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Effect of Foliar Spray with K and Mn on the Growth of *Swietenia mahagoni* (L.) Jacq. under Different Drought Levels

Kamal Shaltout[1], Mohamed Motawee[2], Dalia Ahmed[*1], Mohamed EL- Etreby[2]
[1]*Botany Department, Faculty of Science, Tanta University, 31527, Tanta, Egypt*
[2]*Timber Trees and Forestry Research Department, Horticulture Research Institute, Giza, Egypt*
*Corresponding author e-mail: dalia.ahmed@science.tanta.edu.eg, drdalia1080@yahoo.com
Mobile: +201223712092, ORCID: 0000-0001-7115-9375, SCOPUS ID: 55904705700

Abstract

The present study aims to study the effect of foliar spray of two chemical fertilizers (Potassium sulphate K_2SO_4 and manganese sulphate $MnSO_4$) on growth and drought tolerance of *Swietenia mahagoni* (L.) Jacq. seedlings to obtain their highest growth using the lowest available water resources. An experiment was carried out in an open field of Gemmeiza Agricultural Research Station during February to December 2020. Three levels of water stress were applied (100, 75, and 50 % field capacity). Three concentrations of K_2SO_4 were applied as foliar spray (0, 4 and 6 g L^{-1}), and 3 concentrations of $MnSO_4$ (0, 2 and 4 g L^{-1}). The results indicated that plant height, stem diameter, leaf number, leaf area, fresh and dry weight of the plant organs, relative water content, shoot / root fresh and dry weight ratios and total chlorophyll, were decreased with increasing levels of drought stress. Both K_2SO_4 and $MnSO_4$ spray significantly mitigated drought stress by increasing vegetative growth parameters (plant height, stem diameter, leaf number, leaf area, root length, fresh and dry weight of roots, stems and leaves, total fresh and dry weight, relative water content, shoot / root fresh and dry weight ratios, water use efficiency) and biochemical parameters (chlorophyll a and b contents, Proline contents, and carbohydrates of leaves) of *S. mahagoni* seedlings. Concentration 6 g L^{-1} of K_2SO_4 spray is highly effective than other treatments.

Key words: *Swietenia mahagoni* (L.) Jacq., Water stress, Field capacity, Drought, vegetative growth, Potassium and Manganese Sulfate.
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1. Introduction

Egypt suffers from water deficit that approximates one-third of the available water. The agriculture sector remains the biggest utilize of water in Egypt. In 2015, it acquired 62×10^9 m^3 which accounts for 82% of the total water consumption [1]. Water deficit is the main common environmental factor that determines crop productivity. Global climate change increases the vacillation of severe drought conditions, adversely affecting the morphology, physiology and biochemistry of plants [2].

Drought is the main important abiotic stress factor that determines yield growth and its production. Water deficiency was the main constraint to agricultural production in most countries, particularly in the arid regions, affecting the quality, growth and production of yields [3]. Water is required for germination, cell division and enlargement, promotion of plant growth and metabolic activities (synthesis of organic compounds, photosynthesis, respiration and other physiological and biochemical processes) [4]. Drought affects the plants at all stages, such as internal functions, processes, physical morphology of plants, and production [5]. Foliar application of elements under drought stress conditions is better than soil application because, at this condition, nutrient deficiency cannot be corrected by soil application [6].

Potassium (K) is regarded as a critical macronutrient for growth and development of plants, it aids in cell expansion, maintains plant turgor pressure, aids in cell osmo-regulation and activates of more than 60 enzymes [7]. K is required by plants to control the opening and closing of stomata, which is necessary for the exchange of CO_2, water vapor and O_2 with the environment. It also plays a crucial role in the transfer of water and nutrients throughout the xylem [8].

Manganese (Mn) is one of the most important micronutrients in plants, as it is a constituent of enzymes that are involved in photosynthesis and other functions. It is a part of a major antioxidant structure called superoxide dismutase, which protects plant cells by reducing free radicals that can damage plant tissue. This nutrient is a main constituent of the Photosystem II water splitting protein, which is vital for photosynthesis. It also operates as an electron storage and delivery system for the chlorophyll reaction centers, as well as a stimulator for above 35 enzymes [9]. Foliar spraying of Mn is useful and more influential than soil application**,** because under drought stress, plant roots cannot able to absorb micronutrients such as Mn [10]. The present study aims to study the effect of foliar spray of two chemical fertilizers (K_2SO_4 and $MnSO_4$) with different concentrations on growth and drought tolerance of *Swietenia mahagoni* (L.)

Jacq. seedlings to obtain the highest growth of these seedlings using the lowest available water resources. Three concentrations of K_2SO_4 were applied as foliar spray (0, 6 and 4 g L^{-1}). Also, three concentrations of $MnSO_4$were applied (0, 4 and 2 g L^{-1}). This can be done by increasing vegetative growth parameters (plant height, stem diameter, leaf number and area, root length, fresh and dry weight of plant organs, relative water content, shoot /root fresh and dry weight ratios and water use efficiency) and biochemical parameters (chlorophyll a and b, Proline, and carbohydrates contents of leaves) of *S. mahagoni* seedlings under different levels of drought stress (100, 75, and 50 % field capacity) using foliar spray of these two chemical fertilizers (K_2SO_4 and $MnSO_4$).

2. Study species

In our study, we used the seedlings of timber tree species *Swietenia mahagoni* (L.) Jacq. (family Meliaceae). Its common names include Small-leaved Mahogany, Cuban Mahogany, American, Spanish and West Indian Mahoganies [11]. It is a big semi-evergreen wood tree with a rounded canopy belonging to southern Florida, Cuba, Bahamas, Hispaniola, and Jamaica. It is also grown in tropical countries such as India, Malaysia, and Southern China [12]. In Egypt, it has been successfully grown in a few places [11]. It grows in areas with a mean annual temperature of 11-32°C on well-drained sandy soils and avoids rigid, heavy soils [13].

Mahogany is a hardwood large tropical tree, with a diameter at breast height ranged from 30 to 105 cm and wood density of 560–720 kg m^{-3}. It has a heavy trunk and considered as one of the most valuable timber trees, extremely strong, hard, stable and decay-resistant. The color of its wood ranges from pink to dark reddish-brown and considered as one of the top 12 timber kinds of wood in the world. It has a beautiful color and excellent texture finish stains and polishes to a beautiful natural brightness [14]. It is a large tree reaches a high of 45 meters, which grown in forests and gardens. The fruit is woody capsules of about 13 cm long, brown, split to produce winged seeds [15]. Leaves even, pinnate, flowers greenish-yellow, the light brown seed capsule stands upright, about 6-10 cm long by 4-5 cm diameter, with 5 valves splitting to produce brown, winged seeds, [16].

Mahogany is used as a landscape, ornamental and street shade tree, its wood is used for making fine shapes, furniture, decorative veneers and interiors and pattern-making. It is used in ship building and for fine boat interiors. At times, new model cars are originally carved, full size, entirely out of Mahogany. Once the various parts-front bumper, dashboard, the drive shaft, are first fashioned with this beautiful stable wood [14]. Also, Mahogany is a medicinal plant throughout its bark has an astringent property and is taken orally as a decoction for diarrhea, source of vitamins and iron, and medicine to induce hemorrhage [17]. Also, various parts have been used for the treatment of hypertension, malaria, cancer, amoebiasis, chest pains, fever, anemia, diarrhea, dysentery, depurative and intestinal parasitism [18].

3. Material and methods

An experiment was carried out in an open field of Gemmeiza Agricultural Research Station in the Middle of Nile Delta, Egypt (Lat. 30.97 N, and Long. 30.97 E). The present work was carried out during February to December (2020). In this experiment, timber seedlings of Mahogany tree were used (*Swietenia mahagoni* L. Jacq.). Its seeds were collected from the Timber Trees and Forestry Research Department in Giza (Horticultural Research Institute of Agricultural Research Center). Fruits are left for 5-7 days until they were opened. The seeds were soaked in water for 12 hours before planting. Soil for sowing was prepared from sand and clay (1: 1, after [19]). The seeds were placed in plastic bags of 26 x 14 cm and 8 cm in diameter. The chemical and physical analysis of sowing soil is provided in Table 1 according to [20]. The seeds were sowing in the first half of June, where they were placed in plastic bags with a depth of 2 cm (one seed per bag) and irrigated regularly, then the bags were placed in the nursery of Forestry and Timber Trees Department in Agricultural Research Station in Gemmieza.

On February (2020), seedlings were transplanted individually in black plastic pots (capacity of 45 x 30 cm and diameter of 18 cm). They were transferred at the age of about 8 months, and the treatments were applied to them at the age of 11 months. The bags were filled with 7.5 kg of a soil mixture, sand and manure at 3:1:0.5. Chemical and physical analysis of the agriculture soil was analyzed according to [20], and its physical and chemical analysis were illustrated in Table 1. Seedlings were irrigated with 100 % field capacity.

Table 1: Mean ± SD of the chemical and physical characteristics of sowing and agriculture soil.

Property	Sowing soil	Agriculture soil
pH (1:2.5 soil extract)	8.2 ± 0.42	7.7 ± 0.33
EC (soil paste extract) ds m^{-1}	3.1 ± 0.60	2.4 ± 0.65
Soluble ions (meq L^{-1})		
Ca^{2+}	6.6 ± 0.49	8.2 ± 0.43
Mg^{2+}	7.2 ± 0.59	7.5 ± 0.41
Na^{+}	7.6 ± 0.36	7.3 ± 0.50
K^{+}	0.7 ± 0.45	0.8 ± 0.38
Cl^{-}	6.0 ± 0.54	6.0 ± 0.42
HCO_3^{-}	8.5 ± 0.40	7.9 ± 0.52
SO_4^{--}	10.5 ± 0.50	9.1 ± 0.40
Available NPK (mg kg^{-1})		
N	75.3 ± 0.39	120.5 ± 0.39
P	5.7 ± 0.71	15.2 ± 0.60
K	520.0 ± 0.48	642.4 ± 0.49
Particle size distribution (%)		
Clay	49.8 ± 0.35	51.2 ± 0.36
Silt	29.6 ± 0.29	29.5 ± 0.30
Sand	21.2 ± 0.41	19.3 ± 0.51

Electrical conductivity (EC); deciSiemens per meter (dS/m); Milliequivalents per liter (Meq/L) and SD; standard deviation.

The layout of this experiment was split-plot design, and the pots were distributed in a randomized complete block design with three replications; each replicate included 45 plants. The main plot was water stress, while the sub-plots were devoted to the elements (K2SO4 and MnSO4 as foliar spraying), the total treatments were 15 treatments. Water stress treatments were carried out by weighting the pots every 3 days and adding the depleted amount of water through the entire period of the experiment to obtain the percentage of moisture content to each treatment according to [21]. The irrigation rates expressed as a percentage of field capacity were 100 (control), 75 and 50 % FC. These three levels of water stress were applied at the beginning of May using tap water in the irrigation of seedlings. Chemical analysis of the tap water (after [21]) is presented in Table 2.

Table 2: Chemical analysis of the tap water.

Character	PH	EC ds m^{-1}	Ca^{++}	Mg^{++}	Na	K^{+}	CL^{+}	HCO_3^{--}	SO_4^{--}
			meq L^{-1}						
Mean	7.30	0.70	1.80	1.10	3.50	0.20	1.80	2.80	2.00
SD	0.38	0.37	0.41	0.63	0.42	0.66	0.55	0.27	0.52

Electrical conductivity (EC); deciSiemens per meter (dS/m); Milliequivalents per liter (Meq/L) and SD; standard deviation.

Three concentrations of Potassium Sulfate (K_2SO_4) as foliar spray were used (it contains 50 % of K_2O and 18 % Sulfur): K 0 = 0 g L^{-1} (control), K1 = 6 g L^{-1} and K2 = 4 g L^{-1}. Also, three concentrations of Manganese Sulfate ($MnSO_4$) were used (it contains 31.8 % Mn and 18 % Sulfur): Mn 0 = 0 g L^{-1} (control), Mn1= 4 g L^{-1} and Mn2= 2 g L^{-1}. The foliar solution was prepared at both rates using distilled water. Spraying was applied three times in the morning (at 6-8 a m) using a hand pressure sprayer (May, June and July), while the control was sprayed with distilled water only. The study was terminated after ten months at the beginning of December (after [22]).

The growth parameters have been recorded at the end of the experiment (plant height, stem diameter and root length (in cm), leaf number, fresh and dry weight of roots, stems and leaves (in g), shoot / root fresh and dry weight ratios. The relative water content (RWC) was estimated using ten leaf disks (2 cm^2) taken from mature fresh leaf numbers 7 and 8 from the top of the plant and weighted (FW). Leaf disks were saturated in distilled water at room temperature for 24 hours (SW), and leaf disks were dried at 70 ^{0}C for 24 hours (DW). RWC was calculated as a percentage after [23]:

RWC % = (FW- DW) / (SW- DW) × 100.

Water use efficiency (WUE) was measured as follows after [24]:

WUE = Total fresh weight of seedling (g) / Total water quantities applied (liter).

Total leaf area (cm^2) was calculated mathematically using leaf area-leaf weight relationship from leaf disks obtained by a cork borer at the end of the experiment after [25].

Biochemical parameters have been recorded at the end of the experiment. Total chlorophyll contents (a and b) were determined (0.1 g) from mature fresh leaf numbers 7 from the top of the plant, immersed for 24 h. at 4 ^{0}C in 20 ml methanol (96%) and was measured using a spectro-photometer at a wave length of 666 and 653 nm. The results were expressed as mg g^{-1} fresh weight as follows after [26]:

Chlorophyll (chl.) a = ($15.65A_{666}$ - $7.34A_{653}$); Chlorophyll (chl.) b = ($27.05A_{653}$ – $11.21A_{666}$); Total Chlorophyll =

(chl.) a + (chl.) b

Proline was analyzed from dry weight of the mature leaves number 7 and 8 at stem top. Proline content (mg $100g^{-1}$ dry weight) was determined calorimetrically in the extract of dry leaf tissues using ninhydrin reagent and measured at 520 nm (after [27]). Carbohydrate concentrations (%) were determined from dry weight of the mature leaves number 7 and 8 at stem top [1].

The collected data were subjected to the statistical analysis of variance (ANOVA) by CO - STAT software program. LSD at 5% probability was used to compare between the differences among treatment means [21].

4. Results

All growth parameters of *S. mahagoni* seedlings were significantly affected by different levels of water stress. Plant height, stem diameter, leaf number, leaf area, root length, fresh and dry weight of plant organs were decreased with increasing water stress, except root length which increased with increasing water stress Table 3. On the other hand, shoot / root fresh and dry weight were decreased with increasing water stress. Relative water content decreased with increasing water stress, while water use efficiency increased with increasing water stress. All biochemical parameters of *S. mahagoni* seedlings were significantly affected by different levels of water stress. Total carbohydrates and Proline increased with increasing water stress, while total chlorophyll (a, b) decreased with increasing water stress (Figure 1).

All growth parameters *S. mahagoni* seedlings were significantly affected by foliar spray of Potassium and Manganese Sulfate Fertilization Table 4. Plant height, stem diameter, leaf number, leaf area, root length, fresh and dry weight of roots, stems and leaves, total fresh and dry weight, relative water content, shoot / root fresh and dry weight ratios and water use efficiency significantly increased

by increasing the concentration of foliar spray of Potassium Sulfate fertilization. Also, all biochemical parameters include chlorophyll a and b, Proline and carbohydrates of leaves, significantly increased by increasing the concentration of foliar spray of Potassium Sulfate fertilization from 4g L^{-1} to 6 g L^{-1} compared with the un-treated seedlings (Figure 2).

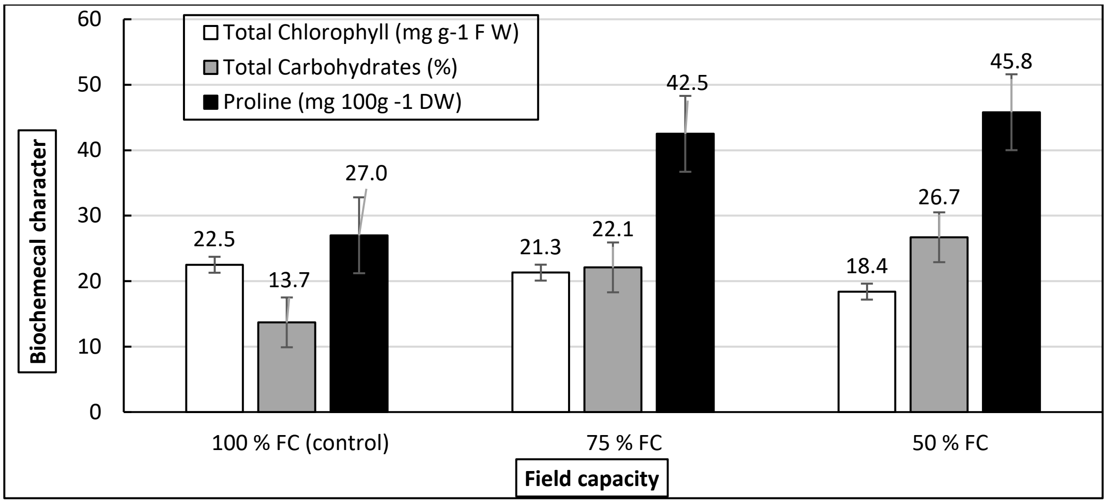
On the other hand, growth parameters of *S. mahagoni* seedlings significantly increased by increasing the concentration of foliar spray of Manganese Sulfate fertilization from 2g L^{-1} to 4 g L^{-1} compared with un-treated of *S. mahagoni* seedlings, except the root length, root fresh and dry weight, relative water content which significantly increased by decreasing the concentration of foliar spray of Manganese Sulfate fertilization. Also, biochemical parameters significantly increased with increasing the concentration of foliar spray of Manganese Sulfate fertilization from 2g L^{-1} to 4 g L^{-1}, except total chlorophyll contents of leaves which significantly increased at 2g L^{-1} than 4 g L^{-1} concentration (Figure 1).

Table 3: Effects of different levels of water stress on the growth parameters of *S. mahagoni* seedlings. (Mean ± SD)

Character \ Drought	100 % FC (Control)	75 % FC	50 % FC
Seedling dimension:			
Plant height (cm)	88.6^a ± 1.99	76.5^b ± 2.62	56.6^c ± 2.15
Stem diameter (mm)	16.2^a ± 1.23	13.9^b ± 0.88	11.7^c ± 0.67
Leaf number	54.7^a ± 2.32	45.8^b ± 2.42	38.1^c ± 2.56
Leaf area (cm^2 $plant^{-1}$)	193.8^a ± 1.18	187.6^b ± 1.35	183.7^c ± 1.03
Root length (cm)	39.9^c ± 1.95	43.5^b ± 1.53	47.1^a ± 1.52
Seedling weight (g $plant^{-1}$):			
Leaf fresh weight	56.0^a ± 1.36	51.3^b ± 0.97	38.1^c ± 1.57
Stem fresh weight	68.6^a ± 1.73	54.4^b ± 1.27	44.3^c ± 0.99
Root fresh weight	31.9^a ± 1.09	29.0^b ± 1.38	25.5^c ± 1.25
Shoot fresh weight	124.5^a ± 3.05	105.7^b ± 2.19	82.4^c ± 2.55
Total fresh weight	156.4^a ± 4.09	134.7^b ± 3.56	107.9^c ± 3.61
Stem dry weight	23.9^a ± 1.13	20.5^b ± 1.13	15.6^c ± 1.10
Leaf dry weight	15.5^a ± 1.36	12.7^b ± 1.16	9.7^c ± 0.98
Root dry weight	14.4^a ± 1.07	12.5^b ± 1.13	10.0^c ± 1.03
Shoot dry weight	39.4^a ± 2.21	33.1^b ± 2.16	25.2^c ± 1.90
Total dry weight	53.8^a ± 3.08	45.6^b ± 3.16	35.2^c ± 2.91
Vegetative weight ratio:			
Shoot / Root fresh weight	3.88^a ± 0.04	3.64^b ± 0.10	3.23^c ± 0.04
Shoot / Root dry weight	2.74^a ± 0.07	2.65^b ± 0.07	2.52^c ± 0.09
Water characteristics:			
Relative water content (%)	52.1^a ± 2.15	48.8^b ± 1.29	41.2^c ± 0.93
Water use efficiency	1.74^c ± 0.05	2.00^b ± 0.05	2.40^a ± 0.08

Means followed by the same letter (s) are not significantly different at 5% according to LSD test.

Where, K1=6gL^{-1}, K2 =4gL^{-1}, Mn1=4gL^{-1}, Mn2=2gL^{-1}, FC= field capacity and S / R =Shoot / Root.



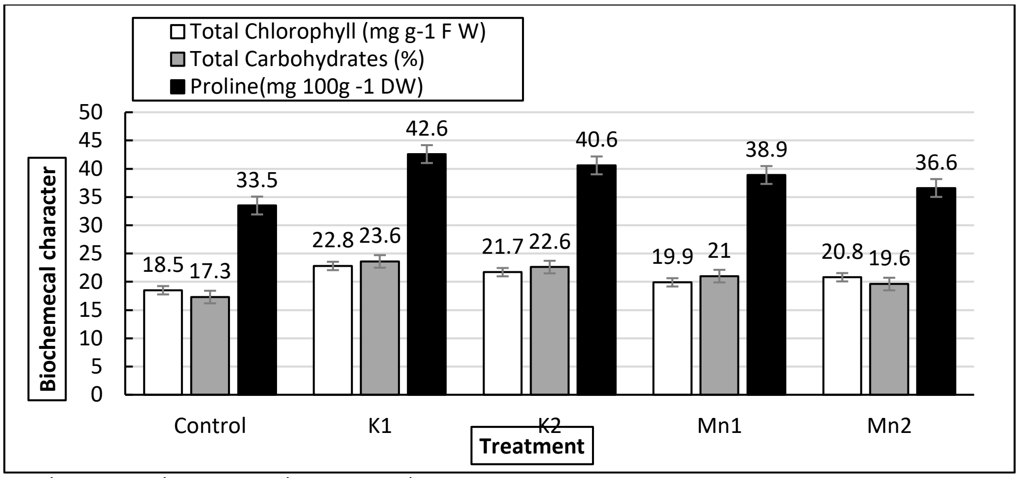
Where, K1=6gL^{-1}, K2 =4gL^{-1}, Mn1=4gL^{-1}, Mn2=2gL^{-1}, and FC= field capacity.

Fig (1): Effect of different levels of water stress on the biochemical parameters of *S. mahagoni* seedlings

Table 4: Effects of foliar spray with Potassium and Manganese Sulfate on the growth parameters of *S. mahagoni* seedlings under water stress. (Mean ± SD)

Character \ Elements	Control	K1	K2	Mn1	Mn2
Seedling dimension:					
Plant height (cm)	66.6^{e} ±2.49	81.1^{a} ±2.17	77.1^{b} ±2.29	73.7^{c} ±2.45	70.9^{d} ±1.86
Stem diameter (mm)	12.9 ^{b} ±1.19	15.1^{a} ±0.57	14.3^{ab} ±1.47	13.9 ^{ab} ±0.84	13.4^{ab} ±0.57
Leaf number	41.9^{d} ±2.53	51.2^{a} ±3.09	48.1^{ab} ±2.70	45.7^{bc} ±2.13	44.1^{cd} ±1.72
Leaf area (cm^{2} plant^{-1})	185.3^{d} ±1.60	191.9^{a} ±1.14	189.6^{b} ±0.80	187.1^{c} ±0.76	188.0^{bc} ±1.64
Root length (cm)	38.0^{d} ±1.57	47.2^{a} ±1.79	45.5^{b} ±1.76	42.7^{c} ±1.39	43.9^{c} ±1.82
Seedling weight (g plant^{-1}):					
Leaf fresh weight	40.7^{e} ±1.44	57.2^{a} ±1.49	51.7^{b} ±1.30	47.0^{c} ±1.24	45.6^{d} ±1.03
Stem fresh weight	47.3^{e} ±1.27	67.9^{a} ±1.54	59.1^{b} ±1.16	52.9^{c} ±1.71	51.6^{d} ±0.97
Root fresh weight	26.0^{d} ±1.12	31.5^{a} ±1.62	30.3^{b} ±1.24	27.8^{c} ±1.07	28.3^{c} ±1.16
Shoot fresh weight	88.0^{e} ±2.70	125.1^{a} ±3.01	110.8^{b} ±2.38	99.9^{c} ±2.90	97.2^{d} ±2.00
Total fresh weight	114.0^{e} ±3.70	156.6^{a} ±4.61	141.1^{b} ±3.56	127.8^{c} ±3.90	125.4^{d} ±2.99
Stem dry weight	17.0^{e} ±1.09	23.1^{a} ±1.20	21.3^{b} ±1.06	19.3^{c} ±1.13	19.1^{d} ±1.12
Leaf dry weight	10.7^{e} ±1.33	15.0^{a} ±0.95	13.7^{b} ±1.06	12.0^{c} ±1.37	11.8^{d} ±1.14
Root dry weight	11.0^{e} ±1.16	13.8^{a} ±1.09	12.9^{b} ±1.12	11.8^{d} ±1.03	12.0^{c} ±0.97
Shoot dry weight	27.7^{e} ±2.12	38.1^{a} ±1.86	35.0^{b} ±2.27	31.3^{c} ±2.10	30.8^{d} ±2.13
Total dry weight	38.7^{e} ±3.20	51.9^{a} ±3.00	47.9^{b} ±3.13	43.1^{c} ±3.04	42.8^{d} ±2.88
Vegetative weight ratio:					
Shoot / Root fresh weight	3.37^{c} ±0.03	3.92^{a} ±0.11	3.63^{b} ±0.07	3.57^{b} ±0.04	3.42^{c} ±0.05
Shoot / Root dry weight	2.50^{d} ±0.08	2.75^{a} ±0.09	2.71^{a} ±0.07	2.66^{b} ±0.08	2.56^{c} ±0.06
Water characteristics:					
Relative water content (%)	43.9^{d} ±1.88	51.0^{a} ±1.44	48.5^{b} ±1.41	46.1^{c} ±1.13	47.4^{bc} ±1.42
Water use efficiency	1.78^{e} ±0.06	2.36^{a} ±0.08	2.15^{b} ±0.05	1.98^{c} ±0.06	1.94^{d} ±0.05

Where, K1=6gL^{-1}, K2 =4gL^{-1}, Mn1=4gL^{-1}, Mn2=2gL^{-1}, and FC= field capacity.



Where, K1=6gL^{-1}, K2 =4gL^{-1}, Mn1=4gL^{-1}, Mn2=2gL^{-1}, and FC= field capacity.

Fig (2): Effect of foliar spray with Potassium and Manganese Sulfate on the growth parameters of *S. mahagoni* seedlings under water stress.

5. Discussion

5.1. Effect of water stress:

In the present study, all the growth parameters of *S. mahagoni* seedlings were affected by different levels of drought stress. Generally, all growth parameters include plant height, stem diameter, leaf number, leaf area, fresh and dry weight of the plant organs, total fresh and dry weight, relative water content, shoot / root fresh and dry weight ratios, were significantly decreased with increasing levels of drought stress ([28], [29], [30] and [31]), they said that drought stress creates morphological and physiological changes in higher plants involving decreased growth and leaves and fresh or dry weights accumulation. The highest values were obtained at 100 % field capacity (FC), while the lowest were obtained at 50 % FC. In contrast, the root length and water use efficiency increased significantly with increasing levels of drought, as the highest value were obtained at 50 % FC, while the lowest value was obtained at 100 % FC. Water stress reduced the plant height and shoot length, while increased the root length [32]. On other hand, biochemical parameters, including Proline and carbohydrate contents of leaves of *S. mahagoni* seedlings, increased significantly with increasing levels of drought as the highest value were obtained at 50 % FC, while the lowest were obtained at 100 % FC. In contrast, the highest values of total chlorophyll contents in leaves were obtained at 100 % FC, while the lowest were obtained at 50 % FC.

In the present study, the results of plant height, stem diameter and leaf number of *S. mahagoni* seedlings agree with the studies of [33] on *Bauhinia faberi* seedlings, and [34] on *Swietenia macrophylla* seedlings. The results of leaf area, leaf fresh weight and dry weight of leaf and shoot, relative water content and carbohydrates content agree with the studies of [1] on *Citrus aurantium* L. seedlings. Also, the results of fresh and dry weight of the plant organs agree with the studies of [35] on *Eucalyptus camaldulensis* and *Eucalyptus citriodora* seedlings and that of [32] on *Andrographis paniculata* seedlings who reported that water stress reduced the plant height and shoot length while increased the root length.

Regarding the water use efficiency, our results agree with the studies of [36] on *Eucalyptus microtheca* seedlings, and [37] on *Poincianella bracteosa* plants. The results of root dry weight, and chlorophyll (a, b) content agree with the studies of [38] on *Acacia senegal* L. seedlings. The results of shoot / root fresh weight agree with the studies of [39] on *Swietenia macrophylla* seedlings, and with [40] on *Prunus africana* seedlings. The results of the stem fresh weight agree with the studies of [41] on *Eucalyptus globulus* seedlings and [42] on *Cassia acutifolia* plants, but the results of stem dry weight agree with the studies of [43] on *Barbados cherry* seedlings. Our results of the root length agree with the studies of [44] on *Khaya senegalensis*, which indicated that root length increased to maximum values in the plants exposed to water stress at a level of 40 % F C, and that of [45] on *Azadirachta indica* seedlings who reported that root length at treatment 50 % FC showed the maximum root length. The results of proline agree with the studies of [21] on *Punica granatum* seedlings and [46] on *Azadirachta indica* seedling which indicated that proline increased with increasing water stress level.

Drought stress creates morphological and physiological changes in higher plants, involving declined growth, loss of turgor, osmotic change, and declined leaf water potential ([28], [29] and [31]). Vegetative growth parameters were affected by drought stress conditions which may be due to that the plant growth is inhibited by the decrease in leaf extension level, rates of cell division and enlargement [47]. Also, under drought stress, water and mineral absorbed and uptaken by plants were declined, which influenced root development and plant growth [48]. Moreover, declined in irrigation rates were affected on overall growth may be due to the lower availability of sufficient moisture around the root and decreasing of root biomass resulting in the lower absorption of nutrients and water leading to lower biomass production [49]. Moreover, the uptake of essential elements and photosynthetic capacity under water scarcity is decreased which reflected indirectly in the formation of vegetative shoots [30], [57]. The plant height is one of the main parameters commonly used to determine the degree of drought stress [29]. Plant height is affected by water stress due to hormonal imbalance (cytokinin and abscisic acid), which influenced plant growth due to changes in cell wall extensibility ([50] and [51]).

Moreover, reducing leaf area and number per plant is a strategy by plants to reduce transpiration surface. It also may be due to a decrease in plant growth, photosynthesis and covering structure during the water stress [28]. Under drought stress, stem elongates slowly, plant remains dwarf and leaves expansion were decreased [51]. [52] and [53] said that the reduction in the growth parameters may be possibly due to decline of the activity of meristematic tissues responsible for elongation. Moreover, total fresh and dry weights declined due to the exposure to drought stress which may be resulted of a decrease in chlorophyll content, and consequently, photosynthetic efficiency ([54] and [53]). According to [55], decrease of shoot / root fresh weight ratio was due to decrease in shoot growth compared with root growth under water stress, to help in water uptake.

[56] reported that, field soil moisture contents in general increase with soil depth, then, an extensive root system can access a larger soil volume to able to extract available water. Also, [30], [57] reported that the uptake of essential elements and photosynthetic capacity under water deficiency is reduced, and this leads to decrease the formation of the vegetative shoots, leaves and fresh or dry weights accumulation. According to [58], the decrease in relative water content of leaves may be due to the lack of water in the soil, root systems will be unable to balance for water loss through transpiration due to decrease in the absorbing surface. [59] reported that plants tolerant to drought maintain higher water use efficiencies by decreasing water loss through closing their stomata under water deficits condition and transpiration water loss is declined to a greater extent, then leaf turgor and water potential are reduced under such condition. According to our data, *S. mahagoni* is considered tolerant to drought because increasing water use efficiencies with increasing water stress [59].

5.2. Effect of Potassium:

In the present study, all growth and biochemical parameters of *S. mahagoni* seedlings were affected by Potassium Sulfate fertilization under different levels of drought stress. Generally, growth and biochemical parameters significantly increased with increasing concentration of Potassium Sulfate under drought stress [53]. The results of plant height, stem diameter, and fresh weight of plant organs and total chlorophyll (a, b) of *S. mahagoni* seedlings in the present study agree with the studies of [60] on *Brassica napus* L. Also, the results of root length, root and shoot dry weight, relative water content, total chlorophyll (a, b) and proline agree with the studies of [61] on *Zea mays* L. The results of leaf number, shoot and root fresh weight, total dry weight and carbohydrate content agree with the studies of [53] on *Triticum aestivum* L., while the results of leaf area, stem and total dry weight agree with the studies of [62] on *Solanum lycopersicum* L. The results of water use efficiency agree with the studies of [63] on *Prunus persica* L., those of the shoot / root fresh and dry weight of *S. mahagoni* seedlings agree with the studies of [64] on *Cucumis melo* L., while those of leaf dry weight agree with the studies of [65] on *Phaseolus vulgaris* L.

[66] suggested that Potassium application alleviated the negative effect of water scarcity and increasing plant growth by maintaining stomatal regulation through osmotic adjustment for increased CO_2 fixation for biosynthesis of photo-assimilates, it is required for the translocation of photo- assimilates in root development and for the stimulation of root growth through increased adequate K supply. According to [67], K enhancing stem diameter because it led to an increase in the thickness of sclerenchyma tissue layers which lead to an increase in stem diameter. [68] added that K is necessary for cell elongation and possibly cell division. According to [69], K is necessary for stem elongation and maximal leaf extension because it plays a key role in maintaining the turgidity of plant cells.

[53] reported that K increased photosynthetic pigments under different water levels, it ameliorates the adverse effects of water stress and enhanced plant growth by increasing biosynthesis of the bioactive compounds like compatible solute (total soluble sugars, proline, total free amino acid) and antioxidant enzyme activities (superoxide dismutase, catalase, peroxidase) and decreased lipid peroxidation. Generally, K feeding is considered to mitigate water stress through good root-soil-searcher, longer leaf lifespan, good cell growing capacity, and good osmotic regulation [70], and activation of the plant defense system against all different stresses [51]. Hussain et al. (2013) and [71] stated that exogenously applied K may be led to increased root length for penetration in soil and partial stomata closure. [54] reported that, water use efficiency improved by K fertilization, because it plays an important function in balancing membrane potential and turgor and controlling osmotic pressure and stomata movement, which led to an increasing of leaf relative water content under water deficit ([72] and [61]).

[73] and [74] reported that K could protect chlorophyll and membranes from degradation. [75], reported that its related to the formation of chlorophyll content or to prevent the decomposition of chlorophyll. Besides, K is necessary to activate at least 60 different enzymes involved in the metabolism and growth of the plant. [61] reported that K plays a major role in carbohydrate synthesis and the transportation of metabolites, which enables plants to resistant to drought stress. Moreover, according to [29], K is essential for carbohydrates metabolism because K is important in translocation of sugars and production of starch and carbohydrates, as well as it helps to regulate the production of high energy compound required to drive metabolic processes. [76] demonstrated that K protects leaves from dehydration by inducing accumulation of solute such as proline, decreasing osmotic potential that is important to maintain plant cell turgor under osmotic stress.

5.3. Effect of Manganese:

In the present study, all growth and biochemical parameters of *S. mahagoni* seedlings were affecting by Manganese Sulfate fertilization under different levels of drought stress. Generally, growth and biochemical parameters significantly increased with Manganese Sulfate fertilization under drought stress compared with un-treated plants [31]. Results of plant height, stem diameter, leaf number, leaf area, stem fresh and dry weight, root length, root dry weight, total chlorophyll (a and b) content, leaf relative water content and water use efficiency of *S. mahagoni* seedlings in the present study agree with the studies of [31] on *Vitis vinifera*, while results of proline, carbohydrate content and water use efficiency agree with the studies of [77] on *Vitis vinifera*. Variation in leaf fresh weight, total fresh and dry weight and shoot fresh weight agree with the studies of [78] on *Brassica junceae*, while those of leaf dry weight, shoot dry weight agree with the studies of [79] on *Carthamus tinctorius* L.

Physiological mechanism by which Mn increases the plant height and plant growth may be due to stimulation of photosynthetic apparatus, cellular elongation and cell division development [80]. In addition, Mn is involved in metabolic processes such as the synthesis of amino acids and hormone activation of indole acetic acid (IAA) through the IAA-oxidases, which are involved in growth ([81] and [31]). Also, Mn increased the stem and root dry weight, due to it inappropriate partitioning of nutrients and assimilates between vegetative and productive parts [82]. Mn application under different levels of water scarcity mitigates the adverse effect of drought stress and increased the leaf relative water content, carbohydrate, Proline and protein contents [31].

Increasing of Manganese doses in leaves can increase the synthesis of organic solute compounds (protein), which contributes to reduce leaf osmotic potential [31]. Also, [83], [9] and [84] suggested that MnSO4 increased the protein accumulation, this organic solute is a major factor in the tolerance mechanisms to water stress conditions. [85] reported that Mn can decline the negative effects of drought and increase water use efficiency indirectly by enhancing the photosynthetic rate, and nitrogen metabolism in the plant body to form other compounds required for plant metabolism.

[81] and [31] concluded that Mn increases the total chlorophyll in leaves due to its involving in the formation of chlorophyll, and it activates several major metabolic reactions in the plants. Also, [86] reported that Manganese is an important element for the resistance of chloroplast. In addition, Mn functions as an activator of various enzymes (some 35 various enzymes), and it is vital in the formation of chlorophyll and its presence is required in photosystem II [9]. In addition, Mn increased the total carbohydrates in leaves, as it plays an important role in the regulation of carbohydrate biosynthesis ([83], [9]and [87]).

[29]and [31] suggested that Mn improved Proline content in leaves because Proline accumulates acts as a protective osmolyte in several plant species as a response to osmotic stress induced by drought stress. The interaction between drought stress and Mn showed that its application under different levels of water scarcity mitigated the adverse effect of drought stress and increased the leaf relative water content, total chlorophyll content, carbohydrate and Proline [31]. So, S. mahagoni plant considered tolerant to drought stress, also K and Mn mitigated the negative effect of drought stress.

6. Conclusion

Exogenous application of both Potassium and Manganese Sulfate spray mitigated drought stress by increasing all the growth and biochemical parameters including plant height, stem diameter, leaves number, leaf area, root length, fresh and dry weight of roots, stems and leaves, total fresh and dry weight, relative water content, shoot / root fresh and dry weight ratio, water use efficiency, total chlorophyll (a and b) contents of leaves, Proline and carbohydrates contents of leaves of *Swietenia mahagoni* (L.) Jacq. seedlings. Spray Potassium Sulfate is highly effective more than that of Manganese Sulfate. Potassium Sulfate and Manganese Sulfate foliar spray are alleviating the adverse effects of drought stress by increasing both growth and biochemical parameters. Concentration of 6 g L-1 of Potassium Sulfate is highly effective than 4 g L^{-1} because it increasing all the growth and biochemical parameters. In addition, concentration of 4 g $L^{-1}$of Manganese Sulfate foliar spray increase both growth and biochemical parameters except root length, root fresh and dry weight, relative water content and total chlorophyll contents of leaves which decreased at 4 g L^{-1}, but increased at 2 g L^{-1} foliar spray concentration.

Conflicts of interest

There are no conflicts to declare.

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