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Enhancement growth of *Swietenia Mahogany* seedlings under different irrigation intervals by foliar application of basil leaves extract

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Abstract---Drought is a global problem that many countries suffer from, as a result of climate change. *Swietenia mahogany* tree is grown as an ornamental and timber tree and its wood is used in shipbuilding and furniture manufacturing. Therefore, the goal is to use this type of plant for its multiple uses, while reducing the quantities of water consumed for its growth to cope with the drought conditions by using basil leaves extract as natural extract and eco-friendly, it is noticed that all vegetative growth parameters and photosynthetic pigments decreased by increasing irrigation intervals, the rest chemical constituents were increased by increasing irrigation intervals except total sugar content which showed the highest value at irrigation every 7 days. Treating the seedlings with BLE at 10% enhanced all vegetative growth parameters and photosynthetic pigments and reduce all oxidative markers and so antioxidant compounds, it was concluded that BLE at 10% enhanced the tolerance of *S. mahogany* seedlings under all irrigation levels. The irrigation every 5 days showed preferable results followed by irrigation every 7 days.

Keywords---drought, climate change, *Swietenia mahogany*, basil leaves extract, lipid peroxidation, osmolytes, antioxidant isoenzymes.

Introduction

Swietenia mahagoni Jacq. is a small, leafy, medium-sized tree native to the West Indies that can be found in India and some African countries. It is a species of the genus *Swietenia*, which belongs to *Meliaceae* family (Arora and Kaur, 2007). The plant is normally a long lived, medium sized tree but it can reach very large sizes, depending on the environmental conditions under which it grows, the species grows at a slow rate. *S. mahagoni* was once the most demanded cabinet wood in the world, and it is still well-known for its wood, which is used in shipbuilding and furniture production. In dry and moist forests, it is planted as an ornamental and managed in plants and natural stands (Divya *et al.*, 2012). Outside of its natural range, the species is now planted as an ornamental and timber tree in several Caribbean islands, Hawaii, India, Sri Lanka, and Fiji. According to reports, this species is best adapted to areas with annual precipitation ranging from 760 mm to 1780 mm. (Orwa *et al.*, 2009). The plant attains a height of about 13 m, with a crown diameter between 9 and 15m. The canopy is symmetrical with a regular outline and individuals all have a more or less identical crown form. The plant has alternate, pinnately compound leaves that are dark green in color. The leaflets are lanceolate or ovate in shape. The branches of the tree droop as the tree grows.

Many countries of the world are facing an economic water shortage (Committee on agriculture, 2018). Evapotranspiration from irrigated agricultural land is one of water scarcity sources in agriculture itself. In some countries, more than 90 percent of the water used by humans is for irrigation, with the remainder used for drinking-water supply, sanitation, industry, mining, navigation and the environment (World Water Assessment Programme (WWAP), 2012). There are additional pressures due to the rapid industry pace and urban water pollution that makes water unsuitable or unsafe for food production (Damania *et al.*, 2019). Climate change is a multiplier of water scarcity, as evidenced by the increasing frequency and severity of droughts (including in countries that have never experienced drought), as well as the increasing incidence of dry spells during the wet season due to increasing seasonal variability and rising mean temperatures. (FAO REGIONAL CONFERENCE FOR ASIA AND THE PACIFIC, 2022). When the plant is exposed to water deficit stress, this negatively affects the growth of the plant in terms of the morphological response, which includes the size and color of the leaves, the shape of the plant stem (Zong *et al.*, 2017) and this drought may lead to the death of the entire root system (Kaczmarek *et al.*, 2017). Drought stress has been shown in previous studies to cause reduced pigment content, imbalanced ion homeostasis, decreased transpiration, stomatal closure, cell enlargement reduction, reduced canopy size, and ultimately plant death (Kamran *et al.*, 2018). The impact of drought stress varies with the intensity and stage of plant growth (Wu *et al.*, 2018). The excessive accumulation of ROS in plants under water-deficient conditions can cause oxidative damage which might lead to significant damage to the cellular organelles (Tiwari *et al.*, 2021). ROS molecules include H_2O_2 , $O_2^{\cdot-}$, and other oxygen-containing molecules which interact with the membrane system and damage mainly the macromolecules present in the cell (Zamani *et al.*, 2020).

A lot of studies told that *Ocimum basilicum* is an important source of antioxidants compounds. Secondary metabolites of plants, such as flavonoids and phenolic acids, contribute to their antioxidant properties (Purushothaman *et al.*, 2018; Majdi *et al.*, 2020). The ethanolic leaves extract of basil had high antioxidant potential and it is characterized by free radical of scavenging nature (Kaurinovic *et al.*, 2011). Therefore, the aim of the research was to increase the intervals between irrigations to reduce the amounts of water consumed in irrigating of *S. mahogany* as a timber-producing tree, using a plant extract as a source of antioxidants to help the plant tolerate water deficit conditions by using basil leaf extract as many studies have reported that it is a rich plant with phenols and antioxidants

Materials and Methods

The experiment was carried out in Horticulture Research Institute (HRI), Agricultural Research Center (ARC), Giza, Egypt during two successive seasons of 2020 and 2021, and the chemical analysis was implemented in Ornamental Plants and Woody Trees Dept. National Research Centre, Dokki, Giza, Egypt. To study the different effects of basil leaves extract on growth and some chemical composition, oxidative stress markers and ROS defensive compounds of *Swietenia mahogany* seedlings under different irrigation intervals.

One year old seedlings of *S. mahogany* with 10-12 leaves and 40-45 cm height were obtained from nursery of Timber and Forestry Research department, Horticulture Research Institute, Agricultural Research Center. The seedlings were planted on the first of March in plastic pots 30 cm (one plant/pot,) filled with 9 kg soil mixture (sand and clay 1:1 by volume) the physical and chemical analysis were shown in Table (1) which was determined according to (Jackson, 1967). The field capacity was 1400 cm³/pot. Irrigation was carried out regularly twice a week immediately after transplanting for a month, and then irrigation treatments were started (irrigation every 5, 7 and 9 days) and lasted until the end of the season. The plants harvested on 15th of November. Temperatures (°C) were recorded daily at 12 p.m. during the two growing seasons, and the average was calculated for each month as shown in Fig. (1).

Five rates of basil leaves extract (BLE) (0, 5, 10, 20 and 40%) were used, the plant were treated with basil leaves extract (BLE) three times of 30 days irrigation regime starting on the first May in both seasons, the second one after another month and so on.

Table (1). The physical and chemical properties of the soil mixture

Soil sample		Coarse sand%	Fine sand%	Silt%	Clay%					
61.44		9.36		12	17.20					
Sandy loam	E.C.(1:1)	Anion (meq/l)			Cation (meq/l)					
	(dS/m)	pH	O.M. (%)	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻	Ca ⁺⁺	Mg ⁺⁺	Na ⁺⁺	K ⁺
	0.48	8.1	1.36	6.88	3.25	2.47	6.00	1.82	2.79	0.78

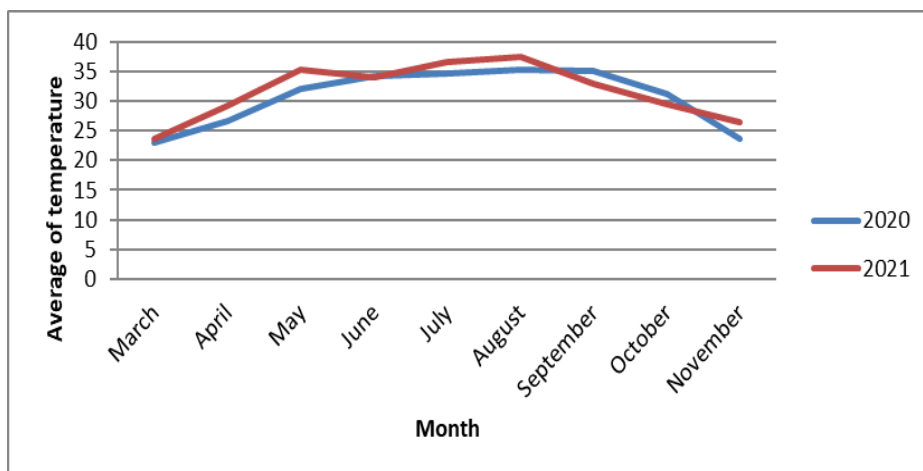


Fig.1. The average of temperature (°C) during 2020 and 2021 seasons

The available commercially fertilizer used through this experimental work Kristalon (NPK 19:19:19) produced Phayzen Company, Holland (Netherlands) the fertilizer rates 3.0 g/pot in four doses 4, 8, 16 and 20 weeks from transplanting.

Preparation of basil leaves extract

Fresh basil leaves were obtained from National Research Centre in Giza, Egypt, and dried in the sun light for a week and mashed into powder. It was extracted according to the techniques described by (Sedky *et al.*, 2022) the basil powder as much as 100g was macerated using 500 ml ethanol 80% over three days for 24h in room temperature and then filtered by cheesecloth and repeated the filtration 3 times and then evaporated the solution using a rotary evaporator vacuum. The obtained crude extract which weighted 2.831g was dissolved in 100 ml ethanol 80% then prepared the mentioned concentrations (v/v). The plant extract was tested for the total phenols content (Quettier-Deleu *et al.*, 2000), and Antioxidant activity (%) was determined by 2, 2 diphenyl-1-picrylhydrazyl (DPPH) according to Burits and Bucar (2000) and the values shown in Table (2).

Table (2) Analysis the total phenols and antioxidant activity in basil leaves extract

Total phenolic (mg/g Extract)	Antioxidant Activity %
	200 µg. ml ⁻¹
122.8 ± 3.39	74.7 ± 2.566

Data recorded

Vegetative growth

1. Leaves parameters: Number of leaves/plant, leaf area (cm²), leaves fresh and dry weights (g)
2. Stem parameters: plant height (cm) stem diameter (cm), stem fresh and dry weights (g)
3. Roots parameters: root length (cm), root fresh and dry weights (g)

Chemical analysis

1. Photosynthetic pigments including chlorophyll a, b and carotenoids (mg. g⁻¹ F.W.) were determined according to (Saric *et al.*, 1987)
2. Osmolytes compounds: Total sugars content (mg. g⁻¹ F.W.) in leaves, stems and roots was determined according to (Dubois *et al.*, 1956) and Proline content (µg. g⁻¹ F.W) was determined according to (Bates *et al.*, 1973)
3. Oxidative stress markers: Lipid peroxidation (µg. g⁻¹ F.W.) was expressed as malondialdehyde (MDA) content and was determined according to (Buege and Aust, 1978) and hydrogen peroxide (H₂O₂) (µmol. g⁻¹ F.W.) was determined according to (Zhang *et al.*, 2010)
4. Total phenols (mg. g⁻¹ F.W.) were determined according to Quettier-Deleu *et al.*, 2000)
5. Total Flavonoids content (mg. g⁻¹ D.W.) in leaves was determined according to (Singleton and Rossi, 1965).

Antioxidants isoenzyme banding patterns

Native polyacrylamide gel electrophoresis (Native-PAGE) isoenzyme electrophoresis was performed to identify isoenzyme differences between control and treatment in the second season.

1. Peroxidase isoenzymes POD (E.C.1.11.1.7) in leaves sample were assessed by the procedure defined by (Barceló *et al.*, 1987)
2. Polyphenol oxidase isoenzyme PPO (E.C. 1.10.3.1) in leaves (100 mg fresh weight) samples were estimated as described by (Bradford, 1976; Thipyapong *et al.*, 1995).

Experiment layout and statistical analysis

The experimental layout was set in factorial experiment in complete block design with three irrigation intervals and sprayed with 5 rates of (BLE) to give 15 treatments with 3 replicates for each season. Obtained results were subjected to two-way ANOVA variance analysis using CoStat (CoHort, Monterey, CA, USA) with least significant differences (LSD) at 5% level according to method described by (Snedecor and Cochran, 1967).

Results and Discussion

Growth Parameters

The data presented in Tables (3, 4 & 5) illustrated that increasing irrigation intervals showed a negative effect on parameters of leaves (number of leaves/plant, leaf area (cm²), leaves fresh and dry weights(g)), stems (plant height (cm), stem diameter(cm), stem fresh and dry weight (g)) and roots (root length (cm), root fresh and dry weights (g)). The highest values of the all parameters were obtained from *Swietenia mahogany* seedlings irrigated every 5 days and the parameters decreased gradually by increasing irrigation intervals. The data in the same Tables (3, 4 & 5) indicated that BLE had different effects on the vegetative growth parameters. BLE played an enhancement role with concentration at 10% followed

by 5%, on the other hand, it led to decrease in the values of aforementioned characteristics.

Table (3). Effect of different irrigation intervals and basil leaves extract (BLE) on leaves traits (number of leaves, leaf area and leaves fresh and dry weights) of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Number of leaves/plant				Leaf area (cm ²)				Leaves fresh weight (g)				Leaves dry weight(g)			
	Irrigation intervals (days) (A)															
	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean
First season																
Control	64.00	55.67	41.00	53.56	43.50	36.67	31.07	37.08	91.96	66.26	37.90	65.37	34.94	25.18	12.51	24.21
5%	66.00	60.67	51.33	59.33	50.40	42.53	38.00	43.64	104.48	75.96	45.54	75.33	42.84	30.38	15.94	29.72
10%	77.33	73.33	65.00	71.89	59.84	48.34	44.58	50.92	110.20	88.52	66.98	88.57	48.49	36.29	25.45	36.74
20%	45.00	52.67	37.00	44.89	41.25	34.44	27.56	34.42	76.59	54.07	38.36	56.34	27.57	18.38	12.27	19.41
40%	39.33	29.33	22.67	30.44	33.83	32.83	24.79	30.48	51.86	53.42	23.21	42.83	22.82	17.63	9.73	16.73
Mean	58.33	54.33	43.40		45.76	38.96	33.20		87.02	67.65	42.40		35.33	25.57	15.18	
LSD _{0.05}	(A): 3.79				(A): 2.44				(A): 2.92				(A): 2.21			
	(B): 2.94				(B): 3.15				(B): 3.77				(B): 2.85			
	(A*B): 6.57				(A*B): 5.46				(A*B): 6.53				(A*B): 4.93			
Second season																
Control	68.00	63.33	35.67	55.67	48.67	46.91	27.84	41.14	97.05	81.40	57.29	78.58	41.74	33.18	22.79	32.57
5%	76.33	73.00	53.33	67.55	57.47	50.44	31.95	46.62	107.69	100.20	67.43	91.77	47.04	43.43	26.97	39.15
10%	83.00	79.67	56.00	72.89	63.24	53.62	48.35	55.07	116.72	111.23	92.17	106.71	51.80	49.01	39.50	46.77
20%	51.67	48.67	31.00	43.78	42.57	40.76	27.15	36.83	87.22	85.34	51.53	74.70	36.79	35.37	20.25	30.80
40%	44.33	39.00	27.67	37.00	37.32	35.54	25.62	32.83	76.62	72.31	43.29	64.07	30.96	29.04	16.89	25.63
Mean	64.66	60.73	40.73		49.85	45.45	32.18		97.06	90.10	62.34		41.67	38.01	25.28	
LSD _{0.05}	(A): 2.65				(A): 2.14				(A): 3.20				(A): 2.30			
	(B): 3.42				(B): 2.76				(B): 4.13				(B): 2.97			
	(A*B): 5.92				(A*B): 4.78				(A*B): 7.16				(A*B): 5.14			

Table (4). Effect of different irrigation intervals and basil leaves extract (BLE) on stem traits (plant height, stem diameter and stem fresh and dry weights) of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Plant height(cm)				Stem diameter(cm)				Stem fresh weight (g)				Stem dry weight (g)			
	Irrigation intervals (days) (A)															
	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean
First season																
Control	152.6	149.4	99.40	133.8	1.66	1.50	1.21	1.46	143.5	126.72	55.98	108.8	77.51	63.36	25.19	55.35
5%	151.9	151.3	105.1	136.1	1.71	1.64	1.3	1.55	150.1	131.22	64.29	115.2	82.53	68.23	30.21	60.32
10%	164.7	159.9	142.3	155.6	1.85	1.79	1.55	1.73	175.1	142.72	113.29	143.7	103.3	79.92	54.37	79.19
20%	126.7	119.5	87.3	111.2	1.35	1.23	1.08	1.22	94.7	59.83	40.58	65.0	48.27	28.12	16.63	31.01
40%	116.1	100.2	85.5	100.6	1.21	1.07	0.90	1.06	74.9	35.46	28.07	46.2	35.95	16.31	12.07	21.44
Mean	142.4	136.1	103.9		1.56	1.45	1.21		127.7	99.19	60.44		69.51	51.19	27.69	
LSD _{0.05}	(A): 2.07				(A): 0.039				(A): 2.53				(A): 2.15			
	(B): 2.67				(B): 0.030				(B): 3.27				(B): 2.78			
	(A*B): 4.63				(A*B): 0.068				(A*B): 5.66				(A*B): 4.81			
Second season																
Control	158.8	155.3	110.5	141.5	1.81	1.76	1.32	1.63	147.6	141.3	79.46	122.8	86.12	82.03	43.16	70.44
5%	163.7	160.5	120.8	148.3	1.88	1.85	1.41	1.71	157.2	149.7	96.25	134.4	93.81	88.62	53.34	78.59
10%	170.3	166.4	148.1	161.6	1.93	1.91	1.68	1.84	179.6	163.1	128.74	157.2	107.8	97.69	73.72	93.06
20%	133.9	125.5	101.1	120.1	1.63	1.60	1.25	1.49	125.3	120.0	67.11	104.2	70.45	67.53	35.93	57.97
40%	129.7	116.2	97.4	114.4	1.55	1.49	1.14	1.39	117.6	113.7	52.62	94.62	65.90	63.33	27.94	52.39

Mean	151.3	144.8	115.6	1.76	1.72	1.36	145.5	137.6	84.84	84.81	79.84	46.82
LSD _{0.05}	(A): 2.53			(A): 0.032			(A): 2.23			(A): 2.30		
	(B): 3.26			(B): 0.041			(B): 2.88			(B): 2.96		
	(A*B): 5.65			(A*B): 0.072			(A*B): 4.98			(A*B): 5.13		

Concerning the interaction treatments between different irrigation intervals and BLE at concentrations ranged from 0 to 40%, it was clear that the *S. mahogany* seedlings sprayed with BLE at 10% showed an improvement in all vegetative growth parameters under different levels of irrigation intervals (5, 7 and 9 days) as compared with the plants exposed to the same levels of irrigation intervals without BLE treatments, where the highest values were obtained from seedlings exposed to irrigation 5 days and received BLE at 10% for all parameters.

Drought stress is well recognized as a limiting factor which alters multiple aspects of plant growth and development. The lowering in growth parameters observed in these studies in response to increasing irrigation intervals appears to be related to a decrease in cell turgor. The reduction observed in plants irrigated every 7 or 9 days must be due to the lower turgor pressure caused by low soil water availability, which involves processes such as cell division and elongation (Shao *et al.*, 2008; Riboldi *et al.*, 2016). Thus plants tended to be smaller in height, leaf area, stem diameter and all growth processes dependent on turgor. This factor was observed in the present study with *S. mahogany* between plants grown under severe stress (irrigation every 9 days) and mild stress (irrigation every 7 days). The former data showed that the root length decreased by increasing drought stress, (Rauf and Sadaqat 2007) stated that drought-stressed plants showed decrease in root length, this decline may be lower production of IAA concentration produced by these plants.

Water scarcity also resulted in decreased leaf area and, as a result, a change in canopy architecture, which can affect gas exchange, water relations, and vegetative growth (Rahmati *et al.*, 2018). Reduced leaf area is a drought-prevention strategy because it results in less water loss through transpiration; this reduction in leaf area is caused by the inhibition of leaf expansion caused by a slower rate of cell division, which results in a loss of cell turgidity (Bangar *et al.*, 2019). (Patmi *et al.*, 2020) stated that exposing rice plant to the drought condition showed a reduction in plant height and leaf area. (Ahmad *et al.*, 2022) exposed the maize plants to drought stress and found a reduction in plant height, root length, stem diameter, fresh and dry weights of leaves stems and roots. (Boudiar *et al.*, 2020) demonstrated the negative effect of drought stress on leaf area, leaves number and shoot and roots dry weights of barley plant.

Table (5). Effect of different irrigation intervals and basil leaves extract (BLE) on root parameters (root length, root fresh and dry weights) of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Root length (cm)				Root fresh weight (g)				Root dry weight (g)			
	Irrigation intervals (days) (A)											
	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean
First season												
Control	54.40	46.18	32.00	44.19	54.66	43.45	20.42	39.51	25.14	18.68	7.55	17.12
5%	56.27	51.27	48.67	52.07	58.16	46.45	24.39	43.00	28.49	21.36	9.26	19.70
10%	63.00	54.27	50.76	56.01	65.41	52.14	35.19	50.91	33.35	25.02	14.42	24.26
20%	49.97	44.37	40.83	45.06	39.97	25.74	19.17	28.29	17.58	10.29	6.32	11.40
40%	47.50	41.33	33.40	40.74	25.11	17.59	12.10	18.27	10.29	6.50	4.01	6.93
Mean	54.23	47.48	41.13		48.67	37.07	22.25		22.97	16.37	8.31	
LSD _{0.05}	(A): 2.69				(A): 2.29				(A): 1.42			

	(B):3.47 (A*B):6.01	(B):2.95 (A*B): 5.12	(B): 1.84 (A*B): 3.18										
Second season													
Control	60.67	57.43	38.13	52.08	55.97	52.29	38.24	48.83	27.51	25.11	17.16	23.26	
5%	65.42	61.94	42.73	56.20	67.36	58.41	42.36	56.04	33.82	29.00	19.19	27.37	
10%	70.35	67.24	56.69	64.76	71.03	64.25	55.26	63.51	36.06	32.11	26.88	31.68	
20%	52.66	47.62	35.25	45.18	54.73	49.02	31.44	45.06	26.42	23.17	14.00	21.20	
40%	50.29	45.05	30.49	41.94	47.46	46.05	24.25	39.25	22.17	21.37	10.71	18.08	
Mean	59.88	55.86	40.66		59.31	54.00	38.31		29.20	26.15	17.59		
	(A):2.31				(A): 2.27				(A): 1.81				
LSD _{0.05}	(B):2.99				(B): 2.93				(B): 2.33				
	(A*B): 5.17				(A*B): 5.07				(A*B): 4.03				

Chemical determinations Photosynthetic pigments

The data presented in Table (6) illustrated that the photosynthetic pigments including chl. a, chl. b and carotenoids showed high production in *S. mahogany* seedlings irrigated every 5 days with values 0.85, 0.31 and 0.48 mg. g⁻¹ F.W., respectively in the first season and 0.90, 0.35 and 0.54mg. g⁻¹ F.W., respectively, in the second season. It was apparent from data in Table (6) that the treatment of BLE at concentration 10% produced augmentation of photosynthetic pigments content in leaves of *S. mahogany* seedlings. Whereas, the presented data also showed a decrease in the values of the photosynthetic pigments content in seedlings sprayed with BLE starting from 20% concentration.

Regarding the interaction treatments presented in Table (6) the highest values of photosynthetic pigments (chl. a, chl. b and carotenoids) were obtained from plants watered every 5 days and treated with BLE at concentration 10% giving values 1.05, 0.40 and 0.61 mg. g⁻¹ F.W., respectively, in the first season and 1.11, 0.44 and 0.64 mg. g⁻¹ F.W., respectively in the second season. While; the lowest values were obtained from seedlings irrigated every 9 days and sprayed with 40% BLE giving values 0.51, 0.14 and 0.23mg. g⁻¹ F.W., respectively in the first season and 0.45, 0.16 and 0.23 mg. g⁻¹ F.W., respectively in the second season.

Reduced leaf area, increased stomata closure and consequent reduced leaf cooling by evapotranspiration increase osmotic stress leading to damages to the photosynthetic apparatus are one of the main constraints for photosynthesis (Zare *et al.*, 2011; Bhargava and Sawant, 2013). Among these, the decrease in photosynthetic process in drought-stressed plants is primarily due to a decrease in CO₂ conductance via stomata and mesophyll limitations (Singh and Thakur, 2018). Decrease in photosynthetic activity due to drought may also be due to reduced ability of stomatal movement (Marcinińska *et al.*, 2013; Chaves *et al.*, 2009). Chlorophyll content, which is of utmost importance for photosynthesis (Rahdari *et al.*, 2012), A photosynthetic property that is substantially influenced by water deficiency and has been identified as a separate indicator of photo oxidation and chlorophyll degradation (Anjum *et al.*, 2011). For example, leaf chlorophyll synthesis and chlorophyll a/b proportion in soybean is altered by drought stress (Chowdhury *et al.*, 2017). Decline in photosynthetic activity, amount of chlorophylls, loss of photosystem II photochemical efficiency, alteration in stomatal movement and disturbance in water status of plants resulted in declined plant productivity (Xiang *et al.*, 2013).

Among others, a major cause for decline in amount of chlorophyll due to drought stress is the drought-promoted O₂ and H₂O₂, which results in lipid peroxidation and ultimately chlorophyll degradation (Karimpour, 2019). The decrease of plant

development and yield in several plant species under water deficit is often associated with decline in photosynthetic action and chlorophyll content impairment (Abid *et al.*, 2017). Water deficit alters the action of photosynthetic moieties and chlorophyll pigments, which ultimately resulted in reduced photosynthetic activities in *Vigna mungo* (Gurumurthy *et al.*, 2019). Acute drought stress conditions also cause the damage to Rubisco enzyme and other enzymes associated with photosynthesis and are responsible for the loss of photosynthetic pigment content (Brito *et al.* 2019). Our results are in the same line as (Ahmad *et al.*, 2022) on the maize plant.

Table (6).Effect of different irrigation intervals and basil leaves extract (BLE) on photosynthetic pigments (chlorophyll a, b and carotenoids) of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Chl. a				Chl. b				Carotenoids			
	Irrigation intervals (days) (A)											
	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean
First season												
Control	0.80	0.76	0.68	0.75	0.30	0.29	0.20	0.26	0.47	0.41	0.36	0.41
5%	0.99	0.81	0.69	0.83	0.38	0.32	0.24	0.31	0.56	0.46	0.36	0.46
10%	1.05	0.88	0.71	0.88	0.40	0.35	0.23	0.33	0.61	0.50	0.37	0.49
20%	0.75	0.73	0.57	0.68	0.27	0.26	0.16	0.23	0.40	0.39	0.28	0.36
40%	0.67	0.62	0.51	0.60	0.20	0.18	0.14	0.17	0.35	0.33	0.23	0.30
Mean	0.85	0.76	0.63		0.31	0.28	0.19		0.48	0.42	0.32	
LSD _{0.05}	(A): 0.03				(A): 0.02				(A): 0.02			
	(B): 0.04				(B): 0.03				(B): 0.03			
	(A*B): 0.061				(A*B): 0.053				(A*B): 0.050			
Second season												
Control	0.86	0.81	0.65	0.77	0.35	0.33	0.21	0.30	0.54	0.51	0.34	0.46
5%	1.03	0.90	0.67	0.87	0.40	0.36	0.24	0.33	0.62	0.56	0.38	0.52
10%	1.11	0.96	0.73	0.93	0.44	0.39	0.27	0.37	0.64	0.57	0.43	0.55
20%	0.78	0.74	0.58	0.70	0.31	0.28	0.19	0.26	0.47	0.45	0.27	0.40
40%	0.70	0.63	0.45	0.59	0.25	0.20	0.16	0.20	0.42	0.31	0.25	0.33
	0.90	0.81	0.62		0.35	0.31	0.21		0.54	0.48	0.33	
LSD _{0.05}	(A): 0.02				(A): 0.02				(A): 0.02			
	(B): 0.03				(B): 0.03				(B): 0.03			
	(A*B): 0.056				(A*B): 0.046				(A*B): 0.059			

Osmolytes compounds

The data presented in Table (7) showed a slight rise in total sugar content in the fresh leaves of *S. mahogany* seedlings irrigated every 7 days. The proline content increased by increasing irrigation intervals, the highest value was obtained from seedlings irrigated every 9 days. The data shown in Table (7) gave that the treatment with BLE led to a gradual increase in total sugars content of the seedlings, where the maximum increase in the levels of total sugars content when the seedlings treated with concentration 20% and then decreased again when treated with 40%. The treatment with BLE at low concentration had an important role in reducing the damage resulted from water deficit on the seedlings, as the plants spraying with the concentration 10% produced the lowest content of proline. On the other hand, the seedlings treated with the highest concentration 40% produced the highest content of proline in the two seasons.

Table (7). Effect of different irrigation intervals and basil leaves extract (BLE) on osmolytes contents (total sugars and proline) of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Total sugars content (mg. g ⁻¹ F.W.)				Proline content (µg. g ⁻¹ F.W.)			
	Irrigation intervals (days) (A)							
	5	7	9	Mean	5	7	9	Mean
First season								
Control	8.24	9.55	8.85	8.88	19.11	21.86	25.34	22.10
5%	8.97	11.29	10.48	10.25	14.73	16.05	19.35	16.71
10%	11.85	14.10	13.68	13.21	10.46	12.23	12.53	11.74
20%	14.67	18.40	16.98	16.68	17.65	21.16	22.26	20.36
40%	12.49	16.43	15.25	14.72	24.93	28.21	31.57	28.24
	11.244	13.954	13.048		17.376	19.902	22.21	
LSD _{0.05}	(A): 0.38				(A): 0.53			
	(B): 0.49				(B): 0.68			
	(A*B): 0.84				(A*B): 1.18			
Second season								
Control	8.59	9.55	9.07	9.07	20.20	24.52	27.13	23.95
5%	10.42	12.24	11.75	11.47	15.72	16.93	23.64	18.76
10%	12.59	16.67	14.56	14.67	10.15	13.03	15.23	12.80
20%	18.06	19.06	18.41	18.51	18.80	20.17	26.49	21.82
40%	16.27	18.73	17.25	17.42	24.17	26.98	28.37	26.51
	13.19	15.25	14.21		17.81	20.33	24.17	
LSD _{0.05}	(A): 0.67				(A): 0.86			
	(B): 0.87				(B): 1.11			
	(A*B): 1.50				(A*B): 1.91			

The data in Table (7) explained that *S. mahogany* plants irrigated every 7 days and received BLE at 20% gave the highest content of total sugars. Moreover, the plants which were watered every 9 days and sprayed with BLE at 40% gave the highest value of proline content in the first and second seasons. Considering that under stress conditions plants must produce osmolytes to protect the photosynthetic apparatus, maintain cell turgor and avoid a hydraulic failure (Gurrieri *et al.*, 2020). The increase in the amount of soluble sugars is evidence of the plant's exposure to drought stress (Chapin, 1990; Sperdouli and Moustakas, 2012a). A possible explanation for such an increase is based on the fact that under moderate drought, plant growth declines before photosynthesis (Sperdouli and Moustakas, 2012a; Sperdouli and Moustakas, 2012b), resulting in an excess of carbon skeletons, which can be directed to osmolytes production (Hummel *et al.*, 2010; Vitale *et al.*, 2011). Proline is widely found in higher plants and generally is accumulated in large amounts during situations of water stress. It is accepted that proline has an important and complex role in drought tolerance of plants and the assistance of osmotic adjustment (Mukesh *et al.*, 2019). Therefore, according to (Ashraf and Foolad, 2007), aside from its role as an osmoregulator, proline also contributes to membrane stabilization and radical oxygen scavenger, preventing plants from being damaged by environmental stresses.

Osmolytes accumulation is essential for osmo-protection and osmotic adjustment against water deficit conditions which can lead to loss of cell turgor and dehydration. Among others, proline acts as an important signaling moiety against drought stress to stimulate mitochondria functioning and alter cell proliferation, stimulating particular drought stress recovery genes (Jayant and Sarangi, 2014). Proline accumulation helps to maintain membrane integrity by diminishing lipids

peroxidation by defending cell redox potential and declining ROS level (Shinde *et al.*, 2016). It has been shown that plants which accumulate higher levels of proline exhibit higher rates of plant survival (Zhou *et al.*, 2009).our results in the line with (Patmi *et al.*, 2020) who mentioned that drought condition increased the accumulation of proline content in rice plant.

Total phenols and total flavonoids

It is obvious from data presented in Table (8) that the irrigation every 9 days increased the content of total phenols (15.96 and 16.54 mg. g⁻¹ F.W. in the first and second seasons, respectively) and total flavonoids (10.33 and 10.82 in the first and second seasons, respectively). The data in the same Table illustrated that the seedlings exposed to BLE at concentration 40% produced the highest values of total phenols (17.96 and 18.60 in the first and second seasons, respectively) and total flavonoids (11.39 and 11.39 in the first and second seasons, respectively), while the lowest content for each compounds produced from plants sprayed with BLE at 10%.

Regarding the interaction treatment, the drought-stressed plants (watering every 9 days) and sprayed with BLE at 40% produced the highest values of total phenols and total flavonoids in both seasons. Phenolic compounds which include many compounds, including flavonoids and total phenols, are naturally synthesized in the cell under optimal conditions, but when there is biotic or abiotic stress, the concentration of these products is significantly affected (Madhvi *et al.*, 2020). Also, any alteration in the activity of biosynthesizing or degrading enzymes may influence the amount of these compounds in plant cells. Considering the fundamental role of phenolic compounds in reducing or inhibiting lipid auto-oxidation, eliminating oxygen free radicals, quenching singlet oxygen or decomposing peroxides, they have also been known as essential antioxidants responsible for protection against proliferation and advancement of the oxidation chain and defense against reactive oxygen species (Sakihama *et al.*, 2002).

Oxidative stress markers (Malondialdehyde (MDA) and Hydrogen Peroxide (H₂O₂) Contents)

The data presented in Table (8) showed that MDA and H₂O₂ increased linearly with increasing irrigation intervals where the highest production was obtained from plants irrigated every 9 days with values 3.53 and 3.91 μg.g⁻¹ F.W. respectively in the first and second seasons for MDA and 2.72 and 3.29 mg. g⁻¹ F.W. in the first and second seasons, respectively for H₂O₂. Data presented in Table (8) showed that seedlings treated with BLE at low rate 10% decreased the production of MDA giving values 1.48 and 1.73 μg⁻¹. g F.W. and H₂O₂ giving values 1.80 and 1.98 mg⁻¹. g F.W. in the first and second seasons, respectively. Furthermore, the production of MDA and H₂O₂ were increased with the highest rate of BLE 40%. Concerning the interaction treatments, the data shown in Table (8) clarified that the *S. mahogany* seedlings showed tolerance under different irrigation levels when sprayed with BLE at 10% which produced the lowest content of MDA and H₂O₂ compared with the other concentrations of BLE under the same irrigation level.

Table (8). Effect of Different irrigation intervals and/ or basil leaves extract (BLE) on total phenols, total flavonoids, MDA and H₂O₂ contents in leaves of *Swietenia mahogany* plant during 2020 and 2021 seasons

BLE (B)	Total phenols				Total flavonoids				MDA				H ₂ O ₂			
	Irrigation intervals (days) (A)															
	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean	5	7	9	Mean
First season																
Control	14.58	16.03	18.69	16.43	9.23	11.07	11.47	10.59	2.33	3.14	4.81	3.43	2.14	3.07	3.21	2.81
5%	9.53	12.83	14.40	12.25	7.28	8.23	9.68	8.40	1.85	2.07	2.56	2.16	1.68	1.96	2.09	1.91
10%	8.70	9.66	10.40	9.59	6.90	7.33	7.71	7.31	1.32	1.47	1.64	1.48	1.62	1.77	2.01	1.80
20%	12.77	15.73	16.85	15.12	8.83	9.10	10.23	9.39	2.26	3.01	3.51	2.93	2.27	2.58	2.85	2.57
40%	16.27	18.17	19.44	17.96	9.76	11.84	12.57	11.39	2.93	3.73	5.13	3.93	2.69	3.26	3.43	3.13
Mean	12.37	14.48	15.96		8.40	9.51	10.33		2.14	2.68	3.53		2.08	2.53	2.72	
LSD	(A): 0.48				(A): 0.41				(A): 0.19				(A): 0.18			
0.05	(B): 0.62				(B): 0.53				(B): 0.25				(B): 0.23			
	(A*B): 1.07				(A*B): 0.91				(A*B): 0.43				(A*B): 0.40			
Second season																
Control	14.82	16.74	19.06	16.87	9.95	10.79	12.25	11.00	2.84	3.85	5.13	3.94	2.40	3.47	3.64	3.17
5%	10.00	13.66	13.89	12.52	7.76	8.63	10.00	8.80	2.29	2.51	3.06	2.62	2.19	2.65	3.27	2.70
10%	8.52	9.94	11.73	10.06	7.03	7.24	8.18	7.48	1.46	1.56	2.18	1.73	1.74	1.93	2.26	1.98
20%	12.75	16.29	18.16	15.73	8.55	9.18	11.31	9.68	2.57	3.55	3.72	3.28	2.99	3.43	3.54	3.32
40%	17.50	18.42	19.88	18.60	10.14	11.68	12.36	11.39	3.24	4.67	5.46	4.46	3.40	3.71	3.72	3.58
Mean	12.72	15.01	16.54		8.69	9.50	10.82		2.48	3.23	3.91		2.54	3.02	3.29	
LSD _{0.05}	(A): 0.50				(A): 0.39				(A): 0.20				(A): 0.14			
	(B): 0.65				(B): 0.51				(B): 0.26				(B): 0.19			
	(A*B): 1.12				(A*B): 0.88				(A*B): 0.44				(A*B): 0.32			

Malondialdehyde (MDA) is one of the final products of oxidative modification of lipids, and is responsible for cell membrane damage including changes to the intrinsic properties of the membrane, such as fluidity, ion transport, loss of enzyme activity and protein cross-linking. These changes eventually result in cell death (Sharma *et al.*, 2012). The free radical-induced peroxidation of lipid membranes is known to reflect stress-induced damage at the cellular level (Shukla *et al.*, 2012). The level of MDA, which produced during peroxidation of membrane lipids, was used as an indicator of oxidative damage (Zhang *et al.*, 2014). The metabolism of H₂O₂ within plant is the main source of activated oxygen species that cause lipid peroxidation. Water stress induced accumulation of H₂O₂ (Chowdhury and Choudhuri, 1985). The author stated that H₂O₂ metabolism can be directly correlated with the stress induced membrane damage (Bandurska *et al.*, 1997). (Chakraborty and Pradhan, 2012) told that proline, phenol, H₂O₂ and MDA contents increased in drought-stressed wheat plant. The H₂O₂ increased in maize plant during the drought stress condition (Ahmad *et al.*, 2022)

Antioxidants isoenzyme banding patterns Peroxidase (POD)

The study showed the different effects of BLE under each irrigation intervals on POD in *S. mahogany* seedlings. The electrophoretic pattern and diagram of peroxidase isoenzymes in Fig. (2-A) and Table (9) illustrated that the POD isoenzyme bands of *S. mahogni* seedlings leaves showed four POD isoforms at R_f (retention factor) (0.223, 0.305, 0.652 and 0.922). The most appropriate isoperoxidase enzymatic activity was when *S. mahogany* seedlings sprayed with 10 % BLE where get three bands at R_f (0.305, 0.223 and 0.652) with a low gradual increase by increasing the rate of irrigation intervals (5, 7 and 9 days)

respectively, compared to all concentrations of basil leaf extract 5, 20 and 40 at all irrigation periods that got High overexpression of isoenzymatic activity.

Comparison with the different irrigation intervals, the results showed that the treatment without foliar application with basil leaves extract showed a highly decrease of isoperoxidase activity by increasing the irrigation intervals (5, 7 and 9 days), as it showed 4 bands at Rf (0.223, 0.305 0.625 and 0.922) at 5 days irrigation then 2 bands at Rf (0.305 and 0.652) in 7 and 9 days irrigation treatments also intensity of these bands where high then moderated then faint intensity bands with increase of irrigation days.

Polyphenol oxidase

Native PAGE in Figures (2 B) and Table (9) showed Two PPO isoenzymes at Rf (0.304 and 0.754). In terms of the interactions between different irrigation intervals and BLE, the resulted indicated that treated *S. mahogany* seedlings with 10% BLE induced the moderated isopolyphenol oxidase activity at irrigation intervals every (5 and 7 days) whereas showed 2 bands at Rf (0.304 and 0.752) faint and moderated intensity respectively. The resulted revealed that seedlings that irrigated every 9 days, the suitable isopolyphenol oxidase activity observed when *S. mahogany* seedlings sprayed with 20% BLE, then followed by both treatments with sprayed at (10% and 5% BLE). The results showed that the treatment without BLE showed a significant gradual decrease with the increase in irrigation intervals.

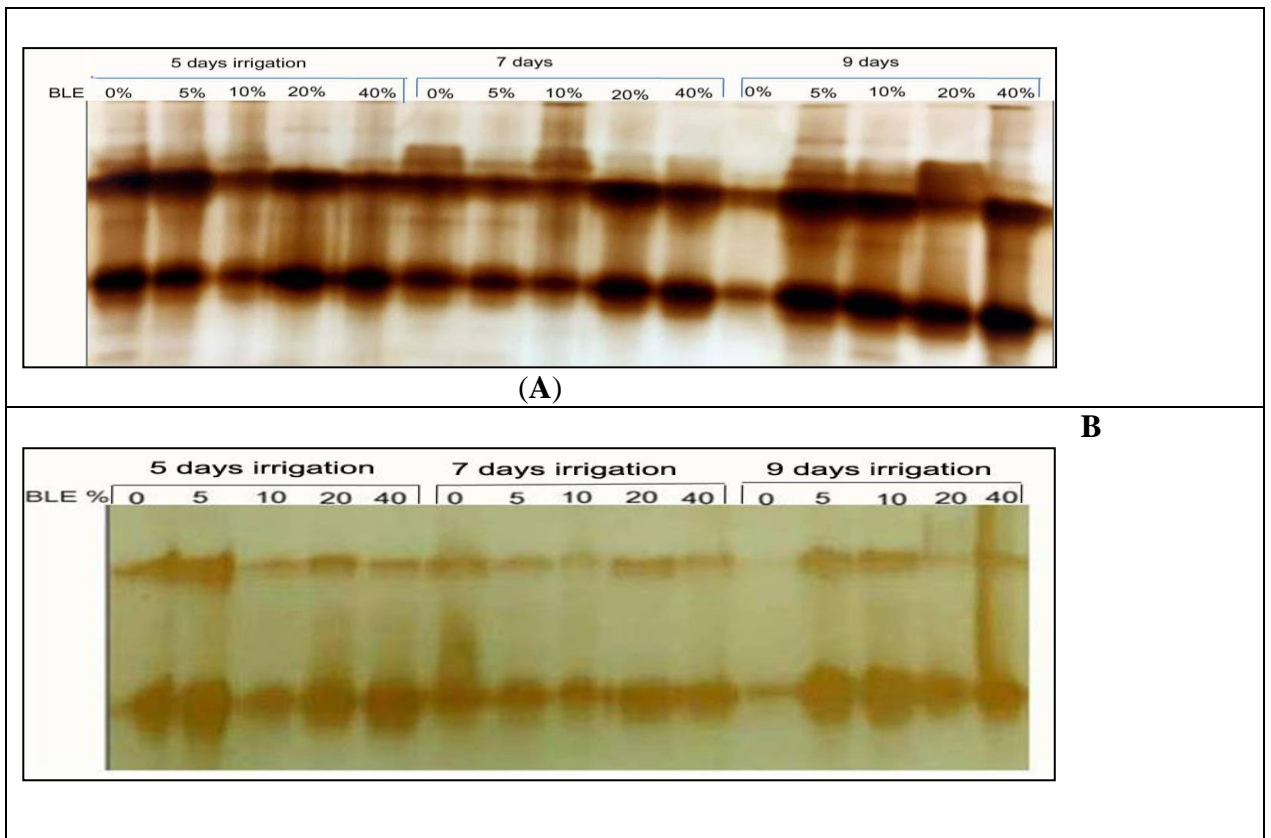


Fig. (2). Effect of different irrigation intervals and/or BLE (A) on Peroxidase isoenzyme banding patterns activity and (B) on polyphenol oxidase isoenzyme banding patterns activity of *S. mahogany* seedlings

Table (9). Isomers of polyphenol oxidase isoenzyme (+/-) and their retention factor (R_f) of effect of different irrigation intervals and/or basil leaves extract (BLE) on Peroxidase and polyphenol oxidase isoenzyme of *Swietenia mahogany* seedlings

BLE% RF	5 days irrigation					7 days irrigation					9 days irrigation				
	0	5	10	20	40	0	5	10	20	40	0	5	10	20	40
Peroxidase															
0.223	+	---		---	---	---	---	---	---	---	---	+	---	+	---
0.305	+++	++	++	+++	++	+++	+++	++	+++	+++	++	+++	+++	+	---
0.652	+++	++	+	+++	+++	++	++	++	+++	+++	+	+++	++	+++	+++
0.922	+	---	---	---	---	---	+	---	---	---	---	+	++	---	---
Polyphenol oxidase															
0.304	++	++	+	+	++	++	+	+	++	+	---	++	++	+	++
0.754	+	++++	++	++	++++	++	++	++	+++	+++	+	+++	+++	+++	++++

Most of the plant defensive system is devoted to contrast the adverse consequences of drought-triggered ROS. In this context, a prompt, powerful and

efficient antioxidant system is of pivotal importance to provide drought tolerance (Hussain *et al.*, 2019). This machinery involves enzymatic and non-enzymatic detoxification moieties, which lessen and repair injury triggered by ROS. Enhancement of the antioxidant apparatus helps in ROS scavenging that decreases electrolyte leakage and lipid peroxidation, therefore maintaining the vitality and integrity of organelles and cell membrane (Gharibi *et al.*, 2016).

It is well recognized that drought induces oxidative stress by generating ROS, for instance $O_2^{\bullet-}$, hydroxyl radicals (OH^{\bullet}), singlet oxygen (1O_2) and H_2O_2 (Impa *et al.*, 2012). The proportion of ROS generation and antioxidant enzyme activities regulates the cell redox state, thereby resulting in ROS control or cell injury and cell death when ROS exceed the physiological levels (Moller *et al.*, 2007). It is clear from the analysis of the aforementioned basil leaf extract that it is a good source of antioxidants; this was confirmed by similar results in previous studies (Elsayed *et al.*, 2022; Corrado *et al.*, 2020), where it was observed when used a sprayed with in low concentrations that it improved the growth of the *S. mahogany* plant, which was evident from the mentioned data.

It has been observed that spraying with basil leaf extract at a concentration of 10% on mahogany plants that have been exposed to different drought periods has improved the vegetative characteristics of the plant by reducing the production of indicators of oxidative stress and stimulating the production of anti-stress compounds, which is positively reflected on the performance of plant growth under stress conditions. The application of BLE led to alteration in gene expression of water channel proteins aquaporins and defense related proteins like dehydrins and amended the biochemical processes in the plant under drought stress, which ultimately provided plant to tolerate stress for more period of time. This alteration in gene expression might have occurred due to certain elicitor molecules which are expected to be present in BLE and induced a series of signaling cascade the plant, resulting better adaptation by the plants under stress (Pandey *et al.*, 2016). In this aspect, our results are agreement with (Pandey *et al.*, 2016) on rice plant .On the other hand, the high concentration of basil leaf extract showed the opposite effect as it led to a decrease in all values of vegetative growth characteristics and led to an increase in stress indicators. This may be due to the basil leaf extract containing many phenolic compounds that in low concentrations are considered antioxidants, but with high concentrations they had an allelopathic effect. Allelochemicals such as phenolic compounds inhibit root and shoot length (Hussain and Reigosa, 2011). Growth inhibition caused by these allelochemicals may probably be due to its interference with the plant growth processes (Gholami *et al.*, 2011). Allelochemicals released to the environment can either inhibit shoot and/or root growth consequently nutrient uptake, this may negatively affect plant growth, in this context, our results are in line with (Dafaallah and Al-Ahmed, 2017) on *Sorghum bicolor*, *Pennisetum glaucum*, *Zea mays* and *Triticum vulgare*.

Conclusions

It was concluded that the seedlings of *S. mahogany* were negatively affected when exposed to water shortage conditions at different periods. While when treating these seedlings with BLE at different concentrations, it was found that the 10%

concentration showed a desirable effect in helping the plant to resist the stressful effect of drought, followed by the 5% concentration, while the rest of the concentrations led to an inhibitory effect on plant growth, and this was proven in this study through Phenotypic measurements and chemical determinations of photosynthetic pigments and some oxidizing and antioxidant compounds.

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Contribution/Originality

This study contributes to enhance morphological and physiological growth of *Swietenia mahogany* seedlings under different irrigation intervals using basil leaf extract

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