) and chlorophyll content were not significantly affected ($P > 0.05$) by different irrigation periods. Furthermore, the seedlings that irrigated daily had the greatest leaf area (3656.78 cm^2) and specific leaf area (200.18 cm^2 g^{-1}), whereas the lowest mean values of these two parameters (747.77 cm^2 and 154.60 cm^2 g^{-1} respectively) were observed for D4. The significant decreasing LA and SLA displayed that leaf enlargement were more sensitive than LWC and chlorophyll content in the leaves to water stress. Thus, well-watered treatment required to enhance leaf expansion of *Paulownia tomentosa* seedlings. This is in conformity with the report of Fotelli *et al.* (2000) who found that leaf size, leaf number and consequently total leaf area tended to be higher in well-watered seedlings than in drought-treated seedlings, for all four oak species (*Quercus frainetto*, *Quercus pubescens*, *Quercus macrolepis* and *Quercus ilex*). Marron et al. (2003) who showed that leaf area and specific leaf area of two *Populus canadensis* (Moench) clones were significantly reduced when were exposed to drought condition. SLA means the ratio between leaf area and leaf dry weight. A lower SLA is a consequence of an increase in the density or thickness of leaf tissue compared with leaf area (Centritto, 2002). So, as a result of drought stress SLA of *Paulownia tomentosa* seedlings declined compared with well-watered treatment. Generally, plants would reduce their leaf area, shed their old ones, and an increase in leaf thickness as a part of survival strategy to conserve water during the period of water limitation (Pallardy, 2008).

The result was in agreement with previously work by other researches that SLA of different plants reduced under drought conditions (Kozlowski, 1997 and Karimi *et al.*, 2012).

Table (10): Effect of irrigation periods on leaf area, specific leaf area, leaf water content and chlorophyll content of *Paulownia tomentosa* seedlings

Irrigation periods	Leaf area (cm^2)	Specific leaf area (cm^2 g^{-1})	Leaf water content (%)	Chlorophyll content
Once daily (D1)	3656.78 a	200.18 a	73.60 a	34.61 a
Once every two days (D2)	1860.23 b	167.28 b	73.58 a	32.41 a
Once every three days (D3)	1190.64 c	182.30 ab	72.70 a	33.49 a
Once every four days (D4)	747.77 d	154.60 b	72.37 a	32.27 a
P- value	*0.000*	*0.038*	*0.086*	*0.138*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Mulching treatments had significant effect ($P < 0.05$) on the leaf area, leaf water content and chlorophyll content. On the other hand, they had not significant impact on the specific leaf area (Table 11). Furthermore, the seedlings mulched (M1) by hay were significantly better than those no mulched (M2) in terms of the leaf area and leaf water content, these may due to the positive effect of mulching treatment which enhance the content and availability of water in soil by reducing evaporative losses to alleviate harmful effects of drought (Awasthi *et al.*, 2006) and consequently increased the leaf area and leaf water content of *Paulownia tomentosa* seedlings. In contrast, the chlorophyll content was significantly higher in the seedlings that were no mulched (M2) compared with those mulched (M1). The decreased of chlorophyll content after applied mulching treatment in the present study might due to increasing the hay mulching level as shown by Zhang *et al.* (2015) who displayed that a suitable hay mulching level significantly increased chlorophyll content, while when the hay mulching level raised to a certain level, it negatively influenced on the chlorophyll content.

Table (11): Effect of mulching on leaf area, specific leaf area, leaf water content and chlorophyll content of *Paulownia tomentosa* seedlings

Mulching treatments	Leaf area (cm^2)	Specific leaf area (cm^2 g^{-1})	Leaf water content (%)	Chlorophyll content
Mulching (M1)	2090.88 a	186.54 a	73.66 a	31.79 b
Non mulching (M2)	1636.83 b	165.64 a	72.46 b	34.60 a
P- value	*0.006*	*0.062*	*0.007*	*0.001*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

Results in Table 12 revealed that combination treatments of irrigation periods and mulching treatments were positively increased seedling leaf area. Moreover, the seedlings were irrigated daily and mulched recorded the biggest leaf area (4526.58 cm^2), whereas the smallest leaf area (705.89 cm^2) was achieved in the seedlings that were irrigated once every four days and non-mulched. The results also demonstrated that the leaf area was dramatically reduced with increasing periods of irrigation especially when the seedlings were no mulched. This indicated that in order to enhancing leaf area the seedlings should be watered daily and mulched with hay because availability of water content in the soil is an essential factor to perform physiological process sufficiently in the plant (Oboho and Igharo, 2017) and mulching has a critical role in water conservation, and adding nutrients to the soil during the hay decomposed (Saeed and Ahmad, 2009).

Results in Table 12, also displayed that the specific leaf area was significantly influenced by combination effect of irrigation period and mulching treatments. Furthermore, the highest specific leaf area was observed in the seedlings that watered daily and mulched. However, the smallest specific leaf area was detected in the seedlings that watered once time every four days and no mulched. This result revealed that leaf area was more expended than the leaf dry weight when the seedling grown under well-watered condition. However, when the seedling grown under drought stress the leaf area reduced and leaf dry weight increased, which are considered as morphological mechanisms to survive under drought stress condition (Pallardy, 2008).

Table (12): Interaction effect of irrigation periods and mulching treatments on leaf area, specific leaf area, leaf water content and chlorophyll content of *Paulownia tomentosa* seedlings

Combination treatments	Leaf area (cm^2)	Specific leaf area (cm^2 g^{-1})	Leaf water content (%)	Chlorophyll content
D1+M1	4526.58 a	238.21 a	74.03 a	34.00 a
D1+M2	2786.98 b	162.15 bc	73.17 a	35.22 a
D2+M1	1687.78 cd	162.49 bc	73.34 a	31.56 a
D2+M2	2032.69 c	172.06 bc	73.81 a	33.25 a
D3+M1	1359.51 de	167.97 bc	73.91 a	31.86 a
D3+M2	1021.78 e	196.63 ab	71.49 a	35.13 a
D4+M1	789.64 e	177.49 bc	73.37 a	29.74 a
D4+M2	705.89 e	131.70 bc	71.36 a	34.80 a
P- value	*0.000*	*0.009*	*0.070*	*0.321*

Means with the same letter in a column are not significantly different by Duncan at p ≤ 0.05.

4. CONCLUSIONS

It can be concluded from the present study that irrigation and mulch were two main abiotic factors that had significant role in enhancing some growth parameters and development of *Paulownia tomentosa* seedlings in the nursery stages. The suitable period of irrigation was once every day and used hay as mulching around the seedlings. The findings will assist nursery workers in producing high-quality, healthy seedlings of *Paulownia tomentosa* to fulfill plantation plans.

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References

Adams, J.C., 1997. Mulching improves early growth of four oak species in plantation establishment. *Southern Journal of Applied Forestry*, *21*(1), pp.44-46.

Aderounmu, A.F., Adenuga, D.A., Ogidan, O.A and Alonge, O.O., 2017. Effect of different watering regimes on the early growth of *Terminalia superba* ENGL and DIELS. In: Adekunle, V.A.J., Ogunsanwo, O.Y and Akinwole, A.O (Eds). Harnessing the Uniqueness of Forest for Sustainable Development in a Diversifying Economy. Proceedings of the 39th Annual Conference of the Forestry Association of Nigeria. pp183-189.

Ahmad, S., Ali, H., Ur Rehman, A., Khan, R.J.Z., Ahmad, W., Fatima, Z., Abbas, G., Irfan, M., Ali, H., Khan, M.A. and Hasanuzzaman, M., 2015. Measuring leaf area of winter cereals by different techniques: A comparison. *Pakistan Journal of Life and Social Sciences*, *13*(2), pp.117-125.

Al Taher, Z.A.A., Hassan, F.A. and Hassan, A.R.O., 2020. Effect of nitrogen fertilizer, ascorbic acid, the number of additions, and their interactions on the physical traits of Paulownia plant (*Paulownia tomentose* L.). *Euphrates journal of agriculture science*, *12*(1), pp. *42-55*.

Alagawany, M., Farag, M.R., Sahfi, M.E., Elnesr, S.S., Alqaisi, O., El-Kassas, S., Al-Wajeeh, A.S., Taha, A.E. and Abd E-Hack, M.E., 2020. Phytochemical characteristics of Paulownia trees wastes and its use as unconventional feedstuff in animal feed. *Animal Biotechnology*, *33*(3), pp.586-593.

Athy, E.R., Keiffer, C.H. and Stevens, M.H., 2006. Effects of mulch on seedlings and soil on a closed landfill. *Restoration Ecology*, *14*(2), pp.233-241.

Awasthi, O.P., Singh, I.S. and Sharma, B.D., 2006. Effect of mulch on soil-hydrothermal regimes, growth and fruit yield of brinjal under arid conditions. *Indian journal of Horticulture*, *63*(2), pp.192-194.

Azzarello, E., Pandolfi, C., Giordano, C., Rossi, M., Mugnai, S. and Mancuso, S., 2012. Ultramorphological and physiological modifications induced by high zinc levels in *Paulownia tomentosa*. *Environmental and experimental Botany*, *81*, pp.11-17.

Barton, I., Nicholas, I. and Ecroyd, C., 2007. Paulownia Handbook. Forest Research Bulletin: Ensis, Private Bag 3020. *231:* 5-68.

Blanco-García, A., Sáenz-Romero, C., Martorell, C., Alvarado-Sosa, P. and Lindig-Cisneros, R., 2011. Nurse-plant and mulching effects on three conifer species in a Mexican temperate forest. *Ecological Engineering*, *37*(6), pp.994-998.

Bian, F., Wang, Y., Duan, B., Wu, Z., Zhang, Y., Bi, Y., Wang, A., Zhong, H. and Du, X., 2021. Drought stress introduces growth, physiological traits and ecological stoichiometry changes in two contrasting *Cunninghamia lanceolata* cultivars planted in continuous-plantation soils. *BMC Plant Biology*, *21*, pp.1-13.

Burgess, P.J., Nkomaula, J.C. and Medeiros Ramos, A.L., 1997. Root distribution and water use in a four-year old silvoarable system. In *Agroforestry Forum (United Kingdom)*. 8:15–18.

Cahill, A., Chalker-Scott, L. and Ewing, K., 2005. Wood-chip mulch improves woody plant survival and establishment at no-maintenance restoration site (Washington). *Ecological restoration*. 23, pp. 212–213.

Calkins, J.B., Swanson, B.T. and Newman, D.L., 1996. Weed control strategies for field grown herbaceous perennials. *Journal of Environmental Horticulture*, *14*(4), pp.221-227.

Caparrós, S., Díaz, M.J., Ariza, J., López, F. and Jiménez, L., 2008. New perspectives for *Paulownia fortunei* L. valorisation of the autohydrolysis and pulping processes. *Bioresource technology*, *99*(4), pp.741-749.

Centritto, M., 2002. Interactive effects of elevated (CO_2) and drought on peach seedlings. *Plant Biosyst*, *5*, pp.177-188.

Chalker-Scott, L., 2007. Impact of mulches on landscape plants and the environment—a review. *Journal of Environmental Horticulture*, *25*(4), pp.239-249.

Chantigny, M.H., 2003. Dissolved and water-extractable organic matter in soils: a review on the influence of land use and management practices. *Geoderma*, *113*(3-4), pp.357-380.

Chaves, M.M., Maroco, J.P. and Pereira, J.S., 2003. Understanding plant responses to drought—from genes to the whole plant. *Functional plant biology*, *30*(3), pp.239-264.

Chaves, M.M., Pereira, J.S., Maroco, J., Rodrigues, M.L., Ricardo, C.P., Osório, M.L., Carvalho, I., Faria, T. and Pinheiro, C., 2002. How plants cope with water stress in the field? Photosynthesis and growth. *Annals of botany*, *89*(7), pp.907-916.

Couteaux, M.M., Bottner, P. and Berg, B., 1995. Litter decomposition, climate and liter quality. *Trends in ecology & evolution*, *10*(2), pp.63-66.

Deligoz, A., Bayar, E. and Yazici, N., 2016. Responses of growth, water relations and compatible solutes contents to repeated drought stress in *Cedrus libani*. *Fresen Environ Bull*, *25(9)*, pp.3760-3767.

Deligoz, A., Bayar, E., 2018. Drought stress responses of seedlings of two oak species (*Quercus cerris* and *Quercus robur*). *Turkish Journal of Agriculture and Forestry*, *42(2)*, pp. 114-123

Dickson, A., Leaf, A.L. and Hosner, J.F., 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *The Forestry Chronicle*, *36*(1), pp.10-13.

El-Showk, S. and El-Showk, N., 2003. The Paulownia Tree. *An alternative for sustainable forestry, Crop Development, Morocco*, pp.1-8.

Emmanuel, G.A., 2014. Effect of watering regimes and water quantity on the early seedling growth of *Picralima nitida* (Stapf). *Sustainable Agriculture Research*, *3*(2), pp.35-43.

Engelbrecht, B.M., Kursar, T.A. and Tyree, M.T., 2005. Drought effects on seedling survival in a tropical moist forest. *Trees*, *19*, pp.312-321. https://doi.org/10.1007/s00468-004-0393-0

Fausett, J.B. and Rom, C.R., 2001. The effects of transitioning a mature high-density orchard from standard herbicide ground-cover management system to organic ground-cover management systems. *Arkansas Agric. Expt. Sta. Res. Series*, *483*, pp.33-36.

Flexas, J., Bota, J., Galmés, J., Medrano, H. and Ribas-Carbó, M., 2006. Keeping a positive carbon balance under adverse conditions: responses of photosynthesis and respiration to water stress. *Physiologia Plantarum*, *127*(3), pp.343-352.

Foshee, W.G., Goff, W.D., Tilt, K.M., Williams, J.D., Bannon, J.S. and Witt, J.B., 1996. Organic mulches increase growth of young pecan trees. *HortScience*, *31*(5), pp.811-812.

Fotelli, M.N., Radoglou, K.M. and Constantinidou, H.I., 2000. Water stress responses of seedlings of four Mediterranean oak species. *Tree physiology*, *20*(16), pp.1065-1075.

Gill, B.S. and Jalota, S.K., 1996. Evaporation from soil in relation to residue rate, mixing depth, soil texture and evaporativity. *Soil Technology*, *8*(4), pp.293-301.

González, J.A., Gallardo, M., Hilal, M.B., Rosa, M.D. and Prado, F.E., 2009. Physiological responses of quinoa (*Chenopodium quinoa*) to drought and waterlogging stresses: dry matter partitioning. *Botanical Studies*, *50*, pp. 35-42.

Gonzalez-Sosa, E., Braud, I., Thony, J.L., Vauclin, M. and Calvet, J.C., 2001. Heat and water exchanges of fallow land covered with a plant-residue mulch layer: a modelling study using the three-year MUREX data set. *Journal of Hydrology*, *244*(3-4), pp.119-136.

Grinstein, A., Kritzman, G., Hetzroni, A., Gamliel, A., Mor, M. and Katan, J., 1995. The border effect of soil solarization. *Crop Protection*, *14*(4), pp.315-320.

Gupta, G.N., 1991. Effects of mulching and fertilizer application on initial development of some tree species. *Forest Ecology and Management*, *44*(2-4), pp.211-221.

Hartmann, T., College, M., and Lumsden, P., 2005. Responses of different varieties of *Lolium perenne* to salinity. In *Annual Conference of the Society for Experimental Biology, Lancashire*.

Haywood, J.D., 1999. Durability of selected mulches, their ability to control weeds, and influence growth of loblolly pine seedlings. *New Forests*, *18*(3), pp.263-276.

Hjelm, K., Mc Carthy, R. and Rytter, L., 2018. Establishment strategies for poplars, including mulch and plant types, on agricultural land in Sweden. *New forests*, *49*(6), pp.737-755.

Jin, X., Shi, C., Yu, C.Y., Yamada, T. and Sacks, E.J., 2017. Determination of leaf water content by visible and near-infrared spectrometry and multivariate calibration in Miscanthus. *Frontiers in plant science*, *8*, pp.1-8.

Karimi, S., Hojati, S., Eshghi, S., Moghaddam, R.N. and Jandoust, S., 2012. Magnetic exposure improves tolerance of fig 'Sabz'explants to drought stress induced in vitro. *Scientia Horticulturae*, *137*, pp.95-99.

Khan, S.R., Rose, R., Haase, D.L. and Sabin, T.E., 1996. Soil water stress: Its effects on phenology, physiology, and morphology of containerized Douglas-fir seedlings. *New Forests*, *12*(1), pp.19-39.

Kozlowski, T.T., 1997. Responses of woody plants to flooding and salinity. *Tree physiology*, *17*(7), pp.490-490.

Marron, N., Dreyer, E., Boudouresque, E., Delay, D., Petit, J.M., Delmotte, F.M. and Brignolas, F., 2003. Impact of successive drought and re-watering cycles on growth and specific leaf area of two *Populus× canadensis* (Moench) clones, 'Dorskamp'and 'Luisa_Avanzo'. *Tree physiology*, *23*(18), pp.1225-1235.

Mishra, A.K., 1996. Effect of mulches on growth of tree species on fly ash. *Environment and Ecology*, *14*, pp.411-414.

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

Ogidan, O. A., Olajire-Ajayi, B. L and Adenuga, D. A., 2018. Assessment of watering regimes on seedling growth performance of *Kigelia africana* (Lam) Benth. Biodiversity Conservation and National Development Potentials and Challenges. In: Gabriel, S.U., Folaranmi, D.B and Edem, A.E (eds). Proceedings of 6th Nigeria Chapter of Society for Conservation Biology (NSCB) Biodiversity Conference. pp 341-345.

Olajuyigbe, S.O., Jimoh, S.O., Adegeye, A.O and Mukhtar, R.B., 2012. Drought stress on early growth of Diospyros mespiliformis Hochst ex A. Rich in Jega, Northern Nigeria. *Nigerian Journal of Ecology 12(1)*, pp. 71-76.

Olubode, O.O., Hammed, L.A., Odeyemi, O.M., Adekoya, F.J., Meroyi, F.M. and Ogunlade, O.I., 2016, August. Influence of moisture regimes and organic manure on nutrient dynamics and growth of cashew. In *III All Africa Horticultural Congress 1225* (pp. 125-132).

Pallardy, S. G., 2008. *Physiology of Woody Plants* (Third Edit). Academic Press.

Ptach, W., Langowski, A., Rolbiecki, R., Rolbiecki, S., Jagosz, B., Grybauskienė, V. and Kokoszewski, M., 2017. The influence of irrigation on the growth of paulownia trees at the first year of cultivation in a light soil. In *International scientific conference. Rural development 2017* (pp. 763-768).

Qadir, S.A., Khursheed, M.Q. and Huyop, F.Z., 2016. Effect of Drought Stress on Morphology, Growth and Yield of Six Bread Wheat (*Triticum aestivum* L.) Cultivars. *ZANCO Journal of Pure and Applied Sciences*, *28*(3), pp.37-48.

Rostami, A.A. and Rahemi, M., 2013. Responses of caprifig genotypes to water stress and recovery. *Journal of Biological and Environmental Sciences*, *7*(21), pp. 131-139

Saeed, R. and Ahmad, R., 2009. Vegetative growth and yield of tomato as affected by the application of organic mulch and gypsum under saline rhizosphere. *Pak. J. Bot*, *41*(6), pp.3093-3105.

Sharma, N.K., Singh, P.N., Tyagi, P.C. and Mohan, S.C., 1998. Effect of Leucaena mulch on soil-water use and wheat yield. *Agricultural Water Management*, *35*(3), pp.191-200.

Sherzad, O.H., Mohd Zaki, H., Hazandy, A.H., Mohamad Azani, A. and Noordin, W.D., (2015). Growth and physiological responses of *Shorea materialis* Ridl. seedlings to various light regimes and fertilizer levels under nursery condition. *The Malaysian Forester*, *78(1)*, pp.133-150.

Sherzad, O.H., Zaki, H.M., Hazandy, A.H. and Azani, A.M., (2017). Effect of different shade periods on *Neobalanocarpus heimii* seedlings biomass and leaf morphology. Journal of Tropical Forest Science, *29(4)*, pp.457-464.

Singh, A.K. and Singh, R.B., 1999. Effect of mulches on nutrient uptake of *Albizia procera* and subsequent nutrient enrichment of coal mine overburden. *Journal of Tropical Forest Science*,11(2), pp.345-355.

Susiluoto, S. and Berninger, F., 2007. Interactions between morphological and physiological drought responses in *Eucalyptus microtheca*. *Silva Fennica*, *41*(2), pp.221-233.

Tomlinson, P.T., Buchschacher, G.L. and Teclaw, R.M., 1997. Sowing methods and mulch affect 1+ 0 northern red oak seedling quality. *New forests*, *13*(1), pp.193-208.

Ugese, F.D., Baiyeri, K.P. and Mbah, B.N., 2010. Effect of sowing depth and mulch application on emergence and growth of shea butter tree seedlings (*Vitellaria paradoxa* CF Gaertn.). *African Journal of Biotechnology*, *9*(10), pp.1443-1449.

Vandoorne, B., Mathieu, A. S., Van den Ende, W., Vergauwen, R., Perilleux, C., Javaux, M., and Lutt, S., 2012. Water stress drastically reduces root growth and inulin yield in *Cichorium intybus* (var. sativum) independently of photosynthesis. *Journal of Experimental Botany*, 63(12), pp. 4359-4373.

Wood, C.B., Smalley, T.J., Rieger, M. and Radcliffe, D.E., 1994. Growth and Drought Tolerance of *Viburnum plicatum* var. tomentosumMariesii'in Pine Bark-amended Soil. *Journal of the American Society for Horticultural Science*, *119*(4), pp.687-692.

Wu, M., Zhang, W.H., Ma, C. and Zhou, J.Y., 2013. Changes in morphological, physiological, and biochemical responses to different levels of drought stress in Chinese cork oak (*Quercus variabilis* Bl.) seedlings. *Russian journal of plant physiology*, *60*(5), pp.681-692.

Zang, U., Goisser, M., Häberle, K.H., Matyssek, R., Matzner, E. and Borken, W., 2014. Effects of drought stress on photosynthesis, rhizosphere respiration, and fine-root characteristics of beech saplings: A rhizotron field study. *Journal of plant nutrition and soil science*, *177*(2), pp.168-177.

Zhang, X., Qian, Y. and Cao, C., 2015. Effects of straw mulching on maize photosynthetic characteristics and rhizosphere soil micro-ecological environment. *Chilean journal of agricultural research*, *75*(4), pp.481-487.