Appl Water Sci (2012) 2:101–108
DOI 10.1007/s13201-012-0027-4

ORIGINAL ARTICLE

Growth, chemical composition and soil properties of *Tipuana speciosa* (Benth.) Kuntze seedlings irrigated with sewage effluent

Hayssam M. Ali · Mohamed H. Khamis · Fatma A. Hassan

Received: 25 March 2011 / Accepted: 2 February 2012 / Published online: 6 March 2012

Abstract This study was carried out at a greenhouse of Sabahia Horticulture Research Station, Alexandria, Egypt, to study the effect of sewage effluent on the growth and chemical composition of *Tipuana speciosa* (Benth.) Kuntze seedlings as well as on soil properties for three stages. The irrigation treatments were primary-treated wastewater and secondary-treated wastewater, in addition to tap water as control. Therefore, the treated wastewater was taken from oxidation ponds of New Borg El-Arab City. Results of these study revealed that the primary effluent treatment explored the highest significant values for vegetative growth and biomass, compared to the other treatments. In addition, the higher significant concentration and uptake of chemical composition in different plant parts were obtained from the primary effluent treatment during the three stages of irrigation. It was found that the concentration of heavy metals in either plant or soil was below as compared to the world-recommended levels. These findings suggested that the use of sewage effluent in irrigating *T. speciosa* seedlings grown in calcareous soil was beneficial for the improvement of soil properties and production of timber trees, and also important for the safe manner of disposal of wastewater.

Keywords Irrigation · Sewage effluent · Vegetative growth · Chemical composition · Soil properties · Heavy metals · *Tipuana speciosa* (Benth.) Kuntze

H. M. Ali (✉)
Botany and Microbiology Department, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia
e-mail: Hayssam77@hotmail.com

H. M. Ali · M. H. Khamis · F. A. Hassan
Timber Trees Research Department, Sabahia Horticulture Research Station, Horticulture Research Institute, Agriculture Research Center, Alexandria, Egypt

Introduction

In many arid and semi-arid countries, water is becoming a scarce resource which must be used economically and effectively to promote further development. At the same time, with the population expanding at a high rate, the need for increased agricultural production is apparent.

Many countries have included wastewater reuse as an important dimension of water resources planning. Many communities have practised excreta reuse and effluent reuse for hundreds of years and it is part of their culture. The quality of river water used in some irrigation projects is such that reuse of human and animal waste is continually taking place, albeit in an uncontrolled fashion. Rapid increases in population and industrial growth have led to more treatments of wastewater in order to reduce pollution and protect receiving waters. It is then a natural progression to seek direct reuse of this treated effluent for lower grade purposes, such as irrigation.

Irrigation of forest species, used for fuel and timber, with wastewater is an approach that helps overcome health hazards associated with sewage farming. Growing green belts around the cities with forest trees under wastewater irrigation also helps in renewal of the ecological balance and improves environmental quality by self-treatment of wastewater through the application and forest irrigation.

The use of primary and secondary effluents in irrigation can improve the quality of soil and plant growth, because they are considered as natural conditioners through their nutrient elements and organic matter. However, the direct application of wastewater on agricultural land is limited by the extent of contamination with heavy metals, toxic organic chemicals and pathogens (Salem et al. 2000; Sebastiani et al. 2004; EL-Sayed 2005; Singh and Bhati 2005).

Tipuana speciosa (Benth.) Kuntze (rosewood) is one of the true mahoganies. It is a large tropical tree with heavy-weight woods and, also, is one of the most valuable timber trees. Rosewood is extremely strong, hard, stable and decay resistant. This wood is used for decorative veneers, interiors and pattern making, as well as in shipbuilding and interiors of fine boats.

As available data on the use of sewage for irrigating forest trees of Egypt are limited, this study aims to explore the effects of irrigation with sewage effluent on the vegetative growth and chemical composition of *T. speciosa*, as well as the chemical properties of the planted soil.

Materials and methods

This study was carried out at a greenhouse in the nursery of Timber Trees Research Department, Sabahia Horticulture Research Station, Alexandria, Egypt, to investigate the effects of sewage effluent on vegetative growth, chemical composition of *Tipuana speciosa* (Benth.) Kuntze and chemical properties of planted soil throughout three stages (8, 16 and 24 months after treatment).

One-year-old seedlings of *T. speciosa* (Benth.) Kuntze were used for this study so that they averaged 28 cm in height and 3.6 mm in diameter (at 5 cm from the soil surface). Moreover, two types of sewage effluents were used to irrigate the seedlings, after 1 month from planting: primary- and secondary-treated wastewaters that were taken from oxidation ponds of a sewage effluent treatment station in New Borg El-Arab City, Alexandria. The sewage effluent contains a mixture of domestic and industrial sources. On the other hand, tap water was used as control treatment. The analysis of the used water in irrigation is shown in Table 1; Table 2 demonstrates the physical and chemical analysis of the planting soil. The tree seedlings were irrigated to field capacity to standardize the irrigation rate for the three treatments.

Trace elements in samples were analyzed using atomic absorption spectrophotometer. Soluble N was determined by the Kjeldahl method (Page et al. 1982). Soluble P was determined by the ascorbic acid molybdenum blue method (Watanabe and Olsen 1965). Dissolved oxygen (DO) was determined by the azide modification of Winkler method and chemical oxygen demand (COD) by dichromate oxidation method. Five-day biochemical oxygen demand (BOD_5) was determined from the amount of oxygen lost after incubation for 5 days in the dark at 20°C (APHA 1995).

At the end of each stage (8, 16 and 24 months), three seedlings from each treatment were chosen randomly to measure the parameters of vegetative growth and chemical composition of leaves, shoots and root. Otherwise, at the end of each stage, soil samples were taken from each treatment to measure their chemical properties according to Page et al. (1982). Heavy metals (Cd, Fe, Ni, Pb, Cu, Mn and Zn) were extracted by DTPA and then measured in solution by atomic absorption spectrophotometer (Lindsay and Norvell 1978).

Table 1 Average of water composition used in irrigation treatments in the experiment

Parameter	Sewage effluent		Tap water	Limits of wastewater for agric. reuse (FAO 1992)
	Primary treatment	Secondary treatment		
pH	6.82	7.56	6.80	6.50–8.40
E.C ds/m	1.60	2.96	0.68	3.00–7.00
Soluble cations (meq/L)				
Ca^{2+}	2.83	3.34	1.10	–
Mg^{2+}	2.21	3.31	1.90	–
K^+	0.23	0.26	0.20	–
Na^+	11.95	16.75	2.60	–
Soluble anions (meq/L)				
CO_3^-	–	–	–	–
HCO_3^-	4.63	5.00	2.00	1.50–8.50
Cl^-	8.41	9.34	3.80	–
DO (mg/L)	0.00	2.90	–	–
BOD5 (mg/L)	220	100	–	40–500
COD (mg/L)	402	311	–	80–600
TSS (mg/L)	1024	1894	–	–
Soluble N (ppm)	1.25	1.08	0.26	–
Soluble P (ppm)	0.38	0.33	0.01	–
Total heavy metals (ppm)				
Cd	0.02	0.01	0.007	0.01
Cu	0.14	0.19	0.009	0.20
Mn	0.06	0.05	0.014	0.20
Ni	0.02	0.01	0.002	0.20
Pb	0.25	0.24	0.02	5.00
Zn	1.86	1.07	0.09	2.00
Fe	12.5	8.60	0.26	5.00

Statistical analysis

The design of the experiment was completely randomized. The three treatments were replicated three times, and each repetition contained four seedlings. The mean values among all treatments were compared by Duncan's multiple range test, according to Snedecor and Cochran (1968).

Results and discussion

Vegetative growth

Significantly, the application of sewage effluent treatments increased all vegetative growth parameters compared with tap water treatment (Table 3). Primary effluent significantly

Table 2 Physical and chemical analyses of soil

Parameter	Mean
Practical size distribution	
Sand (%)	70.00
Silt (%)	20.00
Clay (%)	10.00
Soil texture	Sandy loam
pH	8.31
E.C (ds/m)	2.42
$CaCO_3$ (%)	32.04
Organic matter (%)	0.62
Soluble cations (meq/L)	
Ca^{2+}	5.58
Mg^{2+}	6.15
Na^{+}	14.25
K^{+}	0.74
Soluble anions (meq/L)	
CO_3^{-}	–
HCO_3^{-}	8.30
Cl^{-}	9.10
SO_4^{-}	9.42
Available P (ppm)	4.60
Available N (ppm)	7.28
DTPA—extractable heavy metals (ppm)	
Cd	0.00
Cu	0.77
Mn	1.44
Ni	1.11
Pb	2.13
Zn	0.89
Fe	3.10

Table 3 Effect of sewage effluent on vegetative growth parameters and leaves biomass of *Tipuana speciosa* at the three stages

Treatments	Periods (months)					
	8	16	24	8	16	24
	Plant height (cm)			Stem diameter (mm)		
Tap water	53.00c	87.75c	211.25c	6.13c	12.33c	19.40c
Primary effluent	89.75a	144.75a	338.75a	14.23a	20.82a	35.75a
Secondary effluent	69.00b	117.25b	302.50b	9.33b	16.93b	30.00b
	Leaves number/plant			Leaf area/leaf (cm^2)		
Tap water	11.50c	11.66c	44.25c	188.47c	202.64c	265.71c
Primary effluent	22.75a	39.00a	138.25a	257.19a	285.94a	337.65a
Secondary effluent	17.00b	26.00b	116.50b	211.65b	239.51b	296.29b
	Leaves fresh weight (g/plant)			Leaves dry weight (g/plant)		
Tap water	5.61c	13.99c	86.83c	1.00c	6.03c	36.91c
Primary effluent	34.34a	116.53a	282.14a	7.53a	35.60a	108.46a
Secondary effluent	17.05b	48.03b	239.62b	4.29b	16.97b	94.98b

Mean followed by a similar letter within a column is not significantly different at the 0.05 level probability by Duncan's multiple range test

increased vegetative growth parameters by around 1.5-fold more than secondary effluent treatment throughout the three stages (8, 16 and 24 months).

The plant heights of *T. speciosa* seedlings irrigated with the primary effluent increased by 69.34, 64.96 and 60.00% more than those with tap water at the 8-, 16- and 24-month stages, respectively, whereas for the seedlings irrigated with secondary effluent, they were 30.19, 33.62 and 43.20% more than those with tap water treatment through the three stages, respectively. Consequently, plant heights of the seedlings that were irrigated with primary effluent increased by 1.3-, 1.2- and 1.1-fold after 8, 16 and 24 months, respectively, more than the seedlings irrigated by the secondary effluent.

The same was observed in the stem diameters after 8, 16 and 24 months for the seedling that were irrigated with the primary effluent: they were thicker by 132.14, 66.86 and 84.28%, respectively, more than those with tap water treatment (Table 3). Furthermore, secondary effluent increased stem diameter of the seedlings by 52.20, 37.31 and 54.64% more than control for the 8, 16 and 24 months stages, respectively. On the other hand, the stem diameters of the seedlings that were irrigated with the primary effluent increased by 1.5-fold after 8 months and 1.2-fold after both 16 and 24 months more than the seedlings irrigated by the secondary effluent.

The leaf numbers per plant of *T. speciosa* were counted when the seedlings were irrigated with the primary effluent and were recorded as 97.83, 234.48 and 212.43% more than those with tap water for the 8-, 16- and 24-month stages, respectively, while the seedlings that were irrigated with secondary effluent significantly recorded 47.83, 122.98 and 163.28% more than with tap water for the 8-, 16- and 24-month stages, respectively. It was clear that leaf numbers of the seedlings that were irrigated with primary effluent were 1.3-, 1.5- and 1.2-fold more than those irrigated with the secondary effluent.

Tipuana speciosa seedlings that were irrigated with the primary effluent significantly had the largest leaf area (36.46, 41.11 and 31.53% for 8, 16 and 24 months, respectively) more than control, whereas the leaf areas of the seedlings irrigated with the secondary effluent were 12.30, 18.19 and 15.42% more than the control for the three stages, respectively. Data in Table 3 indicate that the leaf area of the seedlings irrigated with the primary effluent was increased by 1.2-fold after both 8 and 16 months and 1.1-fold after 24 months more than the seedlings irrigated by the secondary effluent.

Table 4 Effect of sewage effluent on the shoots and roots biomass, shoot/root ratio and root length of *Tipuana speciosa* at three stages

Treatments	Periods (months)					
	8	16	24	8	16	24
	Shoots fresh weight (g/plant)			Shoots dry weight (g/plant)		
Tap water	9.06c	37.38c	162.62c	1.71c	12.11c	82.03c
Primary effluent	50.33a	192.75a	659.75a	17.27a	88.35a	343.00a
Secondary effluent	28.80b	98.34b	472.28b	7.18b	43.03b	238.44b
	Roots fresh weight (g/plant)			Roots dry weight (g/plant)		
Tap water	14.33c	18.97c	72.78c	3.69c	8.32c	39.73c
Primary effluent	50.31a	83.76a	243.82a	19.37a	28.31a	114.28a
Secondary effluent	32.19b	45.93b	152.93b	7.86b	16.37b	73.40b
	Root length (cm)					
Tap water	85.75a	100.50a	120.50a			
Primary effluent	80.75a	91.75az	117.00a			
Secondary effluent	72.00a	85.50a	108.75a			

Mean followed by a similar letter within a column is not significantly different at the 0.05 level probability by Duncan's Multiple Range Test

The fresh weights of the leaves of the *T. speciosa* seedlings irrigated with primary effluent were the heavier by 512.12, 732.95 and 224.93% more than those with tap water at the 8-, 16- and 24-month stages, respectively, while for the seedlings irrigated with the secondary effluent, they were 203.92, 243.32 and 175.96% more than those with tap water treatment through the same three stages, respectively. Consequently, leaves fresh weights of the seedlings that irrigated with primary effluent were folded by 2.0, 2.4 and 1.2 after 8, 16 and 24 months, respectively, more than the seedlings irrigated by secondary effluent. Similar trend was observed in the leaves dry weights after 8, 16 and 24 months for the seedling that irrigated with primary effluent where they were heavier by 653.00, 490.38 and 193.85%, respectively, more than tap water treatment (Table 3). In addition, secondary effluent increased leaves dry weights of the seedlings by 329.00, 181.43 and 157.33% more than control for 8, 16 and 24 months stages, respectively. On the other hand, leaves dry weights of the seedlings that irrigated with primary effluent were folded by 1.8, 2.1 and 1.1 after 8, 16 and 24 months more than the seedlings irrigated by secondary effluent.

Shoots fresh weights of *T. speciosa* seedlings which irrigated by primary effluent were the heaviest by 455.52, 415.65 and 305.70% more than tap water for 8, 16 and 24 months stages, respectively. While, they were 217.88, 163.08 and 190.42% more than tap water treatment throughout the same three stages, respectively, for the seedlings that irrigated with secondary effluent. Hence, shoots fresh weights of the seedlings which irrigated by primary effluent were folded by 1.7, 2.0 and 1.4 after 8, 16 and 24 months, respectively, more than the seedlings irrigated by secondary effluent. The dry weights of shoots had similar trend after 8, 16 and 24 months for the seedling which irrigated by primary effluent where they were heavier by 915.88, 629.56 and 318.14%, respectively, more than tap water treatment (Table 4). Also, secondary effluent increased shoots dry weights of the seedlings by 322.35, 255.33 and 190.67% more than control for 8, 16 and 24 months stages, respectively. On the other hand, shoots dry weights of the seedlings that irrigated with primary effluent were folded by 2.4, 2.1 and 1.4 after 8, 16 and 24 months more than the seedlings irrigated by secondary effluent.

These results explained by many investigators, who found that sewage effluent had stimulation effect on vegetative growth of trees, provided the soil with plant nutrients and organic matter as well as improved the physical properties of the soil, that reflected on the growth by enhancing either the cell elongation and division (Kaneker et al. 1993 on *Acacia nilotica*; Hassan Fatma et al. 2002 on *Acacia saligna* and *Leucaena leucocephala*; Berbec et al. 1999 on poplar; Guo and Sims 2000 on *Eucalyptus globules;* Abbaas 2002 on *Casuarina glauca, Taxodium distichum* and *Populus nigra;* Bhati and Singh 2003 on *Eucalyptus camaldulensis;* EL-Sayed 2005 on *Ceratonia siliqua*, *A. saligna* and *Acacia stenophylla*, and Singh and Bhati 2005 on *Dalbergia sissoo*).

Root characteristics

Table 4 exhibited that roots weights of *T. speciosa* had the same trend of the leaves and shoots along the three investigated stages (Table 4). Therefore, roots fresh weights of the seedlings that irrigated with primary effluent were the heaviest by 251.08, 341.54 and 235.01% more than tap water for 8, 16 and 24 months stages, respectively. While, they were 124.63, 142.12 and 110.13% more than tap water treatment through the same three stages, respectively, for the seedlings that irrigated with secondary effluent. Hence, roots fresh weights of the seedlings that irrigated with primary effluent were folded by 1.6, 1.8 and 1.6 after 8, 16 and 24 months, respectively, more than fresh roots of the seedlings irrigated by secondary effluent.

The same trend was detected in the roots dry weights after 8, 16 and 24 months for the seedling that irrigated with primary effluent where they were heavier by 424.93, 240.26 and 187.64%, respectively, more than tap water treatment (Table 4). Also, secondary effluent increased roots dry weights of the seedlings by 113.01, 96.75 and 84.75% more than control for 8, 16 and 24 months stages, respectively. Further, roots dry weights of the seedlings that irrigated with primary effluent were folded by 2.5, 1.7 and 1.6 after 8, 16 and 24 months more than dry roots of the seedlings irrigated by secondary effluent.

In contrast, secondary effluent treatment gave the shortest roots length (16.03, 14.93 and 9.75% less than tap water treatment for 8, 16 and 24 months stages, respectively). Consequently, it followed by primary sewage effluent treatment (5.83, 8.71 and 2.90% less than tap water treatment for 8, 16 and 24 months stages, respectively). This action could be explained by the accumulation of soluble salts and heavy metals in root zone, as a result of applying sewage effluent, which might adverse root elongation. This results are in harmony with these of Nessel et al. (1982) on Pond cypress, Hopmans et al. (1990) on *E. camaldulensis* and *Pinus radiata*, Gogate et al.(1995) on *Tectona grandis*, Hassan Fatma et al. (2002) on *Albizzia lebbek, Taxodium distichum* and *T. speciosa* and Ali et al. (2011) on *Swietenia mahagoni*.

Data of the root characteristics are in agreement with those of Sebastiani et al. (2004) on poplar and EL-Sayed (2005) on *Ceratonia siliqua*.

Chemical composition

Generally, irrigation with primary effluent gave the highest concentrations of N, P, k, Cd, Ni, Pb and Fe in leaves, shoots and roots of *T. speciosa* followed by secondary effluent treatment (Tables 5, 6).

As well as, the concentrations of N, P and K in leaves were much higher than that of shoots and roots. The increase of N, P, K, Cd, Ni, Pb and Fe in plant parts might be attributed to increasing them in the occupancy root zone from applying sewage effluents, which reflected on their uptake by roots.

These results are agreed with the findings of Singh and Bhati (2005) who found that concentrations of N, P and K were greater in foliage compared to the other plant parts. In contrary heavy metals (Cd, Ni, Pb and Fe) tended to be accumulated in root rather than in both leaves and shoots with few exceptions. When irrigation stage enlarged from 8

Table 5 Effect of sewage effluent on N, P and K percentage and total uptake of leaves (L), shoots (S) and roots (R) of *Tipuana speciosa* at three stages

Treatments	Periods (months)											
	8			16			24			8	16	24
	L	S	R	L	S	R	L	S	R			
	N (%)									Total N uptake (g plant^{-1})		
Tap water	0.92c	0.52c	0.57c	0.94c	0.68c	0.66c	0.59b	0.59c	0.54b	0.04c	0.19c	0.92c
Primary effluent	2.09a	1.49a	1.51a	1.82a	1.49a	1.23a	1.92a	1.14a	1.15a	0.71a	2.31a	7.31a
Secondary effluent	1.77b	1.24b	1.24b	1.22b	0.88b	0.96b	1.57a	0.93b	0.95a	0.26b	0.74b	4.41b
	P (%)									Total P uptake (g/plant)		
Tap water	0.34b	0.32c	0.26c	0.22b	0.17b	0.19b	0.21b	0.18b	0.22c	0.03c	0.05c	0.31c
Primary effluent	0.52a	0.54a	0.57a	0.46a	0.22a	0.30a	0.76a	0.52a	0.54a	0.24a	0.44a	3.23a
Secondary effluent	0.47a	0.41b	0.45b	0.37a	0.20ab	0.19b	0.45b	0.36a	0.40b	0.08b	0.18b	1.58b
	K (%)									Total K uptake (g/plant)		
Tap water	0.87b	0.75b	0.42c	0.79b	0.63b	0.43c	0.70b	0.48b	0.46c	0.04c	0.16c	0.83c
Primary effluent	1.39a	0.87a	0.70a	1.16a	0.80a	0.76a	1.23a	0.83a	0.73a	0.39a	1.33a	5.02a
Secondary effluent	0.97b	0.79b	0.56b	0.90	0.73ab	0.58b	0.95b	0.57b	0.60b	0.14b	0.56b	2.70b

Mean followed by a similar letter within a column is not significantly different at the 0.05 level probability by Duncan's Multiple Range Test

Table 6 Effect of sewage effluent on Cd, Ni, Pb and Fe percentage and total uptake of leaves (L), shoots (S) and roots (R) of *Tipuana speciosa* at three stages

Treatments	Periods (months)											
	8			16			24			8	16	24
	L	S	R	L	S	R	L	S	R			
	Cd (ppm)									Total Cd uptake (mg/plant)		
Tap water	0.27b	0.30c	0.57c	0.05b	0.03b	0.06c	0.06b	0.21b	0.22b	0.01c	0.01b	0.03c
Primary effluent	2.83a	2.23a	3.37a	2.60a	1.93a	2.70a	1.96a	1.70a	1.90a	0.13a	0.34a	1.01a
Secondary effluent	0.90b	1.10b	1.87b	0.80b	1.00ab	1.06b	0.56b	1.33a	0.90b	0.03b	0.07b	0.44b
	Ni (ppm)									Total Ni uptake (mg/plant)		
Tap water	12.33c	8.67b	15.33c	14.33c	11.33c	11.67c	10.33c	9.33b	11.66c	0.08c	0.32c	1.61c
Primary effluent	43.33a	37.33a	46.67a	134.33a	117.00a	136.00a	151.33a	126.33a	159.00a	1.87a	18.97a	77.91a
Secondary effluent	31.67b	28.33a	35.33b	98.33b	95.66b	92.67b	114.33b	102.33a	119.66b	0.62b	7.30b	44.04b
	Pb (ppm)									Total Pb uptake (mg/plant)		
Tap water	38.00c	31.00c	39.00c	43.66c	36.33c	36.66c	42.00c	24.33c	31.67b	0.23c	1.01c	4.80c
Primary effluent	122.33a	114.33a	170.00a	131.33a	114.33a	147.00a	150.67a	135.66a	155.33a	6.19a	18.94a	80.62a
Secondary effluent	90.67b	95.33b	111.67b	105.66b	84.67b	81.33b	102.33b	77.33b	162.67a	1.95b	6.77b	40.10b
	Fe (ppm)									Total Fe uptake (mg/plant)		
Tap water	195.67c	147.67c	246.67b	148.67c	95.33b	130.00c	106.67c	93.33c	111.67c	1.36b	3.13c	16.03c
Primary effluent	405.00a	398.67a	530.00a	356.67a	323.33a	370.00a	359.33a	303.33a	346.67a	20.26a	51.74a	182.63a
Secondary effluent	232.33b	242.33b	320.00b	223.33b	174.33b	240.00b	280.00b	213.33b	250.00b	5.25b	15.22b	95.81b

Mean followed by a similar letter within a column is not significantly different at the 0.05 level probability by Duncan's Multiple Range Test

to 24 months, the uptakes of N, P, K, Cd, Ni, Pb and Fe in the whole plant were increased due to enormity increase of vegetative growth. Similarly, EL-Sayed (2005) found that irrigation with secondary effluent increased N, P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, Pb, Cd, Cr and Ni in leaves, stems and roots of *Ceratonia siliqua*, *A. saligna* and *A. stenophylla* compared with tap water.

After 24 months, the magnitude of increase of heavy metals in the whole plant due to primary effluent treatment ranged from 2 to 9 times more than tap water for Cd, Ni, Pb and Fe.

Soil characteristics

Data in Table 7 revealed that soil salinity in terms of electrical conductivity of saturated paste (EC), $CaCO_3$ (%), organic matter (%) and soluble anions and cations were influenced by both primary and secondary effluent treatment. Where, pH value slightly changed by irrigation with sewage effluent. EC values of soil treated with sewage effluent were related to EC values of irrigation water treatment therefore, EC of soil treated with tap water was decreased to 1.50 and 1.44 ds/m after 16 and 24 months of irrigation, respectively. While EC of soil treated with secondary and primary effluent were ranged between 2.76 and 3.48 ds/m, respectively. However, the soluble cations and anions had the same trend of EC of soil except for Ca^{2+} and SO_4^{-}.

It is clear, from Table 7, that irrigation with primary sewage effluent decreased the $CaCO_3$ content from 32.26 to 31.04 and 29.15% for primary sewage effluent treatments after 8, 16 and 24 months, respectively, of irrigation stage. This is probably due to the fact that same $CaCO_3$ was dissolved by the organic acids present in sewage and leached down in soil.

Furthermore, organic matter content increased with irrigation stage was extended from 8 to 16 then 24 months, with higher values for primary effluent compared with secondary (5, 14 and 22% for former stages, respectively). Likewise, available P and N were also maximized more by primary effluent treatment compared to secondary effluent, while tape water gave the lowest values. In addition, it is clear that available P and N were accumulated more as stage of irrigation was extended from 8 to 16 then 24 months.

The results are agree with those of EL-Nennah et al. (1982) who found that use of sewage effluent in irrigation resulted in remarkable change of organic matter, available

Table 7 Means of effect of sewage effluent on the soil properties of *Tipuana speciosa* plantation at three stages

Parameter	8 months			16 months			24 months		
	Tap water	Primary effluent	Secondary effluent	Tap water	Primary effluent	Secondary effluent	Tap water	Primary effluent	Secondary effluent
pH	8.19	8.37	8.00	8.14	8.08	8.05	8.08	8.30	8.33
E.C (ds/m)	2.51	2.60	3.14	1.50	2.76	3.40	1.44	2.95	3.48
$CaCO_3$ (%)	30.26	32.26	31.15	28.48	31.04	30.26	27.26	29.15	30.15
Organic matter (%)	0.64	0.89	0.84	0.67	1.08	0.94	0.67	1.20	0.98
Ca^{2+} (meq/L)	5.15	6.60	3.60	3.90	3.96	3.24	5.88	3.60	3.60
Mg^{2+} (meq/L)	4.40	4.65	2.18	3.13	3.52	3.39	4.22	3.96	3.00
Na^{+} (meq/L)	15.00	20.00	8.75	20.15	27.50	8.75	20.00	28.50	23.50
K^{+} (meq/L)	0.64	0.93	0.48	0.68	0.68	0.30	0.54	0.54	0.62
CO_3^{-} (meq/L)	–	–	–	–	–	–	–	–	–
HCO_3 (meq/L)	2.32	3.98	3.36	2.98	3.65	3.98	4.81	5.81	5.15
Cl^{-} (meq/L)	12.59	18.51	5.10	15.94	18.20	6.92	14.01	19.11	18.20
SO_4^{-} (meq/L)	12.28	9.69	6.65	8.79	13.81	4.78	11.73	11.68	7.97
Available P (ppm)	0.80	6.30	4.40	1.80	8.50	5.20	1.00	9.20	5.90
Available N (ppm)	7.00	13.40	11.20	7.30	21.20	15.12	5.40	22.52	17.60
DTPA: extractable heavy metals (ppm)									
Cd	–	0.07	0.03	–	0.09	0.05	–	0.05	0.01
Fe	3.10	2.98	3.64	3.28	3.40	3.44	3.10	3.12	4.66
Ni	1.11	1.52	6.70	5.10	1.62	6.21	4.10	1.92	5.87
Pb	2.13	2.50	7.96	6.87	2.42	6.50	6.54	2.21	6.32
Cu	0.77	0.57	0.71	0.69	0.66	0.68	0.66	0.59	0.54
Mn	1.44	1.44	1.8	1.62	0.81	0.72	0.66	0.66	0.52
Zn	0.89	0.72	1.54	1.16	0.74	1.50	1.10	0.68	1.42

P and total and soluble N which might have been added to soils upon irrigation.

Extractable-heavy metals

Results given in Table 7 show that DTPA-extractable Cd, Cu, Ni and Pb increased as irrigation stage increased by sewage effluent treatments compared to tap water therefore, the primary effluent treatment gave the greater values (0.05, 0.59, 1.92 and 2.21 ppm for above-mentioned metals, respectively, after 24 months. Whereas, the response of extractable Fe, Mn and Zn were not consistent for different sewage effluent treatments.

Many investigators stated that heavy metals accumulated in soil resulted from continuous irrigation with sewage effluent (EL-Nennah et al. 1982; Abulroos et al. 1996; Salem et al. 2000). This increment of heavy metals in soil and consequently in edible parts of field crop plant should be considered, which adversely affect human and animal health through the food chain. It would be great advantage to grow forest trees such as *T. speciosa* in heavily polluted areas or soil irrigated with sewage effluent without serious problems.

References

Abbaas MM (2002) Effect of some heavy metals in the irrigation water on growth and chemical constituents of some timber trees. PhD Thesis, Faculty of Agriculture Cairo University

Abulroos SA, Holah ShSh, Badawy SH (1996) Background levels of some heavy metals in soil and corn in Egypt. Egypt J Soil Sci 36:83–95

Ali HM, EL-Mahrouk EM, Hassan Fatma A, EL-Tarawy MA (2011) Usage of sewage effluent in irrigation of some woody tree seedlings. Part 3: *Swietenia mahagoni* (L.) Jacq. Saudi J Biol Sci 18(2):201–207. doi:10.1016/j.sjbs.2010.08.001

APHA (1995) Standard methods for the examination of water and waste water, 19th edn. APHA-AWWA-WPCF, Washington DC, pp 4–85, 4–137

Berbec S, Szewczuk C, Sugier D (1999) The effect of irrigation with municipal sewage on the catching and growth rate of poplar trees. Folia Univ Agric 77:27–31

Bhati M, Singh G (2003) Growth and mineral accumulation in *Eucalyptus camaldulensis* seedlings irrigated with mixed industrial effluent. Bioresour Technol 88:221–228

EL-Nennah M, EL-Kobbia T, Shehata A, EL-Gamal I (1982) Effect of irrigation loamy sand soil by sewage effluents on its content of some nutrients and heavy metals. Plant Soil 65:289–292

EL-Sayed NAA (2005) The impact of irrigation with treated wastewater effluent on soil bio-physicochemical properties and on growth and heavy metals content of some fodder trees grown on calcareous soil. PhD Thesis, Faculty of Agriculture, Tanta University

Gogate MG, Farooqui UM, Joshi VS (1995) Sewage water as potential for the tree growth: a study on teak (*Tectona grandis*) plantation. Indian For 121(6):472–481 (CAB.Abst. 1996, 0601478)

Guo LB, Sims REH (2000) Effect of meat works effluent irrigation on soil, tree biomass production and nutrient uptake in *Eucalyptus globulus* seedlings in growth cabinets. Bioresour Technol 72:243–251

Hassan Fatma A, EL-Juhany LI, EL-Settawy AA, Shehata MS (2002) Effects of irrigation with sewage effluent on the growth of some forest trees species, physical and chemical properties of the soil. In: Proceeding of the second conference "sustainable agricultural development" 8–10 May Fayoum, pp 300–311

Hopmans P, Stewart HT, Flinn DW, Hillman TJ (1990) Growth, biomass production and nutrient accumulation by seven tree species irrigated with municipal effluent at Wodonga, Australia. For Ecol Manag 30:203–211

Kaneker P, Kumbhojkar MS, Ghate V, Sarnaik S, Kelkar A (1993) Evaluation of *Acacia nilotica* (L.) DEL. and *Casuarina equisetifolia* forest for tolerance and growth on microbially treated dyestuff wastewater. Environ Pollut 81:47–50

Lindsay WL, Norvell WA (1978) Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci Soc Am J 42:421–428

Nessel JK, Ewel KC, Burnett M (1982) Wastewater enrichment increases mature Pond cypress growth rates. For Sci 28(2): 400–403

Page AL, Miller RH, Keeny DR (1982) Methods of soil analysis, part II. 2nd edn. Agronomy Monogr. ASA and SSSA, Medison

Salem MM, El-Amir S, Abdel-Aziz SM, Kandil MF, Mansour SF (2000) Effect of irrigation with sewage water on some chemical characteristics of soils and plant. Egypt J Soil Sci 40:49–59

Sebastiani L, Scebba F, Tognetti R (2004) Heavy metal accumulation and growth responses in poplar clones eridano (*Populus deltoides* × *maximowiczii*) and I–214 (*P.* × *euramerilana*) exposed to industrial waste. Environ Exp Bot 52:79–88

Singh G, Bhati M (2005) Growth of *Dalbergia sissoo* in desert regions of western India using municipal effluent and the subsequent changes in soil and plant chemistry. Bioresour Technol 96:1019–1028

Snedecor GW, Cochran WG (1968) Statistical methods, 6th edn. The Iowa State University Press, Ames

Watanabe FS, Olsen SR (1965) Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci Soc Am J 22:677–678