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Effect of Irrigation Intervals and Sulphur Fertilization on Vegetative Growth and Absorption of Some Heavy Metals by African Mahogany (*Khaya senegalensis*) Tree Seedlings

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Abstract: This study was carried out at the Gamasa forestry, EL-Dakahlia Governorate, during the period from March 2018 to September 2021 for studying the effect of irrigation intervals and sulphur fertilization rates on vegetative growth and chemical composition of *Khaya senegalensis* seedlings. Four irrigation intervals were used i.e., every day, two, three and four days, intervals. In addition, four sulphur fertilization rates were used as follow: without fertilizer (control), 15, 30 and 45 g/plant. The following data were recorded, stem length, stem diameter, total fresh and dry biomass, chlorophyll a & b and carotenoid leaves contents in addition to Cr, Zn, Mn and S content for roots, branches and leaves. Results indicated that, application of sulphur fertilization at the rate of 45 g / plant produced the tallest, thickest, higher values of total aboveground bio and dry mass for khaya plants. In addition that, there were non-significant differences between irrigation every one or two days in all vegetative growth characters and absorption of heavy metals. On other hand, application of sulfur fertilization at the rate of (45 g/plant) and irrigation every one or two days produced the superior plants in all vegetative characters tested in addition multiple absorption of heavy metals by khaya plants in comparison with the other treatments.

Key words: African · Khaya · Mahagoni · Irrigation · Intervals · Sulphur · Fertilization · Wastewater · Phytoremediations.

INTRODUCTION

In the coming decades, NENA countries (Near East and North Africa Region) will be experiencing more frequent, intense and long droughts because of Climate Change. Probably, these countries will be exposed to a severe intensification of water scarcity, due to several drivers, including tendency to increase food self-sufficiency to reduce vulnerability to import and price volatility, energy demand and overall socio-economic development, urbanization expansion and demographic growth. Availability of Per capita fresh water will probably decrease by 50% at 2050, which has already decreased by another 2/3 over the last forty years [1].

Nowadays, Egypt as a part of arid and semi-arid zone faces various challenges for managing water resources. The largest consumer for water supplies, almost 85%, is the agriculture sector. Application of treated wastewater (recycled or reclaimed water) would supply multi benefits to comprise an affordable solution for water insufficiency and an economic pollution control measurement [2].

One of the main abiotic stresses, in modern decades, are heavy metal contaminations that cause an environmental pollution. Therefore, an environmental contamination has become a great public health problem may affecting the human survival and sustainment, across the globe [3, 4]. One of the major environmental concern presence of heavy metals in agricultural soils that a number of human health hazard are associated with heavy metals regarding their entry into the food chain [5].

There are a great influence of plants on their environment not only by exudation of many molecules

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that are produced in primary and secondary metabolism but also by uptake of substances, so plants considered a chemical factories. Using plants to remediate of contaminated sites classified under the expression "phytoremediation" [6, 7]. Phytoremediation presents one of the environmentally suitable approaches to overcome the toxic metal pollution as a cheap and alternative way to decontaminate the HM-contaminated sites [8]. The phytoremediation technique considered a widely acceptable worldwide consequent to its lower cost in comparison with the conventional remediation methods [9, 10].

In recent years, sulfur has justifiably gained more attention and an important component of complete and balanced crop nutrition. Most soluble sulphur fertilization contains sulfate, but others such as poly sulfides, thiosulfates and bisulfites are also available. Before plants can use Sulphur, it must be oxidized to sulfate; also, in some instances, it can be used to acidify soils [11]. On other hand, the incessant using of the concentrated fertilizer formulations, especially nitrogen and phosphorus, that are lacking S, reduce of emissions of SO_2 from fossil fuel burning to the atmosphere and reduction of S input through rainwater have led to an increase of S scarcity in soils [12].

African mahogany (*Khaya senegalensis*) belongs to Family Meliaceae, up to 20-30 m high, is a deciduous tree and the diameter up to 1.5 m. Khaya is a multipurpose tree with several environmental, economic and medicinal uses. The tree has a characteristic round capsules woody fruits, round evergreen crown of dark shiny foliage pinnate leaves [13]. Its fruit is 4-6 cm in diameter and has four to five valves in which up to 6–18 seeds are embedded. Seeds weigh 289 g per 1000 seeds, 2-2.5 cm long and flat disk-like. The tree is famous for its high quality timber, which is excellent for veneers, furniture, construction, interior fitting, turnery, plywood and joinery. Furthermore, African mahogany is planted as a roadside and an ornamental shade tree [14].

The objective of this work is to study the effect of irrigation intervals and Sulphur fertilization rates on vegetative growth and absorption heavy metals of African mahogany.

MATERIALS AND METHODS

This study was carried out at the Gamsa forestry, EL-Dakahlia Governorate. One year old of Khaya seedlings planted at distance 5X5 m in March 2018 for studying the effect of irrigation intervals and Sulphur fertilization rates on vegetative growth and chemical composition of *Khaya senegalensis* seedlings. Four irrigation intervals were used by wastewater treatment i.e., every day (control), two, three and four days, respectively. In addition, four sulphur fertilization rates used as follow: without fertilizer (control), 15, 30 and 45 g/plant every month. Sulphur fertilizer, which used was produced by Kafr EL-Zayat Company, Egypt, 25 kg for sack. Before planting 500 gm of sulphur was added to each pit.

The following data were recorded, stem length, stem diameter, total fresh and dry biomass, chlorophyll a, b and carotenoid contents in leaves fresh weight were determined according to Saric *et al.* [15]. In addition, Cr, Zn, Mn and S (mg/ kg^{-1}) in the leaves, branches and roots in all tested plant samples at the end of study period (September 2021) were determined by Inductively Coupled Plasma Spectrometry (ICP) (Ultima 2 JY Plasma) and according to Chapman and Pratt [16].

Soil particle size distribution and Ca CO_3 were determined according to Piper [17].The soil and water samples were analyzed for EC, pH, soluble cations and anions according to Black *et al.* [18] and Page [19]. Cr, Zn, Mn and S content in the wastewater, which was used as source of irrigation as well as their available content in soil were extracted according to Soltanpour [20] and American Public Health Association [21] as shown in Tables (a and b).

Table a: Wastewater analysis

Items		EC				Cl	SO_4	Ca	Mg	Na	K	N	P	Fe	Mn	Zn	Cu	B	CO	Cr	Ni
Unit	PH	Ds m^1	SAR	CO_3	HCO_3	---------- Meq L^1 ----------								---------- Mg L^1 ----------							
Mini.	7.8	1.4	6.4	n.d	4.1	8.71	1.03	2.64	1.31	10.12	0.48	14.9	5.51	0.392	0.138	0.232	0.106	0.373	0.011	0.011	0.011
Maxi.	8.10	1.60	7.4	n.d	5.80	10.25	2.14	3.57	1.90	10.70	0.85	21.63	7.49	0.543	0.205	0.291	0.147	0.550	0.016	0.017	0.022
Mean	7.95	1.50	6.90	n.d	4.86	9.30	1.81	3.08	1.75	10.49	0.67	18.27	6.50	0.468	0.172	0.262	0.127	0.462	0.014	0.014	0.017
Egy. cod	6.5-8.4	0.7-3.0	0.9	-	9.0	10.0	-	-	-	-	-	300	-	5.0	0.20	2.0	0.20	3.0	0.05	0.10	0.20
FAO cod	6-6.5	0.7-3.0	0.2-0.7	-	-	-	-	-	-	-	-	-	-	5.0	0.20	2.0	0.02	3.0	0.05	0.10	0.20

Table b: Soil physical and chemical analysis

Parameters	Coarse sand %	Fine sand %	Clay %	Silt %	Texture-class	Chemical analysis	PH	Ec (ds/m)	ESR	N (ppm)	P (ppm)	K+	Ca	Mg^{++}	So^-4	$Hco-_3$	Cl^-	Na+ Mg/kg
	48.13	43.11	5.19	3.57	Sand soil		8.12	2.91	8.14	41.18	5.95	0.38	0.95	0.93	0.89	0.81	1.54	46.66

Mini. = Minimum, Maxi, = Maximum, Egy. = Egypt

Experimental Design: The layout of the experiment was a factorial in complete randomized design, the main factor was irrigation intervals and the sub factor was sulphur fertilization. The experiment included 16 treatments (4-irrigation intervals X 4 Sulphur fertilization), each treatment included 3 replicates; each replicate consisted of five seedlings.

Statistical Analysis: The obtained results were subjected to statistical analysis of variance (ANOVA) according to the method described by Snedecor and Cochran [22] using M STAT program. Least significant ranges (LSR) were used to compare between means of treatments according to Duncan [23].

RESULTS AND DISCUSSION

Vegetative Growth Characteristics

Stem Length and Stem Diameter: It is evident from data presented in Table (1) that, using sulphur fertilization at rate of 45 g/seedling significantly increased both stem length and stem diameter as compared to the other treatments. Also, irrigation every day and two days were superior in stem length (5.12 and 4.87m) and stem diameter (11.85 and 11.08cm), respectively. Regarding the interaction between sulphur fertilization and irrigation intervals, application of the sulphur at the rate of (45 g/plant) with irrigation every day or two days produced the tallest plants (5.92 and 5.58 m) and the thickest stems (13.22 and 12.74 cm). Bakry [24] indicated that, sulfur fertilizer at rate of (250 and 500 kg/fed) gave significant increases in morphological criteria (plant height and root length, fresh and dry weight of shoots and roots). In this regard, El-Khateeb *et al*. [25] found that, there were negative effects on plant height, on *Acacia saligna,* by protracting the irrigation intervals. Farahat *et al*. [26] indicated that, water deficit reduced the growth of plant characters [26].

Total Aboveground Bio and Dry Masses: It is clear from data presented in Table (2) that, the heaviest weight of plants were produced by application sulphur fertilization at the rate of (45g/plant) in comparison with the other treatments. Concerning the effect of irrigation intervals, the same data cleared that, irrigation every day or two days significantly increased in total bio and dry masses as compared to irrigation every three or four days. As regard the interaction between the two factors, irrigation every one or two days combined with the application of (45g/plant) gave the highest values (59.47 and 54.86 kg) and (31.01 and 28.89 kg) for aboveground bio and dry mass, respectively. Farahat *et al*. [26] found that, leaves fresh and dry weights of water-stressed plants were less than the equivalent growth in the well-watered ones. These results are in accordance with the finding of Elfeel and Al-Namo [27] on three arid zone species, the decrease in growth parameters with drought intensity may be due to the decline in net photosynthesis assimilation which brought by decreased leaf water potential [28].

Chemical Composition

Chlorophyll a & B and Carotenoid Contents (mg/g FW): It can be noticed from data presented in Table (3) that, increasing sulphur fertilization rates had a positive effect on the leaves chlorophyll a & b and carotene content. The highest values showed by application the rate of (45g/seedling). On other hand, control treatments showed the least values on this regard. Regarding the irrigation intervals, there were non-significant differences between irrigation every two days and irrigation every day, whereas irrigation every three or four days showed a significant reduction in chlorophyll a & b and carotene content as compared to the other treatments. For the interaction between two study factors, irrigation practice every day or two days sulphur application at the rate of (45g/plant), significantly increased the values of chlorophyll a & b and carotene leaves content as compared to the other treatments. Bakry [24] indicated that, sulfur fertilizer at rate of (250 and 500 kg/fed) gave significant increases in photosynthetic pigments, chlorophyll a, chlorophyll b and carotenoids.

Chromium (Cr) Content: It is obvious from data presented in Table (4) that, using of a high rate of sulfur fertilization (45g) increased the content of Cr roots, branches and leaves (320.57, 349.14 and 462.35 mg/kg) by nearly four times compared to the control treatment (81.17, 128.54 and 152.12 mg/kg). At the same time irrigation every two days showed non- significantly differences with control treatment in this regard. On other hand, irrigation khaya seedlings every four days recorded the lowest values of Cr in the different plant organs as compared with the other irrigation intervals. Concerning the effect of interaction between the two tested factors, irrigation every day with the application of sulphur fertilization at the rate of 45 g/plant produced the highest Cr content (435.98, 450.87 and 637.47 mg/kg) in the roots, branches and leaves, respectively. In this concern, Shehata *et al.* [29] suggested that, found that, the best soil additive was sulfur that increased the metal mobility in the soils of high Cd, Mn, Co and Cr.

Table 1: Effect of irrigation intervals and sulphur fertilization on stem length (m) and stem diameter (cm) of *Khaya senegalensis* plants at the end of study

Treatments	Irrigation intervals									
	Stem length (m)					Stem diameter (cm)				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 days	2 days	3 days	4 days	M
Control	4.14e	4.02ef	3.45f	3.17g	3.70D	10.26d	9.63e	8.76f	7.81g	9.12D
15 g /seedling	4.89c	4.67d	4.10e	3.34fg	4.25C	11.32b	10.67c	9.15ef	7.92g	9.77C
30 g /seedling	5.54ab	5.21b	4.82cd	4.06ef	4.91B	12.57ab	11.28bc	10.41cd	8.36fg	10.66B
45 g /seedling	5.92a	5.58a	5.06bc	4.54de	5.28A	13.23a	12.74a	11.24bc	8.85f	11.52A
M	5.12A	4.87A	4.36B	3.78C		11.85A	11.08A	9.89B	8.24C	

Table 2: Effect of irrigation intervals and sulphur fertilization on total aboveground bio and dry mass (kg) of *Khaya senegalensis* plants at the end of study

Treatments	Irrigation intervals									
	Aboveground biomass (kg)					Aboveground dry mass (kg)				
Sulphur rates	1 days	2 days	3 day	4 days	M	1 days	2 days	3 days	4 days	M
Control	35.57d	32.11ef	27.17g	21.41h	29.07D	19.03cd	16.78e	12.67f	10.34g	14.72D
15 g /seedling	41.25cd	37.21d	30.23f	23.65gh	33.09C	22.48c	18.14d	13.42ef	11.13g	16.29C
30 g /seedling	48.41b	43.85c	34.48e	25.49g	38.06B	25.26b	23.83bc	17.23de	12.82f	19.79B
45 g /seedling	59.47a	54.86a	41.10cd	32.85ef	47.07A	31.01a	28.89a	20.96c	16.96e	24.40A
M	46.18A	42.01A	33.25B	25.85C		24.47A	21.91A	16.07B	12.81C	

Table 3: Effect of irrigation intervals and sulphur fertilization on chlorophyll a & b and carotenoids content (mg/g FW) of *Khaya senegalensis* plants at the end of study

Treatments	Irrigation intervals														
	Chlorophyll a					Chlorophyll b					Carotenoids				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M
Control	0.685de	0.621ef	0.523fg	0.422g	0.563D	0.412ef	0.383fg	0.324gh	0.298h	0.354D	0.471d	0.445e	0.412f	0.385g	0.428C
15 g /seedling	0.742c	0.698d	0.584f	0.452g	0.619C	0.495d	0.442e	0.385fg	0.334g	0.414C	0.499cd	0.458de	0.421ef	0.392fg	0.443B
30 g /seedling	0.811b	0.761bc	0.674e	0.637ef	0.721B	0.587b	0.539c	0.462de	0.400f	0.497B	0.541b	0.512c	0.487d	0.448e	0.497B
45 g /seedling	0.896a	0.823a	0.714cd	0.657e	0.773A	0.665a	0.616a	0.551bc	0.473de	0.576A	0.586a	0.543b	0.510c	0.494cd	0.533A
M	0.784A	0.726A	0.624B	0.542C		0.540A	0.495A	0.431B	0.376B		0.524A	0.490A	0.458B	0.430B	

Table 4: Effect of irrigation intervals and sulphur fertilization on Cr content (mg/kg) of *Khaya senegalensis* plants at the end of study

Treatments	Irrigation intervals														
	Roots Cr (mg/kg)					Branches Cr (mg/kg)					Leaves Cr (mg/kg)				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M
Control	111.98f	98.57g	64.24h	49.87hi	81.17D	164.12g	147.63gh	114.45hi	87.97i	128.54D	197.55e	178.36ef	135.24f	97.32g	152.12D
15 g /seedling	210.81d	174.68e	109.74fg	87.64gh	145.72C	243.85d	224.67de	184.24f	122.28h	193.76C	294.65c	269.76cd	201.37de	121.41fg	221.80C
30 g /seedling	367.56b	270.36c	198.07de	123.31f	239.83B	336.47b	318.33c	240.74de	179.30fg	268.71B	418.32b	388.37bc	299.54c	187.34ef	323.39B
45 g /seedling	435.98a	419.52a	254.32cd	172.44e	320.57A	450.87a	427.25a	304.98cd	213.45e	349.14A	637.47a	594.74a	387.52bc	229.67d	462.35A
M	281.58A	240.78A	156.59B	108.32C		298.83A	279.47A	211.10B	150.75C		387.00A	357.81B	255.92C	158.94D	

Zinc (Zn) Content: For roots, branches and leaves Zn contents, data illustrated in Table (5) revealed that, there were gradual increases in Zn content by increasing sulphur fertilization rates, whereas the same data showed that, there were non-significant difference between sulphur fertilization at the rate of 30 and 45 g/plant. The solubility of Zn increases as soil pH decreases [30]. Therefore, the increase in tissue Zn uptake might be due to acidifying effect of S, which resulted in increased availability of Zn in soil [31]. Islam [32] indicated that, sulfur application increased tissue Zn uptake. According to Souza *et al.* [33] the highest Zn content was detected in the shoots of both the *Khaya senegalensis* and *Khaya ivorensis* plants, accounting for more than 50% of the total accumulated in the plants with added nutrient solution. As regard the irrigation intervals, both irrigation every day and two days produced the highest values of Zn in different plant organs in comparison with the other treatments. On other hand, irrigation every 4 days caused reduction in Zn roots, branches and leaves content. The highest values of Zn were achieved when using (45 g / plant) with irrigation every day, while the lowest ones (11.35, 6.25 and 6.03 mg/kg) for roots, branches and leaves, respectively, when plants were irrigated daily.

Table 5: Effect of irrigation intervals and sulphur fertilization on Zn content (mg/kg) of *Khaya senegalensis* plants at the end of study

	Irrigation intervals														
Treatments	Roots Zn (mg/kg)					Branches Zn (mg/kg)					Leaves Zn (mg/kg)				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M
Control	34.51d	28.94ef	17.44hi	11.35k	23.06C	14.74cd	12.28d	9.58e	6.25f	10.71B	15.13cd	13.93cd	10.07e	6.03f	11.29C
15 g /seedling	46.55bc	42.45c	24.30f	14.24ik	31.89B	18.85bc	15.57c	10.52de	6.84f	12.95B	20.14bc	17.92c	11.67de	7.18f	14.23C
30 g /seedling	59.39ab	54.38b	29.04de	19.54gh	40.59A	22.81a	19.38b	13.17cd	7.37ef	15.68A	26.54ab	22.38b	13.54d	8.64ef	17.78B
45 g /seedling	63.58a	58.22ab	33.21d	20.06gh	43.77A	24.64a	21.98b	15.09c	10.98de	18.17A	30.65a	26.99a	16.33c	9.29e	20.82A
M	51.01A	46.00A	26.00C	16.30D		20.26A	17.30A	12.09B	7.86C		23.12A	20.31A	12.90B	7.79C	

Table 6: Effect of irrigation intervals and sulphur fertilization on Mn content (mg/kg) of *Khaya senegalensis* plants at the end of study

	Irrigation intervals														
Treatments	Roots Mn (mg/kg)					Branches Mn (mg/kg)					Leaves Mn (mg/kg)				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M
Control	227.4ef	204.23f	151.36g	114.8h	174.48D	70.98cd	53.41de	41.24ef	30.14f	48.94C	198.25e	146.34g	119.85gh	96.41h	140.21D
15 g /seedling	308.1d	281.52de	204.25f	147.3g	235.32C	88.47c	61.28d	45.65ef	34.66f	57.52C	287.35c	221.74d	171.85fg	137.52g	199.62C
30 g /seedling	389.2b	354.29c	278.34de	202.6f	306.14B	120.68ab	96.36b	56.32de	40.57f	78.48B	385.14b	329.27c	214.25d	180.36ef	277.26B
45 g /seedling	457.3a	429.74a	330.40cd	248.2e	366.45A	161.22a	139.29a	71.68cd	52.39de	106.15A	517.69a	462.88a	281.39cd	202.51e	366.12A
M	345.5A	317.45A	241.09B	178.3C		110.34A	87.59A	53.72B	39.44B		347.11A	290.06A	196.84B	154.20B	

Table 7: Effect of irrigation intervals and sulphur fertilization on S content (mg/kg) of *Khaya senegalensis* plants at the end of study

	Irrigation intervals														
Treatments	Roots S (mg/kg)					Branches S (mg/kg)					Leaves S (mg/kg)				
Sulphur rates	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M	1 day	2 days	3 days	4 days	M
Control	0.24g	0.21gh	0.17h	0.15h	0.20D	0.22ef	0.18fg	0.11h	0.08h	0.15D	0.39e	0.36ef	0.30g	0.21g	0.32C
15 g /seedling	0.42de	0.38e	0.32f	0.25g	0.34C	0.37c	0.33d	0.26e	0.20f	0.29C	0.48cd	0.44d	0.34f	0.26f	0.38C
30 g /seedling	0.58b	0.53c	0.46d	0.32fg	0.47B	0.49ab	0.44b	0.35cd	0.29de	0.39B	0.57b	0.54bc	0.46d	0.33fg	0.48B
45 g /seedling	0.67a	0.64a	0.48cd	0.41de	0.55A	0.54a	0.50a	0.45b	0.40bc	0.47A	0.73a	0.70a	0.63b	0.55c	0.65A
M	0.48A	0.44A	0.36B	0.28C		0.41A	0.36A	0.29B	0.24C		0.54A	0.51A	0.43B	0.34C	

Manganese (Mn) Content: Data presented in Table (6) indicated that, the highest values of roots, branches and leaves Mn content were recorded by using sulphur fertilization at the rate of 45 g (366.45, 106.15 and 366.12 mg/kg), respectively. The same data showed significant decrease in Mn content in control treatments (0.20, 0.15 and 0.32 mg/kg), respectively during the study period. As regard irrigation intervals, irrigation every 3 and 4 days significantly reduced Mn content as compared the other treatments. Regarding the interaction between two study factors, irrigation every 4 days without addition of sulpher gave the lowest values for Mn content in different plant organs.

Sulphur (S) Content: It is obvious from data presented in Table (7) that, using of a high rate of sulfur fertilization (45g /plant) increased the absorption rate of S and increased its content in roots, branches and leaves content (0.55, 0.47 and 0.65 mg/kg), respectively as compared to the control treatment (81.17, 128.54 and 152.12 mg/kg). Regarding the irrigation intervals, there were significant differences between irrigation every one or two days in comparison with the other treatments. As regard the interaction between the two factors, irrigation every one day with S-application of (45g /plant) gave the highest values of sulphur content (0.67, 0.54 and 0.73 mg/ kg) for roots, branches and leaves, respectively.

The above-mentioned results may be due to that the S (Sulphur) element may be involved the biosynthesis of the heavy metal detoxification agents, such as glutathione (GSH), non-protein thiols (NPTs), Cd-sulfide crystallites and Phytochelatins (PCs) [34].

Recommendations: Irrigation with wastewater every two days leads to save half the amount of water used for irrigation than every day.

Using sulfur fertilization at the rate of (45g/seedling) for increasing the amount of absorption from heavy metals and get the highest vegetative growth characteristics of *Khaya senegalensis* plants.

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