

GROWTH STUDY OF SOME LOCAL AND EXOTIC TIMBER TREE SPECIES IRRIGATED WITH TREATED WASTE WATER

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By
M. I. Bahnasy

*Forestry and Timber Trees Department, Horticultural Research Institute,
Agricultural Research Center, Giza, Egypt.*

ABSTRACT

This study was carried out in the Serapium Forest Plantation, Ismailia Governorate, Egypt during 2015-2018 seasons to study the response of certain tree species to treated waste water. The tree species that have been tested are *Khaya senegalensis*, *Swietenia mahagoni*, *Azadirachta indica*, *Tectona grandis*, *Pongamia pinnata*, *Casuarina equisetifolia*, *Gmelina arborea* and *Corymbia citriodora*. After three years of planting, the tallest plants were *C. citriodora*, followed by *C. equisetifolia* and *Gmelina arborea*. However, the highest increment in the diameter of trees was in *C. citriodora*, followed by *G. arborea* and *C. equisetifolia* in the first ranking. While, the smallest increase in number of branches was in *C. citriodora* as compared to the other tested species. The highest specific gravity value of wood was in *C. citriodora* followed by *P. pinnata*. For the fiber length, *C. equisetifolia* followed by *K. senegalensis* and *P. pinnata* resulted the highest values compared to other tree species. In respect of the accumulation of nickel (Ni) in the leaves, the highest values were obtained by *C. equisetifolia* and in the stem, the highest value in *K. senegalensis*, while *G. arborea* trees gave the highest values of nickel in the root. Concerning the accumulation of lead (Pb) in the leaves, the highest values was noticed with *S. mahagoni*, while in the stem was in *K. senegalensis*, and in the root, the highest value was in *C. equisetifolia* and *S. mahagoni*. It can be concluded from the herein study that using treated waste water in irrigating woody trees was more effective and associated with increment of growth parameters sequence producing healthy trees and enhanced both of specific gravity and fiber length. On the other hand, it is evident that cultivating timber trees irrigated by waste water can be used as phytoremediation by absorbing the heavy metals such as Ni, Pb and Cd which are not recommended in irrigation of the edible plants. It is possible to say that the trees under study can grow under the irrigation conditions of the treated waste water, and also expand their cultivation in the afforestation programs in Egypt for their environmental, economic and aesthetic importance, in particular the trees of *Corymbia citriodora*, *Casuarina equisetifolia*, *Gmelina arborea*, *Khaya senegalensis*, and *Swietenia mahagoni*.

Key words: *timber trees, treated wastewater, growth measurements, specific gravity, fiber length, heavy metals.*

1.INTRODUCTION

The use of treated and untreated waste water in irrigation for biomass production has several advantages besides the mitigation of pollution in the ecosystem (Juwarkar *et al.*, 1995). Significant increase in growth performance in plant-height, branches, root length and the biomass were recorded in *Casuarina equisetifolia* saplings irrigated with untreated municipal raw sewage and treated sewage compared to that irrigated with unpolluted potable water over a period of 13 months (Kumar and Reddy, 2010).

In recent times, the danger of pollution of important water sources in Egypt, whether Nile water or groundwater, is highlighted by the increase in human activities, whether from industrial drainage or sewage. The safe and beneficial disposal of wastewater is to be used in irrigation and the establishment of important tree forests. The use of sewage water in the irrigation of trees is a common practice for many years. Woody trees reduce the environmental degradation of the soil because the trees are long-lived and can absorb and retain small elements of soil, water and air for a long time.

Woody trees also create opportunities to produce biomass and the retention of excess minerals within the plant. Therefore, the use of waste water in irrigation of the artificial forests is a viable option for the economic disposal of wastewater.

The quality of the environment (such as water, air, and soil), micro-organism activities, plant growth, etc. is affected by heavy metal pollutants. Woody trees represent an excellent way to store minerals because of rapid growth, high biomass, widespread roots and little impact on human health (Patel *et al.*, 2015).

The tree species differ in their ability to get rid of heavy metals. In this regard, a study (Yang *et al.*, 2011) was conducted using 12 species of timber trees for the removal of heavy metals from the soil. Their study showed that juniper and poplar trees were the best for removal of copper, chromium and nickel. *Prunus persica*, *Osmnthus fragrans* and *Sophora japonica* trees were best to get rid of zinc, while *Cedrus deodara* trees were the best to get rid of cadmium and copper.

Azadirachta indica, family Meliaceae, is a small to medium-sized tree, usually evergreen, with a height of 15 m and a diameter of 90 cm., Produces wood that can be manufactured but its fibers are rough and difficult to polish.

Casuarina equisetifolia L., family Casuarinaceae, is an evergreen tree with a height of 35 m. Leaves consist of slender, much-branched green to grey-green twigs 0.5–1 mm in diameter. The wood is used for shingles, fencing, and firewood (Masterson, 2009).

Corymbia citriodora (Hook.), family Myrtaceae, is a tall tree, reach to 35 m in height. It is also known as lemon eucalyptus and *Eucalyptus citriodora*. The volatile oil of the tree mainly consists of citronellal (80%). Unrefined oil is used in perfumery and in insect repellents. It is an important forest tree used for structural timber and honey production (Atal and Kapur, 1982 and Rodriguez *et al.*, 2015).

Gmelina arborea Roxb, family Verbenaceae, is a moderately sized to large deciduous tree with a straight trunk. The tree is wide spreading with numerous branches, attains to 30 m in height. The wood produces good-quality pulp, particle board, the manufacture of furniture, matches and timber for light construction (Roshetko *et al.*, 2003).

Khaya senegalensis (Desr.), family, Meliaceae a half- deciduous tree, with a height of 15-30 m and a diameter of more than 1 m.

The tree is resistant to flooding and can be cultivated in wetlands. The tree bears a wide range of soil conditions from neutral to acidic, from clay to sandy coarse soil. The tree produces one of the most important timber in terms of quality and is used on a commercial scale. The specific gravity of wood ranges from 0.60 to 0.85 gm/cm³ according to the site, its wood is resistant to fungus, insects and termites (Maydell, 1986).

Pongamia pinnata (L.) Pierre, family, Fabaceae a medium-sized tree that is evergreen or deciduous for a brief period, up to 15-25 m in height and 50-80 cm in diameter. The tree habitat is humid and subtropical environments. It is resistant to saline and alkaline conditions. Oil is the most important product of the tree and large quantities of seed are produced in India for industrial purposes (Daniel, 1997).

Swietenia mahagoni (L.) Jacq., family Meliaceae, is a long tree, up to 30 m height and up to 1 m in diameter, with abundant branches and gives a heavy shade. It is a deciduous tree in drought-prone areas. The heart wood is very resistant to decay and insect infestation, which makes it a favorite for other mahogany types in world markets. It produces the finest quality wood and introduces the best quality, cabinetwork, joinery, boats and pattern work (Orwa *et al.*, 2009).

Tectona grandis L. family Verbenaceae, is a large deciduous tree with a height of 30 m in preferred growth conditions and a diameter of more than 1 m. It produced a medium-weight timber, moderately soft and has a distinctive appearance. The heartwood is often light yellow at the beginning of the cut and then turns into a dark brown color. The wood has an oily texture and has a leather odor (Katende *et al.*, 1995).

Therefore, the aim of the present work was to study the effect of irrigation with treated waste water on the growth characteristics and chemical components of the above-mentioned trees to determine the most suitable of these tree species and expand their cultivation on waste water in Egypt.

2. MATERIAL AND METHODS

The experiment was carried out at Serapium forest located in North Eastern of Egypt (C 30 28 49.14 N – 32 13 29.86 E) within the Governorate of Ismailia to define the best growth characteristics of certain timber trees irrigated with treated waste water.

2.1. Experimental Design

One-year-old seedlings of *Swietenia mahagoni*, *Tectona grandis*, *Gmelina arborea*, *Khaya senegalensis*, *Azadirachta indica*, *Corymbia citriodora*, *Pongamia pinnata* and *Casuarina equisetifolia* were planted in the field in 2015 season. Seedlings of all species were of the same age, were planted at 2.5 x 2.5 m spacing and irrigated with dripp irrigation system; uniform tree seedlings for all inducted species were selected on the basis of height and stem diameter, ranged average (30-40cm for height and 0.5-0.6 cm for stem diameter). The experiment was carried out using a complete randomized design where each species contains three replicates and each replicate contains 12 plants.

2.2. Growth measurements

The total height (m), diameter at 50% of total height (cm) at the first year from planting and diameter at breast height (DBH) (cm) at second and third year, number of branches and survival % of each tree species were measured at one, two and three years from planting (2016, 2017 and 2018). At the end of the experiment, leaves sample was dried and ground to pass through a 1 mm sieve for analyses of N, P and K. Nitrogen (N %) was determined using the Kjeldahl method. Potassium (K %) was determined by flame photometry, while Phosphorus (P %) was determined by using colorimetric determination according to the methods described by (Cottenie *et al.* 1982). Moreover, heavy metals (ppm) Cd, Pb and Ni in roots, leaves and stems were determined by atomic absorption spectrophotometer after acidifying with nitric acid according to (Brandifeld and Spincer, 1965).

2.3. Specific gravity and fiber length determinations

For determination of specific gravity (gm/cm³) a disc was cut from each tree, then a small specimen was cut from each disk at dimensions of 2 x 2 x 2 cm³; specific gravity was recorded as a green volume by displacement in water and oven-dry weight method. Meanwhile, wood samples of fiber length (mm) measurements were taken; specimens were prepared and measured as mentioned by Franklin (1945).

2.4. Soil and water analysis

Soil chemical properties were determined before and after the experiment; soil samples were randomly collected from two depths (0-30 and 30-60 cm) by digging profiles and analyzed

according to Page *et al.* (1982) as shown in Table (1). The chemical characteristics of treated wastewater as shown in Table (2) were analyzed by using the methodology described in APHA, (1998).

2.5. Statistical analysis

Data were statistically analyzed and means were performed by the new L.S.D. test at 5% level as described by Snedecor and Cochran (1980).

Table (1): Chemical analysis of the soil before and after using of treated waste water for the tested tree species.

Soil Properties	Before planting		After planting	
	Depth			
	0-30 (cm)	30-60 (cm)	0-30 (cm)	30-60 (cm)
pH	7.00	7.03	7.03	7.03
S.P.%	21.00	20.30	22.30	22.50
EC (dS/m)	1.07	1.74	3.07	1.08
Soluble anions (meq/l)				
CO ₃	-	-	-	-
HCO ₃	2.35	1.20	8.82	2.35
Cl	1.79	3.58	9.84	2.68
SO ₄	5.26	10.30	11.00	5.00
Soluble cations (meq/l)				
Ca	2.46	3.69	4.30	1.84
Mg	1.46	0.23	3.05	1.10
Na	4.76	10.63	20.50	6.75
K	0.72	0.53	1.81	0.34

Table (2):Chemical analysis of the treated waste water used for irrigation in the current study.

No.	Parameter	Value
1	TSS (mg l ⁻¹)	28.6
2	pH	7.68
3	TDS (mg l ⁻¹)	620
4	BOD (mg l ⁻¹)	48.3
5	NH ₄ -N (mg l ⁻¹)	23.6
6	Total P (mg l ⁻¹)	2.89
7	EC (dsm ⁻¹)	1.63
8	Pb (ppm)	1.03
9	Ni (ppm)	0.05
10	Cd (ppm)	0.07
11	Cr (ppm)	0.09

3. RESULTS AND DISCUSSION

3.1. Effect of irrigation with waste water on the growth of seedlings at the age of 1, 2 and 3 years from establishment

Table (3) shows the effect of irrigation using treated wastewater on the growth characteristics of the studied tree species during three years of cultivation. There were significant differences between tree species in total height, stem diameter, number of branches and survival percentage of trees. *C. citriodora*, *C. equisetifolia*, *G. arborea* trees were the most common tree species in response to irrigation with treated waste water, where the results indicated that significant increases in height and diameter were obtained compared with the other trees species after one, two or three years from planting.

Data in Table (3) indicated that the total height of *C. citriodora* significantly increased (2.32, 7.13 and 8.97 m) after one, two and three years from planting, respectively, as compared with the other tree species, followed by *C. equisetifolia*, *G. arborea* trees. While *P. pinnata* was the lowest in total height (0.75, 1.54 and 2.01 m, respectively) after one, two and three years from planting, as compared with the other tree species.

Concerning the stem diameter, data in Table (3) show significant differences among tree species. *G. arborea* and *C. citriodora* recorded the highest value of root collar diameter (3.31 and 3.24 cm) after one year from planting as compared with the other tree species, and *C. citriodora* gave the highest diameter at breast height (6.53 and 8.00 cm) after two and three years after planting, respectively. While *A. indica* and *S. mahagoni* gave the lowest values in root collar diameter (1.53 and 1.66 cm) after one year from planting. On the other side, the lowest value of diameter at breast height was in *P. pinnata* and *S. mahagoni* (1.11 and 1.39 cm) after two years from planting, but were 2.20 and 2.39 cm, after three year from planting respectively.

As regard to branches number, data presented in Table (3) illustrated that the highest number of branches exhibited in *K. senegalensis* tree (4.24 branches/ plant) after three years from planting as compared with other tree species. While the lowest values were in *C. citriodora*, *S. mahagoni* and *C. equisetifolia* (1.77, 2.04 and 2.11 branches/ plant respectively), after three years from planting. However, the highest percentage of survival were recorded with *C. citriodora*, *A. indica* and *G. arborea* (97.29,

Table (3): Effect of irrigation with treated waste water on the growth characteristics after one, two and three years from establishment of certain tree seedlings (2016, 2017 and 2018 seasons).

Tree species	Total height (m)			Stem diameter(cm)			Branches number/tree			Survival %		
				Root collar diameter	Diameter at breast height (DBH)							
	1 st	2 nd	3 th	1 st	2 nd	3 th	1 st	2 nd	3 th	1 st	2 nd	3 th
<i>Khaya senegalensis</i>	0.72	1.63	2.62	2.60	1.91	3.07	1.33	2.76	4.24	81.67	79.17	72.92
<i>Swietenia mahagoni</i>	0.76	1.75	2.51	1.66	1.39	2.39	0.67	1.47	2.04	81.76	79.17	72.08
<i>Azadirachta indica</i>	0.93	2.73	3.62	1.53	2.17	3.49	1.33	2.79	2.87	94.00	93.75	93.75
<i>Tectona grandis</i>	0.79	2.08	2.55	2.06	1.95	2.69	1.00	2.31	2.68	78.33	77.08	67.71
<i>Pongamia pinnata</i>	0.75	1.54	2.01	2.12	1.11	2.20	1.33	2.51	2.57	88.33	85.42	75.00
<i>Casuarina equisetifolia</i>	1.64	3.40	4.82	2.22	2.44	4.06	0.67	1.85	2.11	91.67	89.58	87.50
<i>Gmelina arborea</i>	1.21	3.39	4.22	3.31	3.51	5.48	1.00	2.19	2.26	94.33	93.75	92.50
<i>Corymbia citriodora</i>	2.32	7.13	8.97	3.24	6.53	8.00	0.67	1.63	1.77	98.00	97.92	97.29
<i>New L.S.D at (0.05)</i>	0.10	0.21	0.31	0.40	0.35	0.46	0.60	0.24	0.35	5.54	5.02	5.44

93.75 and 92.50% respectively) after three years from planting, as compared with other tree species. While, the lowest percentage of survival was in *T. grandis* (78.33, 77.08 and 67.71%) after one, two and three years from planting, respectively, as compared with other tree species.

Growth parameters of eight tree species were evaluated for selecting the trees that can withstand irrigation by using treated wastewater and can be cultivated as man made forests. For *C. citriodora*, *C. equisetifolia* and *G. arborea* trees, treated with waste water had a positive effect on height and diameter compared to that of the other species. However, for the number of branches, the highest number was observed from *K. senegalensis* and *A. indica* trees, while *C. citriodora*, *A. indica* and *G. arborea* trees were the highest percentage of survival. It can be said that some tree species had the most ability to grow and to withstand the conditions of irrigation with treated waste water (Cornelissen *et al.* 1997; Adrover *et al.*, 2008 and Ghorab *et al.*, 2017).

3.2. Effect of irrigation with wastewater on the specific gravity and fiber length

It is obvious from data in Table (4) that, the highest mean values of specific gravity for the tested woody trees as response to irrigation with wastewater was resulted in *C. citriodora* (0.58 g/cm³), *P. pinnata* (0.57 g/cm³) and *C. equisetifolia* (0.54 g/cm³), while the lowest values were obtained by *A. indica* and *T. grandis* (0.42 g/cm³). Also, the same Table pointed out that, maximum fiber length (1.11, 1.09 and 1.08mm) were recorded in *C. equisetifolia*, *K.*

Table (4): Effect of irrigation with treated wastewater on specific gravity (g/cm³) and fiber length (mm) of wood three years from establishment of certain tree seedlings.

Tree species	Specific gravity (g/cm ³)	Fiber length (mm)
<i>Khaya senegalensis</i>	0.47	1.09
<i>Swietenia mahagoni</i>	0.50	0.69
<i>Azadirachta indica</i>	0.42	0.84
<i>Tectona grandis</i>	0.42	0.96
<i>Pongamia pinnata</i>	0.57	1.08
<i>Casuarina equisetifolia</i>	0.54	1.11
<i>Gmelina arborea</i>	0.45	0.82
<i>Corymbia citriodora</i>	0.58	1.01

senegalensis and *P. pinnata*, under treated wastewater irrigation, respectively, while minimum fiber length were obtained in *S. mahagoni* (0.69 mm) and *G. arborea* (0.82 mm).

Although high- density is preferred where high- strength lumber products are required, it must be recognized that density varies considerably within a given species (Paul, 1963). Fiber length influences were much more important in manufacture the pulp where the paper properties such as tearing resistance is related to fiber length. Pulp and paper properties, including tear resistance and tensile, fold and burst strength. In most cases, long lengths are desirable, Maeglin *et al.* (1977). No significant differences were observed for the specific gravity and fiber length of wood produced from seedlings irrigated by primary treated waste water compared with well water (Al-Mefarrej, 2013). Specific gravity of *Leucaena leucocephala* seedlings was not affected by waste water irrigation (Klem, 1968), however, waste water at 50% concentration increased fiber length of those seedlings (Hassan and Ali, 2013).

3.3. Effect of irrigation with wastewater on the leaves contents of N, P and K

Data in Table (5) indicated the leaves content of N, P and K for 8 tested trees as response to irrigation with treated wastewater. There were differences among tree species. The highest mean values of nitrogen content were recorded with *G. arborea*, *C. citriodora* and *C. equisetifolia* trees (2.82, 2.69 and 2.54%, respectively). Meanwhile, the lowest values of nitrogen were resulted from *P. pinnata* and *T. grandis* (1.33 and 1.60%, respectively). The leaves of *C. equisetifolia* and *C. citriodora*

Table (5): Effect of irrigation with treated wastewater on nitrogen, phosphorus and potassium (%) in leaves three years from establishment of certain tree seedlings.

Tree species	N %	P%	K%
<i>Khaya senegalensis</i>	2.02	0.25	1.16
<i>Swietenia mahagoni</i>	1.86	0.27	1.20
<i>Azadirachta indica</i>	2.39	0.35	1.14
<i>Tectona grandis</i>	1.60	0.20	0.77
<i>Pongamia pinnata</i>	1.33	0.22	0.97
<i>Casuarina equisetifolia</i>	2.54	0.52	0.82
<i>Gmelina arborea</i>	2.82	0.37	1.35
<i>Corymbia citriodora</i>	2.69	0.50	1.25

contained higher phosphorus than that of all the other species (0.52 and 0.50 % respectively). While, *T. grandis* and *P. pinnata* trees produced the lowest values (0.20 and 0.22%, respectively). The content of K in *G. arborea* and *C. citriodora* leaves were more than that of the other species (1.35 and 1.25 %, respectively). While, *T. grandis* and *C. equisetifolia* resulted in the lowest value of K content in their leaves (0.77 and 0.82 %, respectively).

Some of the species, such as *G. arborea*, *C. citriodora* and *C. equisetifolia* trees, contained more nitrogen compared to the other species, while *C. equisetifolia* and *C. citriodora* were greater in phosphorus than all the other species. K content in *G. arborea* and *C. citriodora* leaves was more than that of the other species. Mineral content was differed among species in leaves, stems, and roots. Nitrogen content in leaves was higher in deciduous than in evergreen species (Cornelissen *et al.*, 1997). However, the choice of tree species based on growth and absorption of elements is important for the purification of treated waste water by the tree plantations (Hooda, 2007). Quantity of nutrients absorbed by plants depends on its quantity in the treated waste water, soil qualities and plant species (Bozkurt and Yarılgı, 2003).

3.4. Effect of irrigation with wastewater on Ni, Pb and Cd (ppm) accumulation:

Regarding the heavy metal contents in leaves (Table 6) *C. equisetifolia*, *A. indica* and *S. mahagoni* trees under treated waste water irrigation contained the highest values of nickel (Ni ppm) contents, (0.87, 0.84 and 0.77 ppm,

respectively), while minimum contents were obtained in *T. grandis* and *P. pinnata* (0.43 and 0.51 ppm, respectively) in their leaves. Mean values showed that *S. mahagoni*, *K. sengalensis* and *C. citriodora* with irrigation by treated wastewater contained maximum lead contents (4.74, 4.32 and 4.25 ppm, respectively). Meanwhile, *T. grandis* and *P. pinnata* leaves contained the lowest values of lead (2.42 and 2.64 ppm, respectively). Three years from establishment, the highest values of cadmium were recorded in *S. mahagoni*, *A. indica* and *C. citriodora* (0.27, 0.24 and 0.24 ppm, respectively). While the minimum values were obtained in *T. grandis* and *P. pinnata* leaves (0.11 and 0.12 ppm, respectively).

Mean values of Ni, Pb and Cd accumulation in stem regarding the tested tree species showed that, *K. sengalensis* and *P. pinnata* contained the highest and the lowest values, respectively (Table 7). Also, in the same Table the values of the heavy metals accumulated in the tree stems can be arranged in descending order as follows: lead followed by nickel and cadmium. Maximum nickel (Ni ppm) content was recorded in *K. sengalensis*, *C. equisetifolia* and *G. arborea* (1.15, 0.93 and 0.89ppm, respectively), while the lowest values were recorded in *P. pinnata* (0.53 ppm). Maximum lead (Pb ppm) contents were recorded in *K. sengalensis*, *C. citriodora* and *G. arborea* (6.14, 4.47 and 3.84 ppm, respectively). While minimum contents were obtained in *P. pinnata* and *C. equisetifolia* (2.90 and 2.95 ppm, respectively). However, mean values of cadmium (Cd ppm) in stem revealed that *K. sengalensis* and *G. arborea* attained the highest

Table (6): Effect of irrigation with treated waste water on the heavy metals accumulation in leaves three years from establishment of certain tree seedlings (ppm).

Tree species	Ni	Pb	Cd
<i>Khaya sengalensis</i>	0.75	4.32	0.23
<i>Swietenia mahagoni</i>	0.77	4.74	0.27
<i>Azadirachta indica</i>	0.84	3.34	0.24
<i>Tectona grandis</i>	0.43	2.42	0.11
<i>Pongamia pinnata</i>	0.51	2.64	0.12
<i>Casuarina equisetifolia</i>	0.87	3.08	0.23
<i>Gmelina arborea</i>	0.71	2.76	0.20
<i>Corymbia citriodora</i>	0.76	4.25	0.24

Table (7): Effect of irrigation with treated waste water on the heavy metals accumulation in stem three years from establishment of certain tree seedlings (ppm).

Tree species	Ni	Pb	Cd
<i>Khaya sengalensis</i>	1.15	6.14	0.41
<i>Swietenia mahagoni</i>	0.63	3.48	0.19
<i>Azadirachta indica</i>	0.86	3.69	0.25
<i>Tectona grandis</i>	0.58	3.76	0.17
<i>Pongamia pinnata</i>	0.53	2.90	0.16
<i>Casuarina equisetifolia</i>	0.93	2.95	0.22
<i>Gmelina arborea</i>	0.89	3.84	0.27
<i>Corymbia citriodora</i>	0.84	4.47	0.22

contents (0.41 and 0.27 ppm, respectively). While *P. pinnata* and *T. grandis* contained the lowest one (0.16 and 0.17 ppm, respectively).

It is clear from data in Table (8) that, *G. arborea*, *A. indica* and *S. mahagoni* trees contained maximum nickel (Ni) in their roots (0.95, 0.92 and 0.81 ppm, respectively) as compared to the other species, while *T. grandis* and *P. pinnata* contained minimum values (0.60 and 0.64 ppm, respectively). *C. equisetifolia*, *S. mahagoni* and *K. sengalensis* trees contained the highest values of lead (Pb) in their roots (4.64, 4.14 and 4.03 ppm, respectively) after three years from establishment compared to the other species, while *P. pinnata* and *T. grandis* containe the lowest one (2.90 and 2.96 ppm, respectively). The maximum values of cadmium contents in the roots were recorded in *A. indica*, *G. arborea* and *S. mahagoni* (0.26, 0.26 and 0.24 ppm, respectively). While the minimum values were found in *T. grandis* and *P. pinnata* trees (0.15 and 0.17 ppm, respectively). The potential of using irrigation with treated wastewater for increasing biomass production in forest is considerable (Sopper and Kerr, 1979). However heavy metals absorption was affected by tree species, tree age and its concentrations in the soil. The potential problems that have been recognized in connection with the disposal of using sewage effluent for agricultural lands are the accumulation of heavy metals in the soil and plants (Elsokkary and El-Keiy, 1988). However, these problems depend mainly on the composition of the sewage, frequency of application, soil properties and plant species (Verma *et al.*, 1999). Alloway (1995) revealed that heavy metals are more mobile at acid

Table (8): Effect of irrigation with treated waste water on the heavy metals accumulation in roots three years from establishment of certain tree seedlings (ppm).

Tree species	Ni	Pb	Cd
<i>Khaya sengalensis</i>	0.71	4.03	0.21
<i>Swietenia mahagoni</i>	0.81	4.14	0.24
<i>Azadirachta indica</i>	0.92	3.84	0.26
<i>Tectona grandis</i>	0.60	2.96	0.15
<i>Pongamia pinnata</i>	0.64	2.90	0.17
<i>Casuarina equisetifolia</i>	0.73	4.64	0.22
<i>Gmelina arborea</i>	0.95	3.60	0.26
<i>Corymbia citriodora</i>	0.79	3.97	0.23

conditions and the increasing of pH by liming reduced their bioavailability. Also, Waly *et al.* (1987) reported that available and total heavy metals in soils showed significantly correlation with the organic matter in the soil. Planting timber trees species is very important to utilization of wastewater and for phytoremediation of heavy metals in short period of time if heavy metals can be control from different industries. Also the results showed that *Cupressus sempervirens* trees gave the highest translocation factor (TF) of Zn and Cd from root to stem and *Eucalyptus camaldulensis* trees were increased significantly with (TF) from root to stem of Mn and Ni as compared with *Corymbia citriodora* and *Pinus halepensis* (Ghorab *et al.*, 2012).

Conclusion

Through this study, it can be concluded that, such important tree species can be cultivated under irrigation conditions by using treated waste water and expanded it in the different afforestation programs in Egypt because of their adaptability to the Egyptian environmental conditions, biomass production, phytoremediation, economic and aesthetic importance, especially *C. citriodora*, *C. equisetifolia*, *G. arborea*, *K. sengalensis* and *S. mahagoni* trees.

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دراسة نمو بعض أنواع الأشجار الخشبية المحلية والمستوردة المروية بمياه الصرف الصحي المعالج

مجدي اسماعيل بهنسي

قسم بحوث الأشجار الخشبية والغابات – معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة – مصر

ملخص

أجريت هذه الدراسة لمدة ثلاث سنوات علي ثمانية أنواع شجرية منزرعه بالغابة الشجرية بسراييوم – محافظه الاسماعيلية – مصر بهدف اختيار أفضل هذه الأنواع تحملا لظروف النمو في مثل هذه المنطقة المروية بمياه الصرف الصحي المعالج أوليا بنظام الري بالتنقيط . كانت الأنواع الشجرية المستخدمة هي : الكايا السنغالي: – الماهوجنى بورق رفيع – النيم – التيك – البنجاميا – الكازورينا – المالينا والكافور الليمونى. وكانت أهم النتائج مايلي:
تفوقت أشجار الكافور الليمونى، يليها الكازورينا ثم المالينا فى طول الأشجار مقارنة بباقي الأنواع الشجرية . وبالنسبة لقطر الأشجار أظهرت أشجار الكافور الليمونى يليها المالينا و الكازورينا أعلى القيم الخاصة بقطر الساق وكانت اشجار الكافور الأليمونى اقل تفريرا مقارنة بباقي الأنواع. بخصوص بعض صفات الخشب، كانت أعلى قيم للكثافه النوعيه فى حالة أشجار الكافور الليمونى يليها أشجار البنجاميا، أما بالنسبة لطول الليفة ، اعطت أشجار الكازورينا يليها الكايا السنغالى والبنجاميا اعلي القيم. وبخصوص امتصاص الأشجار للمعادن الثقيلة ، فكان أعلى محتوى للنیکل فى الأوراق فى حالة أشجار الكازورينا ، وفى السيقان كانت القيم العالية فى أشجار الكايا السنغالى، أما فى الجذور فكانت أشجار المالينا متفوقة فى محتواها من النیکل. وبالنسبة لمحتوى الأشجار من الرصاص، أظهرت أشجار الماهوجنى بورق رفيع أعلى القيم فى أوراقها، كما أظهرت أشجار الكايا السنغالى أعلى محتوى من الرصاص فى سيقانها، بينما احتوت جذور الكازورينا ثم الماهوجنى بورق رفيع أعلى كمية من الرصاص مقارنة بباقي الأنواع. يمكن استنتاج انه من خلال الدراسه الحاليه فان استخدام مياه الصرف الصحي المعالج في ري الاشجار كان اكثر تأثيرا في الزيادة في صفات النمو وانتاج اشجار صحيه وزياده الكثافه النوعيه وطول الالياف ومن ناحيه اخري فانه يمكن استخدام الاشجار الخشبيه في الصرف البيولوجي حيث تعمل علي امتصاص العناصر الثقيله مثل الرصاص والنيكل والكاديوم . وعليه يمكن القول بأن الأشجار موضع الدراسة يمكنها النمو تحت ظروف الري بمياه الصرف الصحي المعالج مبدئيا، وأيضا التوسع فى زراعتها فى برامج التشجير بمصر لأهميتها بيئيا واقتصاديا وجماليا، وبصفة خاصة أشجار الكافور الليمونى والكازورينا والمالينا والكايا السنغالى والماهوجنى بورق رفيع.

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