UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DIFFERENT WATER LEVELS, LIGHT INTENSITIES AND DURATIONS OF SHADING ON GROWTH AND DEVELOPMENT OF YOUNG TONGKAT ALI (*Eurycoma longifolia* Jack)

HOOMAN ROWSHANAIE

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By

HOOMAN ROWSHANAIE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

July 2019

DEDICATION

This thesis is dedicated to

My merciful father,

My sympathetic mother, and

My only brother.

For their endless love, support and encouragement

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

EFFECTS OF DIFFERENT WATER LEVELS, LIGHT INTENSITIES AND DURATIONS OF SHADING ON GROWTH AND DEVELOPMENT OF YOUNG TONGKAT ALI (*Eurycoma longifolia* Jack)

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Chairman: Associate Professor Hawa ZE Jaafar, PhD
Faculty: Agriculture

In this study, the effect of different levels of irrigation water, light intensities and durations of shading on growth and development of young Tongkat Ali (TA; *Eurycoma longifolia* Jack) was considered. Large cultivation of TA is still very lacking due to insufficient and inconclusive information of its agronomic cultivation requirements; thus, over collecting from the tropical rain forests for commercial production of traditional medicines will ultimately endanger and lead to the species extinction. In order to sustain the continuous supply of plants raw material for industrial production, there is an urgent need to determine the essential growing requirements of this plant for the establishment of plantations of TA, particularly, in the nursery. Hence, three experiments were conducted to examine the agronomic requirements: Water levels, light intensity and shading duration of young TA. The first experiment was laid down out a Randomized Complete Block Design (RCBD) with five watering regimes imposed onto 6-month old TA seedlings from Hulu Langat, Selangor, Malaysia, namely at 125%, 100%, 75%, 50% and 25% of field capacity (FC), placed in six blocks. The main objective of the study was to evaluate the effect of different levels of irrigation water on growth and development of TA, especially the root growth and its relationship with the shoot growth. There were obvious differences among young TA seedlings for sensitivity to water stress due to the different levels imposed. Growth parameters also decreased with increasing severity of water scarcity, although by the end of the experiment, they were not significantly different under treatment 75% FC compared to non-water stress, especially in total biomass and total leaf area. Root parameters, especially root length, root diameter, root volume and specific root length (SRL) by end of the experiment demonstrated noticeable differences among young TA seedlings treated with different water levels. In the second experiment with the main objective to determine plant responses to the interaction between water availability and various light intensities on growth and development of TA, especially the root growth, the combined treatments were arranged using RCBD with a split plot layout consisting of 2 factors of three different light intensities (no cover, 50% shading, 70% shading)

and three different water treatments (100% FC, 75% FC, 25% FC) blocked three times. Results showed that plant growth parameters including plant height, stem diameter and total biomass were reduced only by light scarcity condition and root/ shoot ratio; meanwhile, height ratio was higher in 70% shading compared to 50% shading and the control conditions. After 4.5 months of combined light and water treatments, seedlings exposed to 50% shading combined with 75% FC (moderate water stress) recorded the highest values for total plant leaf area (TLA; 331cm^2), specific leaf area (SLA; 134 cm^2/g), chlorophyll concentration (CHL; 42.6 µmol/m^2) and nitrogen balance index (NBI; 22.1) compared to 70% shading imposed with water stress at 25%FC showing lower values for TLA (16.7 cm^2), SLA (31.7 cm^2/g), CHL (17.3 µmol/m^2) and NBI (5.1), respectively. Likewise, there were parallel decreasing trend in root parameters (root length, root diameter, root volume and SRL) with non-shaded plants resulting in fine root with decreased root density, which severity escalated (decreased by 46%) with decreasing light intensity at 70% shading compared to non-shaded condition. The second experiment clearly demonstrated the effect of light sensitivity of young TA seedlings, especially on root density, and this sensitivity became severe when plants were further imposed with water deficit. The third experiment investigated plant light requirement based on the duration of 50% shading imposed for 45, 30 and 15 days after start of treatment and combined with three different water treatments (100% FC, 75% FC, 25% FC). Treatments were laid out in a split plot arrangement based on RCBD with three blocks with the objective to investigate the effect of different duration of 50% shading on root system, and the morphological and physiological traits of TA. Results from the experiment showed that there were recognizable differences among young TA seedlings exposed to shading duration and water treatments. The decrease in shading duration from 45 to 15 days seemed to have increased both the peroxidase (POX) and malondialdehyde (MDA) in both root and shoot parts compared with 30 days shade duration treatment. Similarly, plants imposed with 45 and 15 days shading also recorded decrease in plant height (4%~8%), shoot diameter (2%~8%), root length (2%~8%) and root diameter (15%~20%) compared with 30 days of shading duration. The root also seemed to be more sensitive than the shoot to both POX and MDA under either too short (15 d) or too long shading duration (45 d). In the present study, the role of peroxidase in the growth of TA seedlings was examined by relating plant height, stem diameter and root parameters, in particular root length and root diameter, with peroxidase activity, which indicated that reduction in peroxidase activity was associated with the tallness and thickness of the plant, which correlated with root length and root diameter with significant correlation, such that, 30 days shading duration exhibited highest value in shoot and root parameters compared with other shade durations. Conversely, plants exposed to short duration of shading treatment (15 d ≅ longer exposure to sunlight) exhibited greater values of MDA and POX than those exposed to 45 d shading duration with 1.2% increase in MDA in both root and shoot, and in case of POX with 33% increase in root and 20% increase in shoot, respectively. In a nutshell, even though long time shading has negative effects on growth and development, short time shading duration led to excess light intensity and has more detrimental effects. In conclusion, by evaluating the effects of different levels of irrigation water, various light intensities and different durations of shading on root and shoot traits, morphologically, physiologically and biochemically, the 50% shading at 30 d duration combined with water at 75% FC seemed to give the optimum growth and development condition for establishment of TA seedlings.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN PARAS AIR YANG BERBEZA, TERANG CAHAYA DAN JANGKA MASA PEMANTAUAN PERTUMBUHAN AND PEMBANGUNAN TONGKAT ALI MUDA (*Eurycoma longifolia* Jack)

Oleh

HOOMAN ROWSHANAIE

Julai 2019

Pengerusi: Profesor Madya Hawa ZE Jaafar, PhD
Fakulti: Pertanian

Dalam kajian ini, kesan paras air pengairan yang berlainan, terang cahaya dan jangka masa teduhan ke atas pertumbuhan dan perkembangan Tongkat Ali muda (TA; Eurycoma longifolia Jack) dikaji. Penanaman TA secara besar-besaran masih sangat kurang kerana maklumat yang tidak mencukupi dan tidak meyakinkan mengenai keperluan agronomik penanamannya; Oleh itu, pengusahaan yang lebih banyak dari hutan hujan tropika untuk pengeluaran komersil ubat-ubatan tradisional akhirnya akan membahayakannya dan membawa kepada kepupusan spesis. Untuk mengekalkan bekalan bahan mentah yang berterusan untuk pengeluaran perindustrian, terdapat keperluan mendesak untuk menentukan keperluan pertumbuhan pokok yang diperlukan untuk penubuhan ladang TA, terutamanya di tapak semaian. Oleh itu, tiga eksperimen telah dijalankan untuk mengkaji keperluan agronomi: iaitu melalui paras air, terang cahaya dan jangka masa teduhan TA muda. Percubaan pertama dibina dalam Reka Bentuk Blok Lengkap Rawak (RCBD) dengan lima rejim penyiraman yang dikenakan ke atas benih berusia 6 bulan yang berasal dari Hulu Langat, Selangor, Malaysia, iaitu 125%, 100%, 75%, 50% dan 25% daripada kapasiti lapangan (FC), ditempatkan dalam enam blok. Objektif utama kajian ini adalah untuk menilai kesan pelbagai peringkat pengairan air pada pertumbuhan dan pembangunan TA, terutamanya pertumbuhan akar dan hubungannya dengan pertumbuhan yang cepat. Terdapat perbezaan sensitiviti yang ketara dalam kalangan TA muda terhadap tekanan air kerana tahap yang berbeza dikenakan. Parameter pertumbuhan juga berkurangan dengan peningkatan keseriusan kekurangan air. Walaupun pada akhir eksperimen, mereka tidak jauh berbeza di bawah rawatan 75% FC berbanding tekanan selain dari air, terutamanya dalam jumlah biojisim dan jumlah keseluruhan daun. Parameter akar, terutamanya panjang

akar, diameter akar, jumlah akar dan panjang akar spesifik (SRL) pada akhir kajian menunjukkan perbezaan ketara antara anak benih TA muda yang dirawat dengan paras air yang berbeza. Dalam eksperimen kedua, dengan objektif utama untuk menentukan tindak balas tumbuhan kepada interaksi antara ketersediaan air dan pelbagai terang cahaya pada pertumbuhan dan perkembangan TA, terutama pertumbuhan akar, rawatan gabungan disusun menggunakan RCBh dengan susunan plot yang terdiri dari 2 faktor daripada tiga, terang cahaya yang berbeza (tiada perlindungan, teduhan 50%, teduhan 70%) dan tiga rawatan air yang berlainan (100% FC, 75% FC, 25% FC) disekat tiga kali. Keputusan menunjukkan bahawa parameter pertumbuhan tumbuhan termasuk ketinggian tumbuhan, diameter batang dan jumlah biojisim dikurangkan hanya dengan keadaan kekurangan cahaya. Pada masa yang sama, nilai yang lebih rendah dicatatkan untuk nisbah jisim akar dan nisbah akar / pucuk; Sementara itu, nisbah ketinggian adalah lebih tinggi dalam teduhan 70% berbanding dengan teduhan 50% dan keadaan kawalan. Selepas 4.5 bulan gabungan rawatan cahaya dan air, benih yang terdedah kepada teduhan 50% digabungkan dengan 75% FC (tekanan air sederhana) mencatatkan nilai tertinggi bagi kawasan daun tumbuhan (TLA, 331cm^2), kawasan daun spesifik (SLA; 134 cm^2 / g), kepekatan klorofil (CHL; 42.6 μmol / m^2) dan indeks keseimbangan nitrogen (NBI; 22.1) berbanding dengan teduhan 70% yang dikenakan dengan tekanan air pada 25% FC menunjukkan nilai yang lebih rendah untuk TLA (16.7 cm^2), SLA (31.7 cm^2 / g), CHL (17.3 μmol / m^2) dan NBI (5.1). Begitu juga, kecenderungan penurunan paralel pada parameter akar (panjang akar, diameter akar, jumlah akar dan SRL) dengan tumbuhan tidak berteduh menghasilkan akar halus dengan ketumpatan akar berkurang, yang mana keterukan meningkat (menurun sebanyak 46%) dengan mengurangkan terang cahaya 70% teduhan berbanding dengan keadaan tidak berbayang. Eksperimen kedua dengan jelas menunjukkan kesan sensitiviti cahaya anak benih TA muda, terutamanya pada ketumpatan akar, dan kepekaan ini menjadi serius apabila tumbuhan terus dikenakan dengan defisit air. Eksperimen ketiga menyiasat keperluan cahaya tumbuhan berdasarkan jangka masa teduhan 50% yang dikenakan selama 45, 30 dan 15 hari selepas permulaan rawatan dan digabungkan dengan tiga rawatan air yang berbeza (100% FC, 75% FC, 25% FC). Rawatan dibentangkan dalam susunan plot berpecah berdasarkan RCBh dengan tiga blok dengan tujuan untuk menyiasat kesan jangka masa yang berlainan 50% teduhan pada sistem akar, dan sifat morfologi dan fisiologi TA. Hasil daripada eksperimen menunjukkan bahawa terdapat perbezaan yang dapat diiktiraf antara anak benih TA muda yang terdedah kepada sesuatu jangka masa teduhan dan rawatan air. Penurunan dalam jangka masa teduhan daripada 45 hari hingga 15 hari seolah-olah telah meningkatkan kedua-dua peroksidase (POX) dan malondialdehih (MDA) di kedua-dua bahagian akar dan pucuk berbanding dengan jangka masa rawatan selama 30 hari. Begitu juga tumbuhan yang dikenakan dengan teduhan 45 dan 15 hari yang mencatatkan penurunan ketinggian tumbuhan (4% ~ 8%), diameter pucuk tumbuhan (2% ~ 8%), panjang akar (2% ~ 8%) dan diameter akar (15% 20%) berbanding dengan 30 hari jangka masa teduhan. Akar juga nampaknya lebih sensitif daripada pucuk untuk kedua-dua POX dan MDA di bawah jangka masa teduhan,

sama ada terlalu pendek (15 h) atau yang terlalu lama, (45 h). Dalam kajian ini, peroksidase dalam pertumbuhan anak benih TA diperiksa dengan mengenal pasti ketinggian tumbuhan, diameter batang dan parameter akar, khususnya panjang akar dan diameter akar, dengan aktiviti peroksidase, yang menunjukkan bahawa pengurangan aktiviti peroksidase dikaitkan dengan ketinggian dan ketebalan tumbuhan, yang berkorelasi dengan panjang akar dan diameter akar dengan korelasi yang ketara, sedemikian rupa, jangka masa 30 hari teduhan menunjukkan nilai tertinggi dalam parameter untuk pertumbuhan pucuk dan pertumbuhan akar berbanding dengan jangka masa teduh yang lain. Sebaliknya, tumbuhan yang terdedah kepada jangka pendek rawatan teduhan (pendedahan 15 hari yang lebih lama dengan cahaya matahari) memperlihatkan nilai MDA dan POX yang lebih besar daripada yang terdedah kepada 45 h jangka masa teduhan dengan kenaikan MDA 1.2% pada kedua-dua pertumbuhan akar dan pucuk, dan dalam kes POX dengan kenaikan 33% dalam akar dan peningkatan 20% dalam pucuk. Ringkasnya, walaupun teduhan lama mempunyai kesan negatif ke atas pertumbuhan dan perkembangan, jangka masa teduhan yang singkat membawa kepada keamatan cahaya yang berlebihan dan mempunyai kesan yang lebih memudaratkan. Sebagai kesimpulan, dengan menilai kesan-kesan paras. Air pengairan yang berlainan, pelbagai terang cahaya dan jangka masa teduhan berlainan pada sifat akar dan pucuk, morfologi, fisiologi dan biokimia, teduhan 50% pada jangka masa 30 h digabungkan dengan air pada 75% FC nampaknya memberikan pertumbuhan dan perkembangan yang optimum bagi pertumbuhan anak benih TA.

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Declaration by graduate student

I hereby confirm that:

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LIST OF ABBREVIATIONS

Symbol	Means
T.A	Tongkat Ali
EL	Eurycoma longifolia
°C	Degree centigrade
g	Gram
kg	Kilogram
cm	Centimeter
mm	Milimeter
MPa	Mega-Pascal
WAT	Week After Treatment
µmol	Micro mol
mmol	Mili mol
FC	Field Capacity
RWC	Relative Water Content
LAI	Total Plant leaf Area
SLA	Specific Leaf Area
DW	Dry Weight
FW	Fresh Weight
DNMRT	Duncan New Multiple Range Test
SRL	Specific Root Length
NBI	Nitrogen Balance Index
FLV	Total Flavonoied Index
Fv/Fm	Maximum Quantum Efficiency

SMC	Soil Moisture Content
R/S	Root Shoot Ratio
HR	Height Rate Ratio
RMR	Root Mass Ratio
Photo	Leaf Photosynthesis
Condo	Stomatal Conductance
Tri	Transpiration Rate
Chl	Relative Chlorophyl Content
POX	Proxidase Activity
MDA	Malondialdehyde
PAR	Photosynthetic Active Radition
Ψ_L	Leaf Water Potential
EU	Enzyme Unit
µg/g	Microgram per Gram

ABBREVIATIONS OF STATISTIC ANALYSIS

Symbol	**Means**
ANOVA	Analysis of Varition
S.O.V	Standard of Varition
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis Software
p	Probably
n.s	Not significant

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Plants are integral parts of our biosphere and essential components for the existence of mankind (Tripathy, 2015). The use of plants or plant parts as medicines to treat various diseases or other health conditions has been recorded since prehistoric times (Rahman & Hossain, 2002; Wiart et al., 2000). Globally, herbal medications are used partly because the worth of the traditional medical system has been recognized and plants with medicinal value have been identified from indigenous pharmacopoeia that have been proven to possess to have significant natural healing capabilities or in the form of new pharmaceuticals (Lewis, 2001). The herbal and medicinal plants industry of Malaysia is considered as one of the most dynamic and progressive with annual growth estimated at 20% (Fadzil, 2000). While the total significant value of the medicinal and aromatic plants increased from RM 141 million in 1986 to RM 431 million in 1996 (Ghani et al., 2002). The current market value of traditional medicine in Malaysia is estimated to be between RM 1.0 and RM 2 billion (Ali et al., 2002). In terms of current priorities the species that have been identified as medicinal indigenous South East Asia herbs are: *Eurycoma longifolia (Tongkat Ali), Labisia pumila (Kacip Fatima), Andrographis paniculata (Hempedu Bumi), Morinda citrofolia (Mengkudu), Centella asiatica (Pegaga), Orthosphon aristatus (Misai Kucing)* and *Punica granatum (Buah Delima)* (Ghani et al., 2002; Ilham et al., 1999).

1.2 Eurycoma Species

Nowadays, there are three *Eurycoma* species that have been identified; *Eurycoma longifolia* (*E. longifolia; EL*) discovered in Malaysia, *Eurycoma apiculata*, and *Eurycoma haramandiana*, which were discovered recently in Thailand by Kanchanapoom and co-workers (2001).

1.2.1 *Eurycoma longifolia (*Tongkat Ali*)*

Eurycoma longifolia or better known in Malaysia as Tongkat Ali or Malaysian home-grown aphrodisiac (Wan, 2006) has been found to have the greatest local demand as a health tonic and superior herbal plant. The plant owes its popularity to its aphrodisiac claim and has been sought after as an essential component in libido (Chauhan et al, 2014). Moreover, plant extracts especially from the roots, are exclusively used for reinforcing the male hormone (testosterone) levels. In this case some have referred to Tongkat Ali as the Malaysian ginseng (Jaganath & Ng, 2000). Plant parts, which refer to the stem and leaves also have become some of the items in medicinal stalls and have been traditionally used for their unique anti-malaria, anti-microbial and anti-fever activities. These herbs are suitable and useful for the reduction of sugar levels in diabetics, asthmatics, stomach disorders, low blood pressure and intestinal worms. It should be noted though that the main usage of this plants is as an aphrodisiac and curing post-partum. As a tree that cures hundreds of

diseases as claimed by Vietnamese (Bhat and Karim, 2010). *Eurycoma longifolia* products from Malaysia are exported and marketed in the United States of America, Europe and Korea.

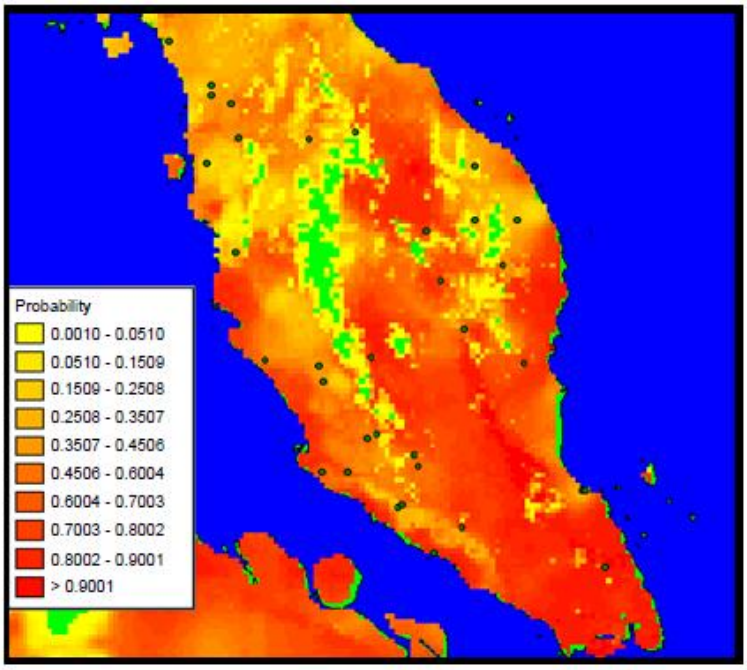

Figure 1.1: The probability distribution of *Eurycoma longifolia* in Peninsular Malaysia based on herbarium records.

In Figure 1.1 the probability distribution of *Eurycoma longifolia* in peninsular Malaysia based on herbarium records shows that in south and west of Peninsular Malaysia the probability distribution of this herb is much more compared to other areas. The plant is uprooted in the process of separating the root, which has led to a serious shortage of this plant (Sobri & Maziah, 2002). In other words, measurements for collecting Tongkat Ali from the depths of wild tropical forests for the commercial production of traditional medicines will endanger and lead to the extinction of this herbal variety in the future (Norkapsi et al., 2009).

From what has been stated above about the importance of TA, there is an urgent need to determine the essential requirements of this plant for the establishment of plantations and nursing the seedlings of this superior herb to sustain the plants raw material supply for industrial production. On the other hand, the most common method to propagate *E.longifolia* is through seeds Sown in a nursery under shade with high humidity (Jaganath & Ng, 2000; Wan, 2006). Domestication of *E.longifolia* is very crucial and although it should be noted that this indigenous South East Asia herbal plant has never been comprehensively domesticated before.

Abiotic stress or water stress is among the most serious concerns in agriculture; and therefore, water tolerance by any plant is massively important (Shao et al., 2008).

This type of tolerance involves the changes and differences in morphological traits such as differences in height and diameter of stem and also differences in leaf area by becoming thick in terms of drought stress to preserve the internal water status of the plant. Physiological responses include leaf gas exchange of plant and plant water relation and even in terms of root characteristics in this kind of herb such as root volume and specific root length in water scarcity (Ryser, 2006). Sufficient amount of water should be supplied for plants to maintain their cells in good condition, especially at the early stage of development and in terms of *E. longifolia*, at the seedling stage and before transferring the plant to the field, in order to produce new tissue and cell progressively and improving the medicinal properties in older stage of growth consequently. Drought conditions can be classified as either terminal or intermittent. Based on terminal drought definitions, the availability of soil water declines progressively and premature plants will perish. Intermittent drought is due to finite and continuous periods of insufficient irrigation occurring at one time or at intervals during the growth and is not necessarily lethal (Neumaan, 2008). Another's main and critical aspects of photosynthesis besides the water are intensity and duration of light. Light has three principal characteristics that affect plant growth: quantity, quality, and duration. Light quantity refers to the intensity or concentration of sunlight and varies with the season of the year. As the sunlight quantity decreases the photosynthetic process decreases. Light quantity can be decreased in a garden or greenhouse by using shade-cloth or shading paint above the plants. It can be increased by surrounding plants with white or reflective material or supplemental lights. Light quality refers to the color or wavelength reaching the plant surface. Light duration or photoperiod refers to the amount of time that a plant is exposed to sunlight. Due to the increase of light intensity and duration of it, it is expected that the maximum, minimum and optimum global temperatures will also increase by 3 - 4ºC (Heinem et al., 2005).

1.2.2 Cultivation of *E.longifolia*

In the case of *E.longifolia*, one of the means to increase its production is to speed up the growth process. This can be possible by using proper irrigation and suitable intensity of light with the optimum duration of light on the seedling. Increase in these three fundamental plant requirements gains is justified to augment total plant's dry biomass to enhance photosynthesis with extra supplies of carbon dioxide (Foyer et al., 2017). Light intensity can affect plant form, flowering, leaf size, and color in both herbaceous (Jeong et al., 2009; Vendrame et al., 2004) and woody species (Hampson et al., 1996). Shade tolerant plants have both morphological and physiological adaptations that allow them to adapt to low-light conditions (Liu & Su, 2016).

1.3 Hypothesis

As little study has been done in the demonstration of Tongkat Ali, the understanding on the impact of water stress, light intensity and light duration on growth and development of young Tongkat Ali may establish the agronomic requirement of T.A cultivation. There are possibilities that different levels of water treatment and light could probably have impact on the root system enhancement, and therefore affect the

growth pattern and domestication of *E.longifolia*. Reducing of oxidative damage cause by the reactive oxygen species (ROS) generated during drought (Xie et al., 2019) would be elaborated. Moreover, different light duration could also possibly trigger root system growth. Therefore, there would be more root enhancement and higher amount of its photochemical products. Hence, slow growing plants like Tongkat Ali, should enhance growth of the root, especially the tap root, at the initial seedling stage, which is very crucial to ensure good therapeutic properties and harvest index in the later productive stage (Jaafar, 2009).

1.4 Research Problem Statement

Water stress tolerance involves the changes in biochemistry and physiological responses of plant and water relation (Guerfel et al., 2009). Drought stress possibly regulates and diminishes plant growth and development; limit plant products (Farooq et al., 2009). Although water deficit is known to retard every aspect of growth including morphological and physiological traits, water stress is not always injurious, because it has been reported to improve the secondary metabolite activities of plant products. Irradiance also plays major role in influencing growth development of plants especially in young seedling. Effect of irradiance levels on the growth performance of Tongkat Ali seedling, need to be examined in order to determine its growth performance which is very crucial at nursery stage. Different time duration of shading has also been known to enhance growth and development of plant. It is important to know the exact amount and duration of light which are needed to improve growth rate of plant such as T.A.

1.5 Objectives of Study

This study was conducted with the following objectives:

a) To evaluate the effect of different levels of irrigation on growth and development of *E.longifolia* specially the root growth and its relationship with the shoot growth.

b) To determine the interaction between water availability and various irradiance proportion in root growth performance of Tongkat Ali.

c) To investigate the effect of different duration of shading on root system and the morphological and physiological traits of *E.longifolia*.

d) To establish the relationship of root growth performance with those of morphological and biochemical traits.

1.6 Organization of the Thesis

In summary, this chapter reported background of study, hypothesis, problem statement and objectives of the study. The next chapter will discuss about the literature review related to the objectives of the study and criticizes about those researches, effect and dimension of stress on growth and development of plant and related to the above and underground organs of plants.

REFERENCES

Abdel-Mawgoud, A.M.R., S.O. El-Abd, S.M. Singer, A.F. Abou-Hadid, and T.C. Hsiao. 1996. *Effect of shade on the growth and yield of tomato plants*. Acta Hort. 434:313-320.

Abrams, M. and Scott, A. 1995. *Gas exchange, leaf structure and nitrogen in contrasting successional tress species growing in open and understory sites during a drought*. Tree physiology 15: 361-370.

Adam, F. and S.S. Barakbah. 1990. *Response to Water stress in Banana, peanut and Rice: A comparative study*. Transactions of Malaysian Soc. Plant Physiology. 1(1990): 99-104.

Akhtar, I. and Nazir, N. 2013. *Effect of Waterlogging and Drought Stress in Plants*. International Journal of Water Resources and Environmental Sciences. 2(2): 34-40.

Akram, M. 2011. *Growth and Yield Components of Wheat under Water Stress of Different Growth Stages*. Bangladesh Journal Agril. Res. 36(3): 455-468.

Ali, M.B., Hahn, E.-J. and Paek, K.-Y. 2005. *Effects of light intensities on antioxidant enzymes and malondialdehyde content during short-term acclimatization on micropropagated Phalaenopsis plantlet*. Environment Experimental. Botany. 54: 109-120.

Aloni, B., Daie, J. and Kami, L. 1991. *Water relations, photosynthesis and assimilate partitioning in leaves of pepper Capsicum annuum transplants: Effect of water stress after transplanting*. Journal of Horticultural Science 66 (1): 75-80.

Alscher, R.G., Erturk, N. and Heath, L.S. 2002. *Role of superoxide dismutases (SODs) in controlling oxidative stress in plants.* Journal of Experimental Botany. 53: 1331-1341.

Amaliotis, D., Therios, I. and Karatissiou, M. 2004. *Effect of nitrogen fertilization on growth, leaf nutrient concentration and photosynthesis in three peach cultivars*. ISHS, Acta Horticulturae, 449: 36-42.

Ang, H. H., Hitotsuyanag, Y., Fukaya, H. and Takeya K. 2002. *Quassinoids from Eurycoma Longifolia*. Phytochemistry. 59: 833-837.

Anyia, A.O, and H. Herzog. 2004. *Water-use efficiency, leaf area and leaf gas exchange of cowpeas under mid-season drought*. Europian Journal of Agronomy. 20:327-339.

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

Aranda, M.P., Villa, V.M. and Trejo, L. 2003. *El Portal Latino Alzheimer's project model program for Latino caregivers of Alzheimer's disease-affected people*. Social Work. 48(2), 259-272.

Araya, A. and Stroosnijder, L. 2010. *Effects of tied ridges and mulch on barley (Hordeum vulgare) rainwater use efficiency and production in Northern Ethiopia*. Agric. Water Manage. 97: 841-847.

Aro, E.M., McCaffery, S. and Anderson, J.M. 1993. *Photoinhibition and D1 protein degradation in peas acclimated to different growth irradiances*. Plant Physiology Journal. 103: 835-843.

Asada, K. 2006. *Production and scavenging of reactive oxygen species in chloroplasts and their functions*. Plant Physiol. 141:391-396.

Ashraf, M.Y., Akhtar, K., Sarwar, G. and Ashraf, M. 2002. *Evaluation of arid and Semi— arid ecotypes of guar (Cyamopsis tetragonobola L.) for salinity (NaCI) tolerance.* J. Arid. Environ. 15**:** 437- 482.

Ashraf, M. and Harris, P.J.C. 2013. *Photosynthesis under stressful environments: An overview*. Photosynthetica. 51(2): 163-190.

Ashraf, M. Y., Azmi, A.R., Khan, A.H. and Naqvi, S.S.M. 1994. *Water relation in different wheat (Triticum aestivum L.) genotypes under water deficit*. Acta Physiologiae Plantarum. 3**:** 231-240.

Atiya, A.M. 2003. *Alteration of Water Relations and Yield of Corn Genotypes in Response to Drought Stress. bulg*. Journal plant physiology. 29(1–2): 63-76.

Atkinson, D. 1991. *Plant Root Growth: an Ecological perspective*. Oxford, Blackwell, London.

Atteya, A.M. 2002. *Characterization of growth and water relations in barley during water stress and after rewatering.* Az. J. Pharm. Science. 29: 285-296.

Awad, M.H. 2001. *Effect of water deficit on growth and leaf gas exchange of pepper plants (Capsicum annuum),* Ph.D. Thesis, Universiti Putra Malaysia, Malaysia.

Azmi, M.M.I., Fauzi, A, Norini, H. 2004. *Economic analysis of E. longifolia (Tongkat Ali) harvesting In Penisular Malaysia*. New Dimensions in Complementary Health Care. 91-99.

Backhausen, J.E., Kelin, M., Klock, M., Jung, S. and Scheibe, R. 2005. *Salt Tolerance of Potato (Solanum tuberosum L.) Plants Depends on Light Intensity and Air Humidity*. Plant Science. 169: 229-237.

Bahari, Z.A., Pallardy, S.G. and W.C. Parker. 1985. *Photosynthesis, water relations, and drought adaptation in six woody species of oak-hickory forests in central Missouri.* Forest Science. 31: 557- 569.

Bai, W.M., Zuo, Q., Huang, Y.F. and Li, B.G. 2001. *Effect of water supply on root growth and water uptake of alfalfa in wulanbuhe sandy region.* Acta Phytoecol Sin 25(1): 35-41 (in Chinese).

Balaguer, L., Pugnaire, F.I., Martinez-Ferri, E., Armas, C., Valladares, F. and Manrique, E. 2002. *Ecophysiological significance of chlorophyll loss and reduced photochemical efficiency under extreme aridity in Stipa tenacissima L.*, Plant Soil Journal. 240: 343-352.

Basu, S., Ramegowda, V., Kumar, A. and Pereira, A. 2016. *Plant adaptation to drought stress*. F1000 research. 5: 1-10.

Basu, PS., Ali, M. and Chaturvedi, S K. 2004. *Adaptation of photosynthetic components of chickpea to water stress*. 4th international crop science congress. Brisbane Australia, 26th Sep.-10th Oct.

Bates, L.S. and Waklren, R.P. 1973. *Rapid determination of free proline water stress studies.* Plant Soil Journal. 39: 205-207.

Begg, J.E. 1980. *Morphological adaptation of leaves to water stress.* In Adaptation of Plants to Water and High Temperature Stress. 33-42. New York: Wiley-Interscience.

Belaygue, C., Wery, J., Cowan, A.A. and Tardieu, F. 1996. *Contribution of leaf expansion, rate of leaf appearance, and stolon branching in growth of plant leaf area under water deficit in white clover*. Crop Science. 36: 1240-1246.

Bhat, R. and A.A. Karim. 2010. *Tongkat Ali (Eurycoma longifolia Jack): A review on its ethnobotany and pharmacological importance*. Fitoterapia. 7: 669-679.

Bjorkman, O. and Holmgren, P. 1963. *Adaptabihty of the photosynthetic apparatus to light intensity in ecotypes from exposed and shaded habitats*. Physiologia Plant, 16, 889.

Bloom, A. J., Chapin, F. S. and Mooney, H.A. 1985. *Resource limitation in plants – an economic analogy.* Annual Review Ecology System. 16: 363-392

Bowes, G. 1993. *Facing the inevitable: plants and increasing atmospheric CO_2.* Annual Review Plant Physiology Plant Molocule Biology. 44: 309-332.

Bowes, G,W., Ogren., L. and Hageman, R.H. 1972. *Light Saturation, Photosynthesis Rate, RuDP Carboxylase Activity, and Specific Leaf Weight in Soybeans Grown Under Different Light Intensities*. United States Departement of Agricalture National Agricaltural Library. Crop science, 12(7): 77-79.

Bramley, H., Turner, N.C., Turner, D.W. and Tyerman, S.D. 2009. *Roles of morphology, anatomy and aquaporins in determining contrasting hydraulic behaviour of roots.* Plant Physiology. 150: 348-364.

Briskin, D.P. and Gawaienowski, M.C. 2000. *Differential effects of light and nitrogen on production of hypericins and leaf glands in Hypericum perforatum.* Plant Physiology. 39: 1075-1081.

Buchner, P., Tausz, M., Ford, R., Leo, A., Fitzgerald, G.J. and Hawkesford, M.J. 2015. *Expression patterns of C- and N-metabolism related genes in wheat are changed during senescence under elevated CO_2 in dry-land agriculture*. Plant Science. 236: 239–249.

Buwalda, J.G. and Smith, G.S. 1992. *Acquisition and utilization of carbon, mineral nutrients and water by the kiwi fruit vines.* Horticulture Review. 13: 307-347.

Calatayud, A., Roca, D. and Martinez, P.F. 2006. *Spatial–temporal variations in ros leaves under water stress conditions studied by chlorophyll fluorescence imaging.* Plant Physiol. Biochemistry. 44: 564-573.

Carr, M.K.V. 2001. *The Water Relations and Irrigation Requirements of Coffee*. Expl. Agric. 37 (1): 1-36.

Callaway, R.M. 2007. *Positive interactions and interdependence in plant communities. Dordrecht*. Springer. 404p.

Ceccarelli, S. 2010. *Drought and drought resistance. Encyclopedia Biotechnol*. Agricultre Food Journal. 1: 205-207.

Chaturvedi, G. and Ingram, K. 1989. *Growth and yield of lowland rice in response to shade and drainage.* Philippine Journal of Crop Science. 14: 61-67.

Chauhan, N.S., Sharma, V., Dixit, V.K. and Thakur, M. 2014. *A review on plants used for improvement of sexual performance and virility*. Biomed Research International Journal. 2014: 1-19.

Chaves, M.M. and Oliveira M.M. 2004. *Mechanisms underlying plant resilience to water deficits: prospects for water-saving agriculture.* Journal of Experimental Botany. 55: 2365-2384.

Chen, J.M., Yu, X.P. and Chen, J.A. 2006. *The application of chlorophyll fluorescence kinetics in the study of physiological responses of plants to environmental stresses. Acta Agriculture.* Zhejiangensis. 18: 51-55.

Chen, Y., Xu, C. and Li, W. 2011. *Photosynthesis and water use efficiency of Populus eurphratica in response to changing ground water depth and CO_2 concentration*. Environmental Earth Science 62: 119-125.

Chengjian, H., Zhao, S., Wang, L., Ahmad Anjum, S., Chen, M., Zhou, C, and Zou, H. 2013. *Alteration in chlorophyll fluorescence, lipid peroxidation and antioxidant enzymes activities in hybrid ramie (Boehmeria niveaL.) under drought stress.* Austrian Journal of crop science. 7(5):594-599.

Choo, C.Y. and Chan, K.L. 2002. *High Performance liquid Chromatography analysis of Cathinone alkaloids from Eurycoma Longifolia*. Planta Medica 68: 382-384.

Clough, B. and Milthorpe, F. 1975. *Effects of water deficit on leaf development in tobacco.* Australian Journal of Plant Physiology. 2: 291-300.

Cochard, H., Coll, L., Leroux, X. and Améglio, T. 2002. *Unravelling the effects of plant hydraulics on stomatal closure during water stress in walnut*. Plant Physiology. 128: 282-290.

Cockshull, K.E., Graves, C.J. and Cave, C.R.J. 1992. *The influence of shading on yield of glasshouse tomatoes*. Journal of Horticultural Science 67: 11-24.

Cornic, G. 2000. *Drought stress inhibits photosynthesis by decreasing stomatal aperture – not by affecting ATP synthesis*. Trends Plant Science 5: 187-188.

Cornic, G. and Massacci, A. 1996. *Leaf photosynthesis under drought stress*. Photosynthesis and the Environment Journal. 5: 347-366.

Craufurd, P.C., Wheeler, T.R., Ellis, R.H., Summer field, R.J. and Williams, J.H. 1999. *Effect of temperature and water deficit on water use efficiency, carbon isotope discrimination and specific leaf area in peanut*. Crop Science. 39:136-142.

Darisa, M., Coda, H., Mizutani, K. and Tanaka, O. 1982. *Eurycomanone and Eurycomanol, Quassinoids from the roots of Eurycoma Longifolia*. Phytochemistry. 21 (8): 2091-2093.

Darko, E., Heydarizadeh, P., Schoefs, B. and Sabzalian, M.R. 2014. *Photosynthesis under artificial light: the shift in primary and secondary metabolism.* Philosophical Transaction of the Royal Society. 369: 1-7.

Dannehl, H., Wietoska, H., Heckmann, H. and Godde, D. 1996. *Changes in D1-protein turnover and recovery of photosystem II activity precede accumulation of chlorophyll in plants after release from mineral stress*. Planta. 199: 34-42.

Daughtry, C.S.T., Walthall, C.I., Kim, M.S., Brown de colstoun, E. and Mcmurtrey, J.E. 2000. *Estimating corn leaf chlorophyll concentracion from leaf and canopy reflectance.* Rem. Sens. of Environment. 74: 229-239.

Davies, W.J., Bacon, M.A., Thompson, D.S., Sobeih, W. and Gonzalez, R.L. 2000. *Regulation of leaf and fruit growth on plants in drying soil: exploitation of the plants' chemical signaling system and hydraulic architecture to increase the efficiency of water use in agriculture*. Journal of Experimental Botany. 51: 1617-1626.

Den Dubbleden, K. and Oosterbeek, M.J. 1995. *The availability of external support affects allocation and morphology in herbaceous climbing plants*. Function Ecology. 9: 628-634.

De Pereira-Netto, A.B., De Maganhaes, A.C.N. and Pinto, H.S. 1999. *Effect of soil water depletion on the water relation in tropical Kudzu.* Pesq. Agropec. Bras, Brasila. 7**:** 1151-1157.

De Souza, C.R., Maroco, J.P., dos Santos, T.P,. Rodrigues, M.L., Lopes, C.M., Pereira, J.S. and Chaves, M.M. 2003. *Partial rootzone drying: regulation of stomata aperture and carbon assimilation in field .grown grapevines (Vitis vinifera cv. Moscatel).* Functional Plant Biology. 30: 653-662.

Diganta, D., Kumar Singh, A. and Kumar Singh, A. 2018. *Effect of Drought Stress on Crop Plants with Special Reference to Drought Avoidance and Tolerance Mechanisms: A Review.* International Journal of Current Microbiology and Apply Sciences. 7(9): 2703-2721.

Dodd, I. 2003. *Hormonal Interactions and Stomatal Responses*. Plant Growth Regulation Journal. 22: 32- 46.

Dong, C., Fu, Y., Liu, G. and Liu, H. 2014. *Low light intensity effects on the growth, photosynthetic characteristics, antioxidant capacity, yield and quality of wheat (Triticum aestivum L.) at different growth stages in BLSS.* Advances in Space Research. 53: 1557-1566.

Dos Santos, T.P., Lopes, C.M., Rodrigues, M.L., de Souza, C.R., Maroco, J.P., Pereira, J.S., Silva, J.R. and Chaves, M.M. 2003. *Partial rootzone drying: effects on fruit growth and quality of field grown grapevines (Vitis vinifera).* Functional Plant Biology. 30:663-671.

Earl, W., Taliercio, G., Romano, J., Scheffler, B. and Ayre, G. 2009. *Expression of genes associated with carbohydrate metabolism in cotton stems and roots*. BMC Plant Biology. 9:11.

EL-aidy, F.M., EL-afry, and Ibrahim, F. 1990. *Effects of shade and fertilizer levels and their interactions on fruit yield of sweet pepper*. 23rd International Horticultural Congress, Italy, p. 3266.

Eissenstat, D.M. 1992. *Costs and benefits of constructing roots of small diameter*. J. Plant Nutr. 15:763-782.

Engelbrecht, B.M.J., Comita, L.S., Condit, R., Kursar, T.A., Tyree, M.T., Turner, B.L. and Hubbell, S.P. 2007. *Drought sensitivity shapes species distribution patterns in tropical forests.* Nature. 447: 80-82.

Epila, J., Hubeau, M. and Steppe, K. 2018. *Drought Effects on Photosynthesis and Implications of Photoassimilate Distribution in 11C-Labeled Leaves in the African Tropical Tree Species Maesopsis eminii Engl*. Forests. MDPI. 9(3):1-15.

Erwin, H.B., Fettig, S., Knake, C., Hartig, K. and Bhattarai, T .2007. *Specific and unspecific responses of plants to cold and drought stress. Bioscience*. Journal. 32:501-510.

Estrada-Campuzano, G., Miralles, D. and Slafer, G., 2008. *Yield determination in triti- cale as affected by radiation in different development phases*. Europian Journal Agronomy. 28: 597-605.

Evans, J.R., Kaldenhoff, R., Genty, B. and Terashima, I. 2009. *Resistances along the CO_2 diffusion pathway inside leaves*. Journal of Experimental Botany. 60: 2235-2248.

Evans, J. R. 1983. *Nitrogen and photosynyhesis in the flag leaf of wheat (Triticum aestivum L.)*. Plant Physiology. 72: 297-302.

Farooq, M., Basra, S.M.A., Wahid, A., Ahmad, N. and Saleem, B.A. 2009. *Improving the drought tolerance in rice (Oryza sativa L.) by exogenous application of salicylic acid.* Agronomy Crop Science. 195: 237-246.

Farooq, M., Bramley, H., Palta, J.A. and Siddique, K.H.M. 2011. *Heat stress in wheat during reproductive and grain filling phases*. Critical Revew Plant Science. 30: 491-507.

Farooq, M., Wahid, A., Ito O., Lee, D.J. and Siddique, K.H.M. 2009. *Advances in drought resistance of rice.* Critical Review Plant Science. 28: 199-217.

Farquhar, J., and Thiemens, M.H. 2000. *Oxygen cycle of the Martian atmosphere-regolith system: $\Delta^{17}O$ of secondary phases in Nakhla and Lafayette*. Journal of Geophysical Research Plants.105, 11991-11997.

Kaiser, W.M. 1987. *Effect of Water Deficit on Photosynthetic Capacity*. Phisiologia Plantarum Journal. 71: 142-149.

Fan, X.X., Zhi-Gang, X., Xiao-Ying, L., Can-Ming, T., Li-Wen, W. and Xue-lin, H. 2013. *Effects of light intensity on the growth and leaf development of young tomato plants grown under a combination of red and blue light*. *Scientia Horticulturae.* 153: 50-55.

Faver, K.L., Gerik, T.J., Thaxton, P.M. and El-Zik, K.M. 1996. *Late season water stress in cotton II. Leaf gas exchange and assimilation capacity*. Crop Science. 36: 922-928.

Fedorenko, A., Lightfoot, P.C., Naldrett, A.J., Czamanske, G.K., Hawkesworth, C.J., Wooden, J.L. and Ebel, D.S. 1995. *Petrogenesis of the Siberian fl oodbasalt sequence at Noril'sk*. International Geology Review. 38: 99-135.

Feng, L., Ali Reza, M., Li, Z., Chen, Y., Hayder Bin Khalid, M., Du, J., Liu, W., Wou, X., Song, C., Yu, L., Zhang, Z., Yuan, Sh., yang, W. and Yang, F. 2019. *The Influence of Light Intensity and Leaf Movement on Photosynthesis Characteristics and Carbon Balance of Soybean*. Frontiers in plant Science. 9: 1-16

Feng, Y.L., K.F. Cao, and Zhang, J.L. 2004. *Photosynthetic characteristics, dark respiration, and leaf mass per unit area in seedlings of four tropical tree species grown under three irradiances*. Photosynthetica. 42**:** 431-437.

Feng, J.A, Hu, X.L., Mao, X.J. 2002. *Application of chlorophyll fluorescence dynamics to plant physiology in adverse circumstance*. Econ. Forest Research. 20: 14-18.

Fernandes, V., Bezerra, L., Feijó, E. and Silva, D. 2013. *Light intensity on growth, leaf micromorphology and essential oil production of Ocimum gratissimum*. Revista Brasileira de Farmacognosia. 23: 419-424.

Ferrio, J.P., Pou, A., Florez-Sarasa, I., Gessler, A., Kodama, N., Flexas, J. and Ribas Carbó, M. 2012. *The Péclet effect on leaf water enrichment correlates with leaf hydraulic conductance and mesophyll conductance for CO_2*. Plant, Cell & Environment 35**:** 611-625.

Field, C. and Mooney, H.A. 1986. *The photosynthesis – nitrogen relationship in wild plants. - In: On the economy of plant form (GIVNISH T. J., Ed.).* Cambridge, University Press. 25-53.

Flagella, Z., Campanile, R.G. and Ronga, G. 1996. *The mainte nance of photosynthetic electron transport in relation to osmotic adjustment in durum wheat cultivars differing in drought resistance.* Plant Science. 118: 127-133.

Flexas, J. and Medrano, H. 2002. *Drought-inhibition of photosynthesis in C-3 plants: Stomatal and nonstomatal limitation revisited*. Annual Botany. 89: 183-1890.

Flexas, J., Bota, J., Loreto, F., Cornic, G. and Sharkey, T.D. 2004. *Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants.* Plant Biology. 6: 1-11.

Flore, J. 1980. *The effect of light on cherry trees.* Annual Report Michigan State Horticultural Society.

Foyer, C.H., Ruban, A.V. and Nixon, P.J. 2017. *Photosynthesis solutions to enhance productivity*. Philosophical Transaction Royal Society Lond B Biology Science. 372(1730):1-4.

Fracheboud, Y., Haldimann, P., Leipner, J. and Stamp, P. 1999. *Chlorophyll fluorescence as a selection tool for cold tolerance of photosynthesis in maize*. Journal of Experimental Botany. 338: 1533-1540.

Franklin, K.A., Larner, V.S. and Whitelam, G.C. 2005. *The signal transducing photoreceptors of plants*. International Journal of Develop Biology. 49: 653-664.

Fresnillo Fedorenko, D.E., Fernandez, O.A. and Busso, C.A. 1995. *The effect of water stress on top and root growth in Medicago minima*. Journal of Arid Environments. 29: 47-54.

Friend, D.J.C. 1965. *The effects of light and temperature on the growth o cereals. In: The Growth of Cereals and Grasses, XII Easter*. School of agric. Sci., Univ. of Nottingham, 181.

Fukuda, N., Fujitan, M., Ohta, Y., Sase, S., Nishimura, S. and Ezura, H., 2008. *Directional blue light irradiation triggers epidermal cell elongation of abaxial side resulting in inhibition of leaf epinasty in geranium under red light condition.* J. HortScience. 115: 176-182.

Fu, W., W.Pingping Li. and Wua, Y. 2012. *Effects of different light intensities on chlorophyll fluorescence characteristics and yield in lettuce*. Scientia Horticulturae. 135: 45-51.

Gaff, D.F. and Loveys, B.R. 1992. *Abscisic Acid Levels in Drying plants of A Resurrection Grass.* Transactions of Malaysian Soc. Plant physiol. 3(1992): 286-287.

Galle, A., Feller, U .2007. *Changes of photosynthetic traits in beech saplings (Fagus sylvatica) under severe drought stress and during recovery*. Physiol Plant. 131: 412-421.

Gathaara, M.P.H. and Kiara, J.M. 1988. *Effect of irrigation rates and frequency on the growth and yield of Arabica coffee*. Kenya Coffee. 53 (618): 309-312.

Gent, M. 2007. *Effect of Degree and Duration of Shade on Quality of Greenhouse Tomato*. HortScience. 42: 514-520.

Georgios, P., Merwin, I.A., Lakso, A.N. and Lakso, J.A. 2000. *Root Growth Phenology, Root Longevity, and Rhizosphere Respiration of Field Grown 'Mutsu' Apple Trees on 'Malling 9' Rootstock.* American society for Horticulture Science Journal. 125(5):596-602.

Gerganova, M., Popova, V., Stanoeva, A. and Velitchkova, D.M. 2016. *Tomato plants acclimate better to elevated temperature and high light than to treatment with each factor separately*. Plant Physiology and Biochemistry. 104: 234-241.

Ginter-Whitehouse, D.L., Hinckley, T.M. and Pallardy, S.G. 1983. *Spatial and temporal aspects of water relations of three tree species with different vascular anatomy*. For Science. 29:317-329.

Givnish, T.J., Montgomery, R.A. and Goldstein, G. 2004. *Adaptive radiation of photosynthetic physiology in the Hawaiian lobeliads: light regimes, static light responses and whole-plant compensation points.* American Journal of Botany. 91: 228-246.

Glslerod, H.R., Eidsten, I.M. and Mortensen, L.M. 1989. *The interaction of daily lighting period and light on growth of some greenhouse plants*. Scientia Horticulturae. 38: 295-304.

Goins, G., Yorio, N., Sanwo, M. and Brown, C. 1997. *Photomorphogenesis, photosynthesis, and seed yield of wheat plants grown under red lightemitting diodes (LEDs) with and without supplemental blue lighting*. Journal of Experimental Botany. 48: 1407-1413.

Gómez-Aparicio, L. 2009. *The role of plant interactions in the restoration of degraded ecosystems: a meta-analysis across life-forms and ecosystems*. Journal of Ecology. 97:1202-1214.

Gowing, D.J., Davies, W.J. and Jones, H.G. 1990. *A positive root-sourced signal as an indicator of soil drying in apple, Malus_domestica Borkh*. Journal of Experimental Botany. 41: 1535-1540.

Grant, O.M., Incoll, L.D. and McNeilly, T. 2005. *Variation in growth response to availability of water in Cistus albidus populations from different habitats.* Functional Plant Biology. 32: 817-829.

Greenway, H. and Setter, T.L. 1979. *Accumalation of proline and sucrose during the first hour after transfer of chlorella emersonii to high NaCl*. Plant Phisiology. 6: 69- 79.

Griffiths, H., Weller, G., Toy, L.F.M. and Dennis, R.J. 2013. *You're so vein: bundle sheath physiology, phylogeny and evolution in C3 and C4 plants. Plant*. Cell & Environment 36: 249-261.

Grimshaw, H., Havens, K., Sharfstein, B., Steinman, A., Anson, D., East, T., Maki, R., Rodusky, A. and Jin, K.-R. 2002. *The effects of shading on morphometric and meristic characteristics of Wild Celery, Vallisneria americana MICHX, transplants from Lake Okeechobee, Frorida. Arch.* Hydrobiology Journal. 155: 65–81.

Groom, Q. and Baker, N.R. 1992. *Analysis of light-induced depressions of photosynthesis in leaves of a wheat crop during the winter*. Plant Physiology. 100: 1217-1223.

Gutierrez, C. *The Arabidopsis cell division cycle*. 2009. Arabidopsis Book.

Hadi. P.A., Moucheshi. A.S., Pakniyat. H. and Pessarakli. M. 2016. *Stomatal responses to drought stress.* Water Stress and Crop Plants: A Sustainable Approach. 1: 24-40.

Hafid. R.E., Smith, D.H., Karrou, M. and Samir, K. 1998. *Physical responses of spring durum in a Mediterranean environment*. Annual Botany. 81**:** 363-370.

Hamidou, F., Zombre, G. and Braconnier, S. 2007. *Physiological and biochemical response of cowpea genotypes to water stress under glasshouse and field condition*. Journal of Agronomic Crop Science. 193: 229-239.

Hassan, I.A., Mohd Razi, I., Mohd Mokhtaruddin, M. and Halimi, M.S. 2003. *Effect of partial rootzone drying (PRD) on growth, yield and water use efficiency (WUE) of tomatoes on soilless culture. Trans*. Malaysian Society Plant Physiology. 12: 128-139.

Hasina, G., Zaman Khan, A., Khan Khalil, S.H., Ur rahman rehman, H., Anwar, S.H., Saeed, B. and Farhatullah., A. 2013. *Crop growth analysis and seed development profile of wheat cultivars in relation to sowing dates and nitrogen fertilization.* Pakistan Journal of Botany. 45(3): 951-960.

Hayat, S., Hayat, Q., Alyemeni, M.N., Wani, A.S., Pichtel, J. and Ahmad, A. 2012. *Role of proline under changing environments: a review*. Plant Signal Behavour. Journal. 7(11):1456-1466.

Hayatu, M. and Mukhtar, F.B. 2010. *Physiological responses of some drought resistant cowpea genotypes (vigna unguiculata (l.) walp) to water stress*. Bayero Journal of Pure and Applied Sciences. 3(2): 69-75.

Heath, R.L. and Packer, L. 1968. *Photoperoxidation inisolated chloroplast. I. kinetics and stoichiometry of fatty acid peroxidation*. Archive of Biochemistry and Biophysics 125: 189-198.

Hemm, M.R., Rider, S.D., Ogas, J., Murry, D.J. and Chapple, C. 2004. *Light induces phenylpropanoid metabolismin Arabdosis roots.* The Plant Journal, 38(5): 765-778.

Herbinger, K., Tausz, M., Wonisch, A., Soja, G., Sorger, A. and Grill, D. 2002. *Complex interactive effects of drought and ozone stress on the antioxidant defence systems of two wheat cultivars. Plant Physiol*. Biochem. 40: 691-696.

Herpich, W.B. and Peckmann, K. 1997. *Responses of gas exchange, photosynthesis, nocturnal acid accumulation and water relations of Aptenia cordifolia to short-term drought and rewatering*. Journal of Plant Physiology. 150: 467-474.

Herzog, V. and Fahimi, H. 1973. *A new sensitive colorimetric assay for peroxidase using 3,3'-diaminobenzidine as hydrogen donor*. Annal Biochemistry. 55: 554-562.

Hiesey, W.M., Nobs, M.A. and Bjorkman, O. 1967. *Light-saturated rates o photosynthesis in Mimulus cardinahs.* Carnegie Inst. Yr Bk. 65: 461.

Hocking, P.J. and Meyer, C.P. 1991. *Effects of CO_2 enrichment and nitrogen stress on growth and partitioning of dry matter and nitrogen in wheat and maize*. Austuralian Journal Plant Physiology. 18: 339-356.

Hoenecke, M., Bula, R.J. and Tibbitts, T.W. 1992. *Importance of 'blue' photon levels for lettuce seedings grown under red light-emitting diodes.* J. *HortScience*. 27: 427-430.

Hogewoning, S.W., Trouwborst, G., Maljaars, H., Poorter, H., Ieperen, W.V. and Harbinson, J. 2010. *Blue light dose-responses of leaf photosynthesis, morphology, and chemical composition of Cucumis sativus grown under different combinations of red and blue light.* Journal Experimental Botany. 61: 3107-3117.

Hörtensteiner, S. and Kräutler, B. 2011. *Chlorophyll breakdown in higher plants*. Biochimica et Biophysica acta. Science Direct. 1807: 977-988.

Hsiao, T.C. 1973. *Plant Response to Water Stress*. Annu. Rev. Plant Physiology. 24: 519-570.

Hsiao, T.C. and Jackson, R.B. 1999. *Interactive effects of water stress and elevated carbon dioxide on growth, photosynthesis and water use efficiency in Carbon dioxide and environmental stress*. Academic Press, San Diego. 3-26.

Hunt. R. 1978. *Plant growth analysis*. 26-38. Edward Arnold, Olondon, UK.

Hurd, R.G. and Thornley, J.H.M. 1974. *Analysis of the growth of young tomato plant in water culture at different light integrals and CO_2 concentration I.* Physiological aspect. Annals of Botany. 38: 375-378.

Hussain, B. and Ali, B. 2015. *Leaf Longevity in Plants under Water Stress – A Review*. Indian Journal of Plant Sciences. 4: 127-133.

Hussey, G. 1963. *Growth and development in the young tomato: I. The effect of temperature and light intensity on growth of the shoot apex and leaf primordia.* J. Exp. Bot. 14: 316-325.

Iqbal, N., Khan, NA., Ferrante, A., Trivellini, A., Francini, A. and Khan, M.I.R. 2017. *Ethylene Role in Plant Growth, Development and Senescence: Interaction with Other Phytohormones*. Frontier Plant Science. 8: 1-19.

Iqbal, R.M. 2003. *Equilibration study to determine procedure for determining net photosynthesis and photon flux densities response curves*. Asian Journal. Plant Science. 2(15):1083-1087.

Irving, D.E. and Drost, J.H., 1987. *Effects of water deficit on vegetative growth, fruit growth and fruit quality in Cox's Orange Pippin apple*. Journal of Horticulture. Sci. 62: 427-432.

Ismail, M.R. and Davies, W.J. 1997. *Water relations of Capsicum genotypes under water stress*. Biol Planta. 39 (2): 293-297.

Ismail, M.R., Burrage, S.W., Tarmizi, H. and Aziz, M.A. 1994. *Growth, plant water relations, photosynthesis rate and accumulation of proline in young carambola plants in relation to water stress*. Science Horticulture 60 101-114.

Ismail, M.R. and Awang, M. 1992. *Growth and physiological changes ofAverrhoa carambola as influenced by water availability*. Pertanika, 15 (1): 1-7.

IturbeOrmaetxe, I., Escuredo, P.R., Arrese-Igor, C. and Becana, M. 1998. *Oxidative damage in pea plants exposed to water deficit or paraquat*. Plant Physiology. 116: 173-181.

Jaafar, H.Z. 1995. *Impact of environmental stress on reproductive development of sweet pepper (Capsicum annuum L.).* PhD Thesis, University of Nottingham, UK.

Jaafar, H.Z., Mohd Hafiz, I. and Ehsan. K. 2012. *investigated Lyase and Antioxidant Activity Responses to Elevated CO_2 in Labisia pumila (Myrisinaceae).* Molecules. 17: 6331-6347.

Jaafar, H. Z.. Mohd Hafiz, I. and Nur Farhana, M.F. 2012. *Impact of Soil Field Water Capacity on Secondary Metabolites, Phenylalanine Ammonia-lyase (PAL), Maliondialdehyde (MDA) and Photosynthetic Responses of Malaysian Kacip Fatimah (Labisia pumila Benth).* Molecules 17: 7305-7322.

Jackson, R.B., Mooney, H.A. and Schulze, E.D. 1997. *A global budget for fine root biomass, surface area, and nutrient contents*. Proc. Nat. A. Scienc. 94:7362-7366.

Jackson, R.B. Sperry, J.S. and Dawson, T.E. 2000. *Root water uptake and transport: using physiological processes in global predictions.* Trends in Plant Science. 5: 482-488.

Jaganath, I.B. and Ng, L.T. 2009. *Herbs: The Green Pharmacy of Malaysia.* Kuala Lumpur: Vinpress Sdn. Bhd.

Jagtap, V., Bhargava, S., Sterb, P. and Feierabend, J. 1998. *Comparative effect of water, heat and light stresses on photosynthetic reactions in Sorghum bicolor (L.) Moench*. J. Exp. Bot. 49: 1715-1721.

Janssen, L.H., Wams, H.E. and Hasselt, P.V. 1991. *Temperature dependence of chlorphyll fluorescence induction and photosynthesis in tomato as affected by temperature and light conditions during growth*. Journal of Plant Physiologyl. 139.

Jeangros, B. and Nösberger, J. 1992. *Comparison of the growth response of Rumex obtusifolius L. and Lolium perenne L. to photon flux density*. Weed Research. 32**:** 311-316.

Jedel, P.E. and Hunt, L.A. 1990. *Shading and thinning effects on multi-and standard-floret winter wheat.* Crop science. 30: 128-133.

Liao, J.X., Zou, X.Y. and Ge, Y. 2006. *Effects of light intensity on growth of four Mosla species*. Botanical Studies.47: 403-408.

Jiwanjinda, S., Santisopasri, V., Murakam, A.H., irai, N. and Ohigashi, H. 2001. *Quassinoid from Erycoma Longifolia as plant growth inhibitors*. Phytochemistry. 58: 959-962.

Kabayashi, K.D. and M.A. Nagao. 1986. *Irrigation effects on vegetative growth of coffee*. HortScience. 21 (3): 533-539.

Kang, S. Liang, Z. Hu, W. and J. Zhang. 1998. *Water use efficiency of controlled root- division alternate irrigation on maize plants*. Agricultural Water Management. 38: 69176.

Kappel, F. and Flore, J. 1983. *Effect of shade on photosynthesis, specific leaf weight, leaf chlorophyll content, and morphology of young peach trees [Prunus persica]*. Journal of Society Horticulture Science. 108.

Karrou, M. and Maranville, J.W. 1995. *Response of wheat cultivars to different soil nitrogen and moisture regimes: II. Leaf water content, stomatal conductance and photosynthesis*. Journal of Plant Nuitrient. 4**:** 777-791.

Kavi Kishor, P.B., Hima Kumari, P., Sunita, M.S. and Sreenivasulu, N. 2017. *Role of proline in cell wall synthesis and plant development and its implications in plant ontogeny.* Frontier Plant Science. 6: 1-17.

Kawamitsu, Y., Driscoll, T. and Boyer, J.S. 2000. *Photosynthesis during desiccation in an Intertidal Alga and a Land Plant. Plant Cell Physiol*. 41 (3): 344-353.

Keya, G.A. 1998. Growth, water relations and biomass production of the savannas grasses Chloris roxburghiana and Cenchrus ciliaris in Kenya. Journal of Arid Environ. 38: 205-219.

Khatib, K.A. and Paulsen, G.M. 1989. *Enhancement of thermal injury to photosynthesis in wheat plants and thylakoids by high light intensity*. Journal of Plant Physiology. 90, 1041-1048.

Kim, H.H., Gregory, D.G. and Raymond, M.C. 2007. *Green-light supplementation for enhanced lettuce growth under red- and blue-light-emitting diodes. J. HortScience*.58: 3099-3111.

Kim, H.-H., Goins, G.D., Wheeler, R.M. and Sager, J.C. 2004. *Green-light supplementation for enhanced lettuce growth under red- and bluelight-emitting diodes.* HortScience. 39: 1617-1622.

Kohl, D.H., Kennely, E.D., Schubert, K.R. and Shearer, G., 1991. *Proline accumulation, nitrogenase (C_2H_2 reducing) activity and activities of enzymes related to proline metabolism in drought-stressed soybean nodules*. Journal of Experimental Botany. 42: 831-837.

Kooten, O.V. and Snel, J.F.H. 1990. *The use of chlorophyll fluorescence nomenclature in plant stress physiology.* Photosynthesis Research. 25: 147-150.

Kpyoarissis, A., Petropoulou, Y. and Manetas, Y. 1995. *Summer survival of leaves in a soft-leaved shrub (Phlomis fruticosa L., Labiatae) under Mediterranean field conditions: avoidance of photoinhibitory damage through decreased chlorophyll contents.* Journal of Experimental Botany. 46: 1825-1831.

Krause, G.H., Winter, K., Krause, B. and Virgo, A. 2015. *Light-stimulated heat tolerance in leaves of two neotropical tree species, Ficus insipida and Calophyllum longifolium.* Function Plant Biology. 42: 42-51.

Kremer, E. and Kropff, M.J. 1999. *Comparative growth of triazine-susceptible and -resistant biotypes of Solanum nigrum at different light levels*. Annual Botany Journal. 83: 637-644.

Krieg, D.R. 1983. *Photosynthetic activity during stress*. Agriculture Water Manage journal. 7: 249-263.

Krishna Surendar, K., Durga Devi, D., Ravi, I., Krishnakumar, S., Ramesh Kumar, S. and Velayudham, K. 2013. *Impact of Water Deficit on Photosynthetic Pigments and Yield of Banana Cultivars and Hybrids*. Plant Gene and Trait. 4: 1-4.

Kuang, J.B., Turner, N.C. and Henson, I.E. 1990. *Influence of xylem water potential on leaf elongation and osmotic adjustment of wheat and lupin*. Journal of Experimental Botany. 41: 217-221.

Kuczynska, P., Jemiola-Rzeminska, M. and Strzalka, K. 2015. *Photosynthetic Pigments in Diatoms*. Marine Drugs. 13: 5847-5881.

Kulshrestha, S., Mishra D.P. and Gupta, R.K. 1987. *Changes in content of chlorophyll, protein and lipids in whole chloroplast membrane fractions at different leaf water potential in drought resistant and sensitive genotypes of wheat.* Photosynthetica. 21:65-70.

Kumar, D. 1979. *Some aspects of the physiology of Coffea arabica L.:* A review. Kenya Coffee. 44 (519): 9-41.

Kyparissis, A., Petropoulou, Y. and Manetas, Y. 1995. *Summer survival of leaves in a soft-leaved shrub (Phlomis fruticosa L., Labiates) under Mediterranean field conditions: Avoidance of photoinhibitory damage through decreased chlorophyll contents.* Journal of Experimental Botany. 46:1825-1831.

Lambers, H., Chapin, F.S. and Pons, T.L. 2008. *Plant physiological ecology*, 2nd edn. Springer, New York.

Lambers, H. and Poorter, H. 1992. *Inherent variation in growth rate between higher plants: a search for physiological causes and ecological consequences*. Advances in Ecological Research. 23: 187-261.

Lawlor, D.W. 2002. *Limitations to photosynthesis in waterstressed leaves: stomatal vs. metabolism and the role of ATP*. Annual Botany. 89: 871-885.

Lentz1, K.A. and Cipollini, D.F. 1998. *Effect of light and simulated herbivory on growth of endangered northeastern bulrush, Scirpus ancistrochaetus Schuyler*. Plant Ecology. 139**:** 125-131.

Lessani, H. and Mojtahedi, M. 2002. *Introduction to Plant Physiology (Translation)*. 6th Edn., Tehran University press, Iran. 726.

Levitt, J. 1980. *Responses of plants to environmental stresses, Water, Radiation, Salt, and Other Stresses.* New York: Academic Press. 2.

Liao, J.X., Ge, Y., Huang, C.C., Zhang, J., Liu, Q.X. and Chang, J. 2005. *Effects of irradiance on photosynthetic characteristics and growth of Mosla chinensis and M. scabra*. Photosynthetica. 43: 111-115.

Liang, X., Zhang, L., Natarajan, S.K. and Becker, D.F. 2013. *Proline mechanisms of stress survival*. Antioxidants Redox Signal. 19 (9):998-1011.

Ligia, T.B., Robert, C. and Julie, G. 2019. *Impact of Stomatal Density and Morphology on Water-Use Efficiency in a Changing World*. Plant Science. 10: 225.

Lilley, J.M. and Fukai, S. 1994. *Effect of timing and severity of water deficit on four diverse rice cultivars II. Physiological responses to soil water deficit.* Field Crops Research. 37: 215-223.

Lisar, R., Motafakkerazad, M.M.H. and Rahman, I.M.M. 2012. *Introductory Chapter Water Stress in Plants* : Causes, Effects and Responses. 1-15.

Li, S.H., Huguet, J.G., Schoch, P.G. and Orlando, P. 1989. *Response of peach tree growth and cropping to soil water deficit at various phenological stages of fruit development.* J. Horticulture Science. 64: 541-552.

Li, Q. and Kubota, C. 2009. *Effects of supplemental light quality on growth and phytochemicals of baby leaf lettuce*. J. Environ. Exp. Bot. 67: 59-64.

Li, X., Chen, L., Forde, B.G. and Davies, W.J. 2017. *The Biphasic Root Growth Response to Abscisic Acid in Arabidopsis Involves Interaction with Ethylene and Auxin Signalling Pathways*. Front Plant Science. 8:1493.

Li, X., Jiao, D.M. and Liu, Y.L. 2002. *Chlorophyll fluorescence and membrane lipid peroxidation in the flag leaves of different high yield rice variety at late stage of development under national condition*. Acta Bot. Sin. 44: 413-421.

Lichtenthaler, H.K. and Babani, F. 2000. *Detection of photosynthetic activity and water stress by imaging the red chlorophyll fluorescence*. Plant Physiology and Biochemistry. 38: 889-895.

Lichtenthaler, H.K., Marek, M.V., Kalina, J. and Urban, O. 2007. *Differences in pigment composition, photosynthetic rates and chlorophyll fluorescenc images of sun and shade leaves of four tree species. Journal of Plant Physiology*. Biochemistry. 45: 577-588.

Lingling, L., Renzhi, Z., Zhuzhu, L. and Weili, L. 2014. *Evolution of soil and water conservation in rain-fed areas of China*. International soil and water conservation research. 2: 78-90.

Liu, C., ZGuo, C., Wang, Y.C. and Ouyang, F. 2002. *Effect of light irradiation on hairy root growth and artemisinin biosynthesis of Artemisia annua*. Process Biochemistry 38: 581-585.

Liu, J., Zeng, D., Lee, D.K., Fan, Z. and Zhong, L. 2008. *Leaf traits and their interrelationship of 23 plant species in southeast of Keerqin Sandy Lands, China.* Frontial Biology. China 3:332-337.

Liu, W. and Su, J. 2016. *Effects of light acclimation on shoot morphology, structure, and biomass allocation of two Taxus species in southwestern China*. Scientific Reports. 6:35384.

Ludlow, M.M. and Muchow, R.C. 1990. *A critical Evaluation of Traits for improving Yield in water limited Environments*. Advance Agronomy. 43:107-153.

Macedo, A.F., Marcos, V.L., Tavares, E.S., Lage, C.L.S. and Esquibel, M.A. 2011. *The effect of light quality on leaf production and development of in vitro-cultured plants of Alternanthera brasiliana Kuntze*. Journal of Environment Experimental Botany. 70: 43-50.

Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P.C. and Sohrabi, Y. 2010. *Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars*. 580-585.

Maskova, T. and Herben, T. 2018. *Root: shoot ratio in developing seedlings: How seedlings change their allocation in response to seed mass and ambient nutrient supply*. Wiley Ecology and Evolution. 7143-7150.

Masri, M. and Abdul Razak, S. 1992. *Effects of water stress on reproductive growth of papaya (Carica papaya L.).* In: Y.W. Ho, M.K. Vidyadaran, A. Norhani, M.R. Jainudeen and A.R. Bahaman (Editors), Proceedings of National IRPA (Agriculture Sector), Vol. 1, Crops and Plants. Ministry of Science and Environment, Kuala Lumpur, Malaysia. 5-6.

Mathur, S., Agrawal, D. and Jajoo, A. 2014. *Photosynthesis: Response to high temperature stress.* Journal of phytochemsitry and phytobiology.137: 116-126.

Matin, M.A., Brown, J.H. and Ferguson, H. 1989. *Leaf water potential, relative water content and diffusive resistance as screening techniques for drought resistance in barley*. Agronomy Journal. 81: 100-105.

Matthes, U. and Larson, D.W. 2006. *Microsite and climatic controls of tree population dynamics: an 18-year study on cliffs*. Journal of Ecology 94: 402-414.

Matos, F.S., Wolfgramm, R., Cavatte, P.C., Villela, F.G., Ventrella, M.C. and DaMatta, F.M. 2009. *Phenotypic plasticity in response to light in the coffee tree.* Journal of Environment Experimental Botany. 67: 421-427.

McAusland, L., Vialet-Chabrand, S., Davey, P., Baker, N.R., Brendel, O. and Lawson, T. 2016. *Effects of kinetics of light-induced stomatal responses on photosynthesis and water-use efficiency*. New Phytol. 211(4):1209-1220.

McDermitt, D.K. 1987. *Photosynthesis measurement systems: Performance comparison of the LI-6200 to the LI-6000. LICOR, inc. Lincoln, Neb*. USA. LI-COR Application Note 6200.1-9.

Medici, L.O., Azevedo, R.A. and Canellas, L.P. 2007. *Stomatal conductance of maize under water and nitrogen deficits. – Pesq.* Agropec. Bras. 42: 599-601.

Meinzer, F.C., Saliendra, N.Z., and Crisosto, C.H. 1992. *Carbon isotope discrimination and gas exchange in Coffea Arabica during adjustment to different soil moisture regimes.* Austuralian Journal of Plant Physiology. 19(2): 171-184.

Mekhaldi, A. Benkhelifa, M. Belkhodja, M. 2008. *The effect of salinity on gas exchange on different developmental stages of mung bean (Vigna radiata L. Wilczek). Intl J. Bot*. 4(3): 269-275.

Middelboe, A. L., Sand-Jensen, K. and Binzer, T. 2006. *Highly predictable photosynthetic production in natural macroalgal communities from incoming and absorbed light*. Oecologia 150: 464-476.

Mingo, T.J.C., Bacon, M.A., Davies, W.J. and Dodd. I.C. 2004. *Biomass allocation in tomato (Lycopersicon esculentum) plants grown under partial root I zone drying: enhancement of root growth*. Functional Plant Biology 31: 971-978.

Miller, S.S., Hott, C. and Tworkoski, T. 2015. *Shade effects on growth, flowering and fruit of apple.* Journal of Applied Horticulture. 17(2): 101-105.

Mirnoff, N. 1993. *The role of active oxygen in the response of plants to water deficit and desiccation.* New Phytology. 125: 27-58.

Misra, A.N., Misra, M. and Singh, R. 2011. *Nitric oxide ameliorates stress responses in plants*. Plant Soil Environ. 57(3):95-100.

Misra, A.N., Misra, M. and Singh, R. 2012. *Chlorophyll fluorescence in plant biology. Biophysics*. (Ed. Misra A N) ISBN 979-953-307-290-5.

Misra, A.N., Latowski, D. and Strzalka, K. 2006. *The xanthophylls cycle activity in kidney bean and cabbage leaves under salinity stress*. Russian Journal of Plant Physiology. 53: 102-109.

Misra, A.N., Biswal, A.K. and Misra, M. 2002. *Physiological, biochemical and molecular aspects of water stress responses in plants, and the biotechnological applications.* Proc. Nat. *Acad. Sci*. 72(2): 115-134.

Misra, A.N., Srivastava, A. and Strasser, R.J. 2001. *Utilisation of fast Chlorophyll a fluorescence technique in assessing the salt/ion sensitivity of mung bean and brassica seedlings*. Journal of Plant Physiology. 158:1173-1181.

Misra, A.N., Srivastava, A. and Strasser, R.J. 2001. *Fast chlorophyll a fluorescence kinetic analysis for the assessment of temperature and light effects: A dynamic model for stress recovery phenomena*. Photosynthsis PS2001. CSIRO Publ., Melbourne, Australia S3-007.

Mitchell, K.J. 1953. *Influence of light and temperature on the growth of ryegrass (Lolium spp.). 1. The pattern of vegetative development*. Physiologia PL, 6-21.

Mohd Razi, I. and Ali, Z. 1994. *Effects of Low Irradiance on Growth, Water Uptake and Yield of Tomatoes Grown by the Nutrient Film Technique*. PertanikaJ. Trap. Agric. Sci. 17(2): 89-93.

Mohd Razi, I. and Awang, M.1992. *Growth and physiological changes ofAverrhoa carambola as influenced by water availability*. PertanikaJ. Trap. Agric. Sci. 15 (1): 1-7.

Mohd Razi, I. and Yusof, M.K.1996. *Effect of Irradiance on Growth, Physiological Processes and Yield of Melon (Cucumis mela) Plants Grown in Hydroponics*. Pertanika J Trop. Agri. Sci. 19(2/3): 103-110.

Mohd Razi, I, Burrage, S.W., Tarmizi, H. and Aziz, M.A. 1994. *Growth, plant water relations, photosynthesis rate and accumulation of proline in young carambola plants in relation to water stress.* Science Horticulture. 60: 101-114.

Molnar, I., Gaspar, L., Stehli, L., Dulai, S., Sarvari, E., kirali, I., Galiba, G. and Molnar- Lang, M. 2002. *The effect of drought stress on the photosynthetic processes of wheat and of Aegilops biuncialis genotype originating from various habitats.* Acta. *Biol. Szeged*. 4: 115-116.

Montagu, K.D. and WOO, K.C. 1999. *Recovery of tree photosynthetic capacity from seasonal drought in the wet-dry tropics: The role of phyllode and canopy processes in Acacia auriculiformis.* Aust. Journal of Plant Physiology. 26: 135-145.

Montgomery, R.A. and Chazdon, R.L. 2002. *Light gradient partitioning by tropical tree seedlings in the absence of canopy gaps*. Oecologia. 131: 165-174.

Morais, H., Medri, M.E., Marur, C.J., Caramori, P.H., Ribeiro, A.M. and Gomes, J.C. 2004. *Modifications on leaf anatomy of Coffea arabica caused by shade of Pigeonpea (Cajanus cajan). Braz. Arch. Biol. Technology Journal.* 47: 863-871.

Morita, H., Kishi, E., Takeya, K., Itokawa, H. and Litaka, Y, 1993. *Squalene derivatives from Eurycoma Longifolia*. Phytochemistry. 34(3): 765-771.

Muchow, R.C. 1985. *Phenology, seed yield and water use of grain legumes grown under different soil water regimes in a semi-arid tropical environment*. Field Crops Research. 11: 81-97.

Mwanamwenge, J., Loss, S.P., Siddique, K.H.M. and Cocks, P.S. 1999. *Effect of water stress during floral initiation, flowering and podding on the growth and yield of faba bean (Vicia faba L.).* Europian Journal of Agronomy. 11: 1-11.

Nadia, M.E., Mohamed, N., Muhammad, N., Naina Mohamad, I. and Nazrun Shuid, A. 2012. *Eurycoma longifolia: Medicinal Plant in the Prevention and Treatment of Male Osteoporosis due to Androgen Deficiency.* Evidence-Based Complementary and Alternative Medicine. 2012: 1-9.

Nageswara Roa, R.C., Talwar, H.S. and Wright, G.C. 2001. *Rapid assessment of specific leaf area and leaf nitrogen in Peanut (Arachis hypogaea L.) using chlorophyll meter*. Journal of crop Science. 189: 175-182.

Naoya, F., Mitsuko, F., Yoshitaka, O., Sadanori, S., Shigeo, N. and Hiroshi, E. 2008. *Directional blue light irradiation triggers epidermal cell elongation of abaxial side resulting in inhibition of leaf epinastyin geranium under red light condition.* Journal of Science Horticuture. 115: 176-182.

Naser, A. 2013. *The impact of drought stress on photosynthetic quantum yield in Haloxylon aphyllum and Haloxylon persicum*. African Journal of Plant Science. 7 (6): 185-189.

Naser, A. 2009. *The examination of dryness induction effect in growth, some of physiological relations (parameters of water relations), physiological changes and increasing of drought tolerance range in Haloxylon persicum and H. aphyllum*, Thesis submitted for degree of Ph.D in plant physiology. Department of Biology Sciences, Teacher Training (Tarbiyat Moallem) University of Tehran.

NeSmith, D.S. and Ritchie, J.T. 1992. *Short- and long-term responses of corn to a pre-anthesis soil water deficit*. Agronomy Journal. 84: 107-113.

Niinemats, U. 2002. *Stomatal conductance alone does not explain the decline in foliar photosynthetic rates with increasing tree age and size in Picea abies and Pinus sylvestris.* Tree Physiology. 22: 515-535.

Nilsen, E.T. and Orcutt, DM. 1996. *Physiology of Plants Under Stress, Abiotic Factors.* 2nd Edn., John Wiley and Sons Inc., New York. pp: 689.

Niyogi, K.K. 1999. *Photoprotection revisited: genetic and molecular approaches*. Annu Rev Plant Physiol Plant Mol Biol 50: 333-359.

Norkapsi, K., Raja Zulkifli, R.O., Suoh, I. and Wahid, O. 2009. *Potensi Penanaman Integrasi Tongkat Ali (Eurycoma Longifolia) dan Kelapa Sawit dengan Sistem Tanaman Dua Baris Kembar*. Herbal Globalisation: A new Paradigm for Malaysian Herbal Industry. 20-36.

Oda, Y. 1996. *Effects of light intensity, CO_2 concentration and leaf temperature on gas exchange of strawberry plants-feasibility studies on CO_2 enrichment in Japanese conditions.* In: III International Strawberry Symposium. 439.

Ogren, E. and Sjoistrom, M. 1990. *Estimation of the effect of photoinhibition on the carbon gain in leaves of a willow canopy*. Planta. 181: 560-567.

Olsovska, K., Kovar. M., Brestic, M., Zivcak, M., Slamka, P. and Shao, H.B. 2016. *Geno typically Identifying Wheat Mesophyll Conductance Regulation under Progressive Drought Stress*. Frontiers in Plant Science. 7: 1111.

Ommen, O.E., Donnelly, A., Vanhoutvin, S., Van, O.M. and Manderscheid, R. 1999. *Chlorophyll content of spring wheat flag leaves grown under elevated CO_2 concentrations and other environmental stresses within the ESPACE-wheat project.* Europian Journal of Agronomy. 10: 197-203.

Omprakash, R.G., Bisen, P., Baghel, M. and Nishant C.K. 2017. *Resistance/Tolerance Mechanism under Water Deficit (Drought) Condition in Plants.* International Journal of Current Microbiology and Applied Sciences 6: 66-78.

Omran, G. R. 1980. *Peroxide levels and the activities of catalase, peroxidase and indoleacetic acid oxidase during and after chilling cucumber seedlings*. Plant physiology. 65: 407-408.

Osaki, M., Iyoda, M., Yamada, S. and Tadano, T. 1995. *Effect of mutual shading on carbon distribution in rice plant*. Soil Sci. Plant Nutr. 41: 235-244.

O'Toole, J.C., Ozbun, J.L. and Wallace, D.H. 1977. *Photosynthetic response to water stress in Phaseolus vulgaris.* Physiology Plant. 40: 111-114.

Pandey, V., Awashti, M., Singh, S., Tiwari, S. and Dwivedi, U. 2017. A Comprehensive Review on Function and Application of Plant Peroxidases.Biochemistry and Analytical Biochemistry. 6: 1-16.

Pandey, R.K., Herrera, W.A.T., Villegas, A.W. and Penletion, J.W. 1984. *Drought response of grain legumes under irrigation gradient. III.* Plant growth. 76: 557-560.

Passioura, J.B. 1988. *Root signals control leaf expansion in wheat seedlings growing in drying soil.* Austeralian Journal of Plant Physiology. 15: 687-693.

Pearcy, R.W., Chazdon, R.L., Gross, L.G. and Mott. K.A. 1994. *Photosynthetic utilization of sunflecks: a temporally patchy resource on a time scale of seconds to minutes. In M. M.Caldwell and R. W. Pearcy [eds.], Exploitation of environmental heterogeneity by plants.* Academic Press, San Diego, California, USA. 175-208.

Pei, Y. and Bie, Z. 2007. *Effects of different irrigation minima on the growth and physiological characteristics of lettuce under plastic greenhouse*. Trans. Chin. Soc. Agric. Eng. 23: 176-180.

Pennisi, E. 2008. *The blue revolution, drop by drop, gene by gene*. Science. 32: 17 173.

Pennypacker, B.W., Leat, K.T., Stout, W.L. and Jr. Hill, R.R. 1990. *Technique for simulating field drought stress in the greenhouse.* Agronomy Journal. 82: 951-957.

Pereira, J.S. and Chaves, M.M. 1993. *Plant water deficits in Mediterranean ecosystems. In: Smith, J.A.C., Griffiths, J. (Eds.),Water DeficitsdPlant Responses from Cell to Community.* Bios Scientific Publishers, Oxford. 221-235.

Peterson, T.A., Blackmer, T.M., Francis, D.D. and Scheppers, J.S. 1993. *Using a chlorophyll meter to improve N management. AWebguide in Soil Resource Management: D-13 Fertility.* Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE, USA.

Pic, E., de La Serve, B.T., Tardieu, F. and Turc, O. 2002. *Leaf senescence induced by mild water deficit follows the same sequence of macroscopic, biochemical, and molecular events as monocarpic senescence in pea*. Plant Physiology. 1: 236-246.

Pirasteh-Anosheh, H., Saed-Moucheshi, A., Pakniyat, H. and Pessarakli, M. 2016. *Stomatal responses to drought stress***.** Water Stress and crop Plant. 1: 24-40.

Poorter, L. 2001. *Light-dependent changes in biomass allocation and their importance for growth of rain forest tree species*. Functional Ecology. 15: 113-123.

Pothier, D. and Prévost, M. 2002. *Photosynthetic light response and growth analysis of competitive regeneration after partial cutting in a boreal mixed stand*. Trees. 16**:** 365-373.

Pugnaire, F.I., Serrano, L. and Pardos, J. 1999. *Constraints by Water Stress on Plant Growth.* In *Handbook of Plant and Crop Stress,* ed. M.Pessarakli. 271-283. New York: Marcel Dekker.

Purbajanti, E.D., Anwar, S., Kusmiyati, F.W. 2012. *Drought stress effect on morphology characters, water use efficiency, growth and yield of guinea and napier grasses.* International Research Journal. 3(4): 47-53.

Qaderi, M., Martel, A. and Dixon, S. 2019. *Environmental factors influenceplant vascularsystem and water regulation*. MDPI Plants. 8: 1-25.

Quero, J. L., Rafael Villar, T.M., Regino, Z., Dolores, V. and Lawren S. 2008. *Relating leaf photosynthetic rate to whole-plant growth: drought and shade effects on seedlings of four Quercus species*. Functional Plant Biology. 35: 725-737.

Radin, J.W. and Ackerson, R.C. 1981. *Water relations of cotton plants under nitrogen deficiency. III. Stomata1 conductance, photosynthesis, and abscisic acid accumulation during drought.* Plant Physiology. 67:115-119.

Rahnama, A., Poustini, K., Tavakkol-Afshari, R. and Tavakoli, A. 2010. *Growth and stomatal responses of bread wheat genotypes in tolerance to salt stress*. – Int. J. Biol. Life Sci. 6: 216-221.

Rajapakse, N.C., Pollock, R.K. and McMahon, M.J. 1992. *Interpretation of light quality measurements and plant response in spectral filter research*. J. HortScience. 27: 1208-1211.

Ramanjulu, S., Sreenivasalu, N. and Sudhakar, K.G.C. 1998. *Photosynthetic characteristics in mulberry during water stress and rewatering*. Photosynthetica. 35(2): 259-263.

Razi Ismail, M., Burrage, S.W., Tarmizi, H. and Aziz, M.A. 1994. Growth, *Plant water relations, photosynthesis rate and accumulation of proline in young carambola plants in relation to water stress*. Scientia Horticulturae. 101-114.

Reekie, E.G. and Wayne, P. 1992. *Leaf canopy display, stomatal conductance, and photosynthesis in seedlings of three tropical pioneer tree species subjected to drought.* Canadian Journal of Botany. 70: 2334-2338.

Reich, P.B., Tjoelker, M.G., Walters, M.B., Vanderklein, D.W. and Buschena, C. 1998. *Close association of RGR, leaf and root morphology, seed mass and shade tolerance in seedlings of nine boreal tree species grown in high and low light.* Functional Ecology. 12: 327-338.

Rensburg, L.V. and Kruger, G.H.J. 1994. *Evaluation of components of oxidative stress metabolism for use in selection of drought tolerant cultivars of Nicotiana tabacum L*. J. Plant Physiol. 143:730-737.

Rhizopoulou, S., Meletiou-Christou, M.S. and Diamantoglou, S. 1991. *Water relations I for sun and shade leaves of four Mediterranean Evergreen Sclerophylls.* Journal of Experimental Botany. 42(238): 627-635.

Rivero, R.M., Mestre, T.C., Mittler, R., Rubio, F., Garcia-Sanchez, F. and Martinez, V. 2014. *The combined effect of salinity and heat reveals a specific physiological, biochemical and molecular response in tomato plants*. Plant Cell & Environment. 10: 11-19.

Rizwan, S. and Aftab, F. 2018. *Morphological and Biochemical Responses of Jatropha curcas under Water Stress*. International journal of agriculture & biology. 20(9):1929-1936.

Rmikil, N.E., Brunet, C., Cabioch, J. and Lemoine, Y. 1996. *Xanthophyllcycle and photosynthetic adaptation to environment in macro and microalgae*. Hydrobiologia. 326: 407-413.

Robinson, D.W. 1990. *Developments with plastic structures and materials for horticultural crops.* Paper presented at the International Seminar on Hydroponic Culture of High Value Crops in the Tropics. Nov 25-27, 1990, Universiti Pertanian Malaysia, Serdang, Malaysia.

Robson, M.T., Rodríguez-Calcerrada, J., Sánchez-Gómez, D. and Aranda, I. 2009. *Summer drought impedes beech seedlings performance more in a sub-Mediterranean forest understory than in small gaps*. Tree Physiol. 29: 249-259.

Ruiz-Sa'nchez, M.C, Domingo, R., Torrecillas, A. and Pe'rez-Pastor, A. 2000. *Water stress preconditioning to improve drought resistance in young apricot plants.* Plant Science. 156:245-251.

Ryser, P. and L. Eek. 2000. *Consequences of phenotypic plasticity vs. interspecific differences in leaf and root traits for acquisition of aboveground and belowground resources.* Am. J. Bot. 87**:** 402-411.

Ryser, P. 2006. *The mysterious root length*. Plant and Soil. 286: 1-6.

Rylski, I. and M. Spigelman. 1986. *Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation.* Scientia Horticulturae. 29: 31-35.

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

Saebo, A., Krekling, T. and Appelgren, M. 1995. *Light quality affects photosynthesis and leaf anatomy of birch plantlets in vitro*. J. Plant Cell Tissue. 41: 177-185.

Saliendra, N.Z., Sperry, J.S. and Comstock, J.P. 1995. *Influence of leaf water status on stomatal response to humidity, hydraulic conductance, and soil drought in Betula occidentalis.* Planta. 196: 357-366.

Sanchez, F.J., Manzanares, M., De Andres, E.F., Tenorio, J.L. and Ayerbe, L., 1998. *Turgor maintenance, osmotic adjustment and soluble sugar and proline accumulation in 49 pea cultivars in response to water stress.* Field Crops Research. 59: 225-235.

Sánchez-Gómez, D., Valladares, F. and Zavala, M.A. 2006. *Performance of seedlings of Mediterranean woody species under experimental gradients of irradiance and water availability: trade-offs and evidence for niche differentiation*. New Phytologist. 170: 795-806.

Satisha, J., Prakash, G.S., Bhatt, R.M. and Kumar, P.S. 2007. *Physiological mechanisms of water use efficiency in grape rootstocks under drought conditions*. International Journal Agriculture Research. 2(2):159-164.

Scalet, M., Federico, R., Guido, M. and Manes, F. 1995. *Peroxidase activity and polyamine changes in response to ozone and simulated acid rain in Aleppo pine needles*. Environment Exprimental Botany. 35: 417-425.

Schlemmer, M.R., francis, D.D., Shanahan, J.F. and Schepers, J.S. 2005. *Remotely measuring chlorophyll content in corn leaves with differing nitrogen levels and relative water content*. Agron. J. 97:106-112.

Schneider, S., Ziegler, C. and Melzer, A. 2006. *Growth towards light as an adaptation to high light conditions in Chara branches*. New Phytol. 172: 83–91.

Schreiber, U. 2004. *Pulse-amplitude (PAM) fluorometry and saturation pulse method. In: Papageorgiou, G., Govindjee (Eds.), Chlorophyll Fluorescence: A Signature of Photosynthesis.* Advances in Photosynthesis and Respiratio Series. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Seki, M., Kameiy, A., Yamaguchi-Shinozaki, K. and Shinozaki, K. 2003. *Molecular responses to drought, salinity and frost: common and different paths for plant protection.* Curr Opin Biotechn. 14:194-199.

Shangguan, Z., Shao, M. and Dyckmans J. 1999. *Interaction of osmotic adjustment and photosynthesis in winter wheat under soil drought.* Journal of Plant Physiology. 154: 753-758.

Siddique, B.M.R., Hamid, A. and Islam, M.S. 2000. *Drought stress effect on water relation of wheat.* Bot. Bull. Acad. 41**:** 35-39.

Sims, D.A. and Pearcy, R.W. 1994. *Scaling sun and shade photosynthetic acclimation of Alocasia macrorrhiza (Araceae) to a transfer from low to high light.* Am. Journal of Botany. 79: 449-455.

Sims, D.A. and Pearoy, R.W. 1992. *Responses of leaf anatomy and photosynthetic capacity in Alocasia macrorrhiza to a transfer from low to high light*. Am. Journal of Botany. 73: 445-449.

Simova-Stoilova, L., Demirevska, K., Petrova, T., Tsenov, N. and Feller, U. 2008. *Antioxidative protection in wheat varieties under severe recoverable drought at seedling stage*. Plant Soil Environ. 54:529-536.

Sims, D.A. and Pearcy, R.W. 1994. *Scaling sun and shade photosynthetic acclimation of Alocasia macrorrhiza (Araceae) to a transfer from low to high light.* Am. Journal of Botany. 79: 449-455.

Singh, T. and Pun, K.B. 2015. *Abiotic Stress Management in Rice***.** Integrated Soil and Water Resource Management for Livelihood andEnvironmental Security. 219-258.

Siram, R.K., Deshrnukh, S.P., Shukia, S.D. and Ram, S. 1990. *Metabolic activity and grain yield under moisture stress in wheat genotypes.* Indian Journal of Plant Physiology. 33(3): 226-231.

Smith, T. and Huston, M. 1989. *A theory of the spatial and temporal dynamics of plant communities.* Vegetatio. 83: 49-69.

Stephanie, E.B., Svoboda, V.P., Paul, A.T., Marc, W. and Van, I. 2005. *Controlled Drought Affects Merphology And Anotomy Of Salvia splendens*. Journal of the American Society for Horticultural Science. 130(5): 775-781.

Stephenson, R.A. 1990. *The macadamia nut. Chapter 13 in fruit.* Tropical and subtropical, ed. 490-521.

Stitt, M. and Krapp, A. 1999. *The interaction between elevated carbon dioxide and nitrogen nutrition: the physiological and molecular background*. Plant Cell Environ. 22: 583-621.

Stitt, M. 1991. *Rising CO_2 levels and their potential significance for carbon flow in photosynthetic cells*. Plant Cell Environ. 14: 741-762.

Stoll, M., Loveys, B. and Dry, P. 2000. *Hormonal changes induced by partial rootzone drying of irrigated grapevine.* Journal of Experimental Botany. 51: 1627-1634.

Srivastava, A. and Strasser, R.J. 1997. *Constructive and destructive action of light on the photosynthetic apparatus. J. Sci. Industr. Res*. 56: 133-148.

Smirnoff, N. 1995. *Antioxidant systems and plant response to the environment In: Smirnoff V (Ed.), Environment and Plant Metabolism: Flexibility and Acclimation*. BIOS Scientific Publishers, Oxford, UK.

Smith, T. and Huston, M. 1989. *A theory of the spatial and temporal dynamics of plant communities. Vegetatio.* 83: 49-69.

Sofi, P., Rather, A.G. and Zargar, M.Y. 2006. *Breaking yield barriers in rice: Remodeling photosynthesis.* Am. Journal Plant Physiol. 1(2):113-126.

Steinger, T., Roy, B.A. and Stanton, M.L. 2003. *Evolution in stressful environments II: adaptive value and costs of plasticity in response to low light in Sinapis arvensis. J. Evol. Biol*. 16: 313-323.

Stephenson, R.A. and Callagher, E.C. 1990. *Some aspects of water relations in macadamia*. Acta Hortic. 75: 559-567.

Sultan, S. 2003. *Phenotypic plasticity in plants: a case study in ecological development*. Evolution and Development. 5(1), 25-33.

Takahashi, S. and Murata, N. 2008. *How do environmental stresses accelerat photoinhibition?*. J. Trends Plant. 13: 178-182.

Tan, C.S. and Buttery, B.R. 1982. *The Effect of Soil Moisture Stress to Various Fractions of the Root System on Transpiration, Photosynthesis, and Internal Water Relations of Peach Seedlings*. *J. Amer. Soc. Hort. Sci.* 107(5): 845-849.

Tan, S., Yuen, K.H. and Chan, K.L. 2002. *HPLC analysis of Plasma 9-methoxycanthin-6-one from Eurycoma Longifolia and its application in a bioavailability/ pharmacokinetic study*. Plant Media Journal. 68: 355-358.

Tardieu, F. and Davies, W.J. 1993. *Integration of hydraulic and chemical signaling in the control of stomatal conductance and water status of droughted plants*. Plant Cell Environment. 16: 314-349.

Teare, I.D., Kanemasu, E.T., Powers, W.L. and Jacobs, H.S. 1973. *Water use efficiency and its relation to crop canopy area, stomatal regulation, and root distribution.* Agronomy Journal. 65: 207-211.

Techawongstien, S., Nawata, E. and Shigenage, S. 1992. *Effects of Sudden and Gradual Water Stress on Growth and Yield of Chilli Pepper*. Japanese Journal of Tropical Agriculture. 36(4): 275-280.

Tereza, K., Puschel, D., Janouskova, M., Gryndler, M. and Jansa, J. 2015. *Duration and intensity of shade differentially affects mycorrhizal growth- and phosphorous uptake responses of Medicago truncatula.* Front Plant science. 6(65): 1-11.

Tesfaye, S.G. 1995. *Influence of Shading, Mulching and Watering Frequency on Seedling Growth of Arabica Coffee*. M.Sc. Thesis, Alamaya University of Agriculture, Ethiopia.

Tezara, W. and Lowlord, D.W. 1995. *Effect of water stress on the biochemistry and physiology of photosynthesis in sunflower*. Photosynthesis Research. 625-628.

Thameur, A., Lachiheb, B. and Ferchichi, Ali. 2012. *Drought effect on growth, gas exchange and yield, in two strains of local barley Ardhaoui, under water deficit conditions in southern Tunisia*. Journal of Environmenta Management. 113: 495-500.

Thompson, W.A., Kriedemann, P.E. and Craig, I.E. 1992. *Photosynthetic response to light and nutrients in sun-tolerant and shadetolerant rainforest trees. I. Growth, leaf anatomy and nutrient content.* Australian Journal of Plant Physiology. 19: 1-18.

Thorup-Kristensen, K., Kirkegaard, J. 2016. *Root system-based limits to agricultural productivity and efficiency*. Annual Botany. 118(4): 573-592.

Tognetti, R., Johnson, J.D. and Michelozzi, M. 1997. *Ecophysiological responses of Fagus sylvatica seedlings to changing light conditions. I. Interactions between photosynthetic acclimation and photoinhibition during simulated canopy gap formation.* Journal of Physiology Plant. 101: 115-123.

Torcott, G.A. and Gosselin, A. 1989. *Influence of continuous and discontinuous supplemental lightening on the daily variation in gaseous exchange in greenhouse cucumber.* Scientia Hort. 40: 9-22.

Tripathy, S. 2015. *Importance of plants and animals in medicine*. J. Exp. Zool. Indi. 18(2): 1-11.

Tschaplinski, T.J. and Blake, T.J. 1985. *Effects of root restriction on growth correlations, water relations and senescence of alder seedlings*. Journal of Physiology Plant. 64:167-176.

Tucker, M. 2004. *Primary Nutrients and Plant Growth. - In: Essential Plant Nutrients (SCRIBD, Ed.).* North Carolina Department of Agriculturae.

Turk, K. and Hall, A. 1980. *Drought adaptation of cowpea. IV. Influence of drought on water use and relations with growth and seed yield*. Agronomy Journal. 72: 434-439.

Turner, L. B. 1991. *The effect of water stress on the vegetative growth of white clover (Trifolium repens L.), comparative of long-term water deficit and short-term developing water stress*. Journal of Experimental Botany. 42: 311-316.

Turner, N.C. 1974. *Stomatal response to light and water under field conditions. In: R.L Bielski, A.R. Ferguson and M.M. Creswell (Editors), Mechanisms of Regulation of Plant Growth.* Bulletin 12, the Royal Society of New Zealand, Wellington. 423-432.

Valladares, F. and Pearcy, R.W. 2002. *Drought can be more critical in the shade than in the sun: a field study of carbon gain and photo-inhibition in a Californian shrub during a dry El Niño year.* Plant, Cell and Environment. 25**:** 749-759.

Van Kooten, O. and Snel, J.F.H. 1990. *The use of chlorophyll fluorescence nomenclature in plant stress physiology*. Photosynthesis Research. 25:147-150.

Veloso, C.C., Bitencourt, A.D., Cabral, L.D.M., Franqui, L.S., Dias, D.F., Santos, M.H., Soncini, R. and Giusti-paiva, A. 2010. *Pyrostegia venusta attenuate the sickness behavior induced by lipopolysaccharide in mice*. Journal of Ethnopharmacology. 132: 355-358.

Vendeland, J.S., Sinclair, T.R., Spaeth, S.C. and Cortes, P.M. 1982. *Assumptions of plastochron index evaluation with soybean Glycine max cultivar Wilkin under field drought conditions*. Annals of Botany 50: 673-680.

Vincor, B. and Altman, A. 2005. *Recent advances in engineering plant tolerance to abiotic stress: achievments and limitations*. Curr Opin Biotechnol. 16:123-132.

Volkmar, K.M. and Woodbury, W. 1995. *Plant-water Relationships. In Handbook of plant and crop physiology, ed. M. Pessarakli*. New York: Marcel Decker, Inc. 23-43.

Vu, J.C.V. and Yelenosky, G. 1988. *Water deficit and associated changes in some photosynthetic parameters in leaves of 'Valencia' orange (Citrus sinensis L. Osbeck).* Plant Physiol Journal. 88:375-378.

Wahid, A. and Close, T.J. 2007. *Expression of dehydrins under heat stress and their relationship with water relations of sugarcane leaves*. Biol. Plant. 51: 104-109.

Wan Hassan, W.E. 2006. *Healing Herbs of Malaysia.* Kuala Lumpur: FELDA.

Wang, B.L., Xu, M., Shi, X.H. and Cao, J.H. 2004. *Effects of high temperature stress on antioxidant systems, chlorophyll and chlorophyll fluorescence parameters in early cauliflower leaves.* Sci. Agric. Sin. 37: 1245-1250.

Wayne, P.M. and Bazzaz, F.A. 1993. *Birch seedling responses to daily time courses of light in experimental forest gaps and shadehouses*. Ecology. 74: 1500-1515.

Wentworth, M., Murchie, E.H., Gray, J.E., Villegas, D., Pastenes, C., Pinto, M. and Horton, P. 2006. *Differential adaptation of two varieties of common bean t abiotic stress*. Journal of Experimental Botany. 57: 699-709.

Wenrao, L., Zhang, S, Shan, L. and Eneji, A.E. 2011. *Changes in root characteristics, gas exchange and water use efficiency following water stress and rehydration of Alfalfa and Sorghum.* Australian Journal of Crop Science. 5(12):1521-1532.

Whiteman, P.C. and Wilson, G.L. 1965. *Effects of water stress on the productive development of Sorghum vulgare pers*. University Qld Department of botany Papers 4 14:233-234.

Wilson, D. and Cooper, J.P. 1967. *Assimilation of Lolium in relation to lea mesophyll.* Nature, Lond. 214, 989.

Wilson, D. and Cooper, J.P. 1969. *Effect of light intensity and CO_2 on apparent photosynthesis and its relationship with leaf anatomy in genotypes of Lolium perenne L*. New PhytoL, 68, 627.

Wilson, D. and Cooper, J.P. 1969. *Apparent photosynthesis and leaf characters in relation to leaf position and age, among contrasting Lolium genotypes*. New PhytoL, 68, 645.

Wong, S.C., Cowan, I.R. and Farquhar, G.D. 1978. *Leaf conductance in relation to assimilation in Eucalyptus pauciflora Sieb. Ex Spreng: Influence of irradiance and partial pressure of carbon dioxide*. Plant Physiol. 62: 670-674.

Wright, G.C., Nageswara, R.C. and Farquhar, G.D. 1994. *Water use efficiency and carbon isotop discrimination in peanut under water deficit conditions*. Crop SCI. 34: 92-97.

Wu, G., Liu, H., Hua, L., Lu, Q., Lin, Y., He, P., Feng, Sh., Liu, J. and Ye, Q. 2018. *Differential Responses of Stomata and Photosynthesis to Elevated Temperature in Two Co-occurring Subtropical Forest Tree Species*. Frontier Plant Science. 9: 1-8.

Xie, X., He, Z., Chen, N., Tang, Z., Wang, Q. and Cai, Y. 2019. *The Roles of Environmental Factors in Regulation of Oxidative Stress in Plant*. Biomed Research International. 2019:9732325.

Xu, Y., Sun, X., Jin, J. and Zhou, H. 2010. *Protective effect of nitric oxide on light-induced oxidative damage in leaves of tall fescue*. J. Plant Physiol. 167: 512-518.

Xu, Y., Xiao-Y.L., Gang, X.Z. and Xue- L,J. 2017. *Effects of light intensity on leaf microstructure and growth of rape seedlings cultivated under a combination of red and blue LEDs*. Journal of Integrative Agriculture. 16 (1): 97-105.

Yancey, P.H., Clark, M.E., Hand, S.C., Bowlus, R.D. and Somero, G.N. 1982. *Living with water stress: evolution of osmolyte syste*ms. Science. 217:1214 - 1222.

Yang, X.Q., Zhang, S.Q., Liang, Z.S. and Shan, Y. 2004. *Effects of water stress on chlorophyll fluorescence parameters of different drought resistance winter wheat cultivars seedlings.* Acta Botan. Bor.-Occident. Sin. 24: 812-816.

Yano, S. and Terashima, I. 2004. *Developmental process of sun and shade leaves in Chenopodium album L.* Plant, Cell and environment. 27: 781-793**.**

Yao, C., Moreshet, S. and Aloni, B. 2001. *Water relations and hydraulic control of stomatal behavior in bell pepper in partial soil drying*. Plant Cell & Environmental Journal. 24: 227-235.

Yeoh, K.C. 1991. *Construction of rainshelter and infrastructure for crop production in Malaysia. Paper presented at the International Seminar on Cultivation under Simple (PlasticI Greenhouse) Construction in the Tropics and Subtropics.* 4-10 Nov 1991. Taiwan.

Zavala, J.A. and Ravetta, D.A. 2001. *Allocation of photoassimilates to biomass, resin and carbohydrates in Grindelia chiloensis as affected by light intensity*. Journal of Field Crop Research. 69: 143-149.

Zhang, S., Ma, K. and Chen, L. 2003. *Response of photosynthetic plasticity of Paeonia suffruticosa to changed light environments*. Journal of Environment Experimental. Botany. 49: 12-133.

Zlatev, Z. and Cebola Lidon, F. 2012. *An overview on drought induced changes in plant growth, water relations and photosynthesis*. Emirate Journal of Food Agriculture. 24 (1): 57-72.

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LIST OF PUBLICATIONS

Rowshanaie, H., Jaafar, H.Z., Halim, M.R.A., Wahab, P.E.M. and Rowshanaie, O. 2014. *Impact of Different Water Levels on Growth, Plant Water Relations and Leaf Characteristics in Seedling of Tongkat Ali (EURYCOMA LONGIFOLIA JACK).* Journal of Multidisciplinary Engineering Science and Technology, 1(4): 197-201.

Rowshanaie, H., Jaafar, H.Z., Halim, M.R.A., Wahab, P.E.M. and Rowshanaie, O. 2014. *Impact of Different Water Levels on Growth, Plant Water Relations and Photosynthesis Parameters in Seedling of Tongkat Ali (EURYCOMA LONGIFOLIA JACK).* OPEN JOURNAL OF WATER POLLUTION AND TREATMENT 1(3): 11-20.

Rowshanaie, H., Jaafar, H.Z., Halim, M.R.A., Wahab, P.E.M., Yusof, M.M. and Rowshanaie, O. 2019. *Stablishment and Domestication of Young Tongkat Ali (Eurycoma longifolia Jack) by Investigating the Effect of Three Different Shade Durations Combination with Different Water Levels on Plant Physiology Parameters.* PeerJ-the journal of Life & Environmental Sciences. Under Review.

Rowshanaie, H., Jaafar, H.Z., Halim, M.R.A., Wahab, P.E.M., Yusof, M.M. and Rowshanaie, O. 2019. *Conservation and Domestication of Young Tongkat Ali (Eurycoma longifolia Jack) by Investigating the Effect of Different Intensities of Light Combination with Different Water Levels on Plant Growth Parameters.* Advances in Agriculture. Under Review.

Rowshanaie, H., Jaafar, H.Z., Halim, M.R.A., Wahab, P.E.M., Yusof, M.M. and Rowshanaie, O. 2019. *Protection of Young Seedling of Tongkat Ali (Eurycoma longifolia Jack) from Extinction by Investigating the Effect of Three Different Shade Durations under Three Different Water Regimes on Growth Parameters of This Herb*. Journal of Tropical Agricultural Science. Under Review.