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Reducing the Potential Environmental Impacts of Nile Tilapia (*Oreochromis niloticus* L.) Culture Effluents Through its Use in the Irrigation of Desert Willow (*Chilopsis linearis* (Cav.) Sweet) Seedlings

[1]*Amira F.Y. El-Kady and* [2]*Ashraf Soluma*

[1]Department of Ornamental Horticulture, Faculty of Agriculture, Cairo University, Giza, Egypt
[2]Department of Animal Production, Faculty of Agriculture, Cairo University, Giza, Egypt

Abstract: Environmental impacts of aquaculture effluents are substantial and may lead to ecosystem changes. This study explores the possibility of reducing the dire environmental impacts of various Nile tilapia (*Oreochromis niloticus* L.) culture effluents via reusing it as an irrigation and a fertilizer sources for desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings. Nile tilapia culture effluents with varying components (low and high chicken manure (Ch. M.) fertilizers and low and high nitrogen and phosphorus (NP) mineral fertilizers) were used. The effluents effects were assessed through the comparison between seedlings irrigated with the previous effluents and those irrigated with fresh water (contol), in addition to seedlings fertilized with nitrogen, phosphorus and potassium (NPK) added directly to the soil. Details of evaluating the vegetative growth (plant height, stem diameter, leaves, shoots and roots number/plant and leaves, shoots and roots fresh and dry weights (F.W. and D.W.)), leaves chemical constituents (pigments content, total macro and micro nutrients and total carbohydrates) and soil chemical properties (pH, EC, organic matter and residual nutrients loading (total macro and micro nutrients)) are included. This pot experiment was conducted at the experimental area of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt, during two successive seasons, 2010 and 2011. The effluents were taken from tilapia ponds and used directly for irrigation at the rate of 700 ml pot^{-1}, twice week^{-1}. The data reveal that NPK mineral fertilization treatment was superior to other treatments in improving desert willow seedlings growth and leaves chemical constituents, followed by tilapia culture effluents with: high Ch. M., high NP, low Ch. M. and low NP, when compared to the control. Moreover, soil chemical properties were also influenced by previous treatments. The present study points out that usage of different types of tilapia culture effluents in irrigating desert willow seedlings is an economic way for disposing the effluents and holds promise for making irrigation much profitable, a valuable source for fertilization and soil amendment and a mean to minimize environmental impacts.

Key words: Integrated agriculture-aquaculture · Tilapia effluents reuse · Desert willow · Environmental impacts · Irrigation · Chicken manure · NPK

INTRODUCTION

Developing nations, many of which are in arid and semiarid climates, are mostly affected by the sharp increase in population [1]. Populated areas require adequate access to fresh water resources, but as populations increase and anthropogenic influences expand, meeting fresh water demands will require a balance between wastewater disposal and water resource protection. Adequate water resource protection is critical as fresh water systems provide multiple environmental services such as supporting numerous species and supplying water for drinking and irrigation. With the combined effect of increasing populations and greater water demand creating larger volumes of wastewater in concentrated areas, sustainability of critical water resources will therefore depend upon effective wastewater managements [2]. Globally, aquaculture is the fastest growing food sector and its economic importance is increasing concomitantly [3-5]. Farmers add many different food-based nutrients to their ponds to produce fish. Higher production can be achieved with greater

Corresponding Author: Amira F.Y. El-Kady, Department of Ornamental Horticulture, Faculty of Agriculture, Cairo University, Giza, Egypt.

amounts of nutrient inputs [4]. When farmers apply larger quantities of nutrients, they tended to discharge more effluents [6]. Aquaculture effluents may contain a variety of constituents include nutrients specially nitrogen (N) and phosphorus (P) [2, 3, 7, 8], dissolved or particulate organics and specific organic or inorganic compounds [7, 8]. Disadvantages of high aquaculture water-exchange rates could cause negative impacts when released into the environment including flushing out nutrients and algae, potential public health risks involved and eutrophication of adjacent surface waters [9]. Issues associated with eutrophication include increased algal biomass, decreased water transparency, low dissolved oxygen (DO) levels, increased fish mortality and more frequent incidences of toxic phytoplankton [2]. The impact on the environment depends on the total amount or concentration released and the assimilative capacity of the environment for the particular constituent [7, 8]. Aquaculturists are continually searching for new ways to produce more fish with less water, land and environmental impact [10]. The goal of best management practices is to make aquaculture environmentally responsible, while considering social and economic sustainability [5].

Integrated agriculture-aquaculture (IAA) systems are often considered a sustainable agricultural model in developing countries [9]. A broader definition of integrated farming includes the use of off-farm resources, such as agro-industrial products and by-products, to enable the farmers to identify unused resources and visualize their use as inputs [1, 4]. When water is used for fish culture and the resulting fertility such as metabolic and solid wastes, fecal matter, algae, uneaten feed, nutrients and organic matter from fish effluents [4, 7, 9-14] are used for plant production and soil amendments, the system is an excellent mean of raising revenues, resource recovery, energy conservation and a cost-effective effluent treatment option that has small environmental impacts [9, 11, 13]. Two types of pond inputs can be distinguished: nutrients and non nutrients. Nutrients are applied in organic (feed, organic fertilizers) and inorganic (inorganic fertilizers) form. Non nutrients include liming materials, pesticides, algaecides, flocculants and medicines [5]. Fertilization pathways in the pond starts from plant waste or manure entering the water, followed by decomposition by pond micro-organisms and the development of natural fish food such as phytoplankton, zooplankton, benthic organisms and detritus [4, 15].

The use of ornamental plants in an integrated system provides a number of potential advantages over the use of agronomic field crops because: (1) effluent quality is not as great concern with ornamental plants, as it would be with food crops, (2) contaminants such as antibiotics used to treat the fish would not be acceptable in a food crop whereas they may be sequestered using ornamental plants, (3) many of these ornamental plants have low nutrient requirements which may be nearly of fully satisfied by aquaculture effluent, (4) ornamental plants have a higher economic value than many field crops and thus provide more potential return and finally (5) this system could have a particular benefit in the production of plant material for land reclamation projects since the ornamental trees are acclimated to desert conditions [11]. Shrubs are important not only for landscape, but also in revegetation of former mining lands and other disturbed areas. They provide the best option for long-term reclamation on many arid sites in some of the desert areas. Shrubs are also valuable for soil stabilization and provide feed for wildlife [11]. Desert willow (*Chilopsis linearis* (Cav.) Sweet), one of family Bignoniaceae members, is a deciduous shrub or small tree that grows in alkaline soils with a pH range of 6–9 and tolerates full sun exposure and drought conditions [16, 17]. It is a long-lived plant which grows abundantly along intermittent desert watercourses in late spring and early summer [18]. *Chilopsis linearis* attain height of 3 to 7.5 m or occasionally more. Its growth can be rapid, up to 1m annually [19]. Desert-willow produces showy zygomorphic flowers on terminal inflorescences between April and August throughout its range [18, 20, 21]. The fruit is a 2-celled capsule about 10 to 30 cm long. It ripens from late summer to late fall and persists through winter. The numerous light-brown oval seeds are about 8 mm long and have a fringe of soft white hairs on each end [22]. The plant is useful for wildlife cover, erosion control, restoration, stream stabilization and ornamental plantings in arid regions. The wood is used for house frames, granaries and bows. The fibrous bark is used for weaving nets, shirts and breechclouts [20].

Based on the previous information and as integration showed success with many edible crops but is still limited for ornamental plants, this research was conducted to: (1) compare different types of Nile tilapia (*Oreochromis niloticus* L.) culture effluents generated by organic and inorganic fertilizers in irrigating desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings, (2) study the effect of Nile tilapia culture effluents on vegetative growth and leaves chemical analysis of desert willow seedlings and (3) quantify the effects of discharged Nile tilapia culture effluents on the soil chemical properties.

MATERIALS AND METHODS

Experimental Design and Treatments: The present investigation was conducted at the experimental area of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt, during two successive seasons, 2010 and 2011. The layout of the experiment was a randomized complete block design with six treatments, each treatment was replicated three times and six seedlings were presented in each replicate. The treatments used were as follows:

Control: Fresh water (tap water) was used in irrigating seedlings.

Nile Tilapia Culture Effluents: four types of Nile tilapia (*Oreochromis niloticus* L.) culture effluents were taken as an irrigation sources. These effluents contained low and high chicken manure (Ch. M.) fertilizers and low and high nitrogen and phosphorus (NP) mineral fertilizers. The Nile tilapia effluents were taken from rectangular concrete ponds (2.2 x 1.2 x 1.0 m) at a static outdoor unit. Ch. M. fertilizers of low and high doses added to tilapia ponds fresh water were 7 and 28g dry matter m^{-3} $week^{-1}$, respectively. NP fertilizers of low and high doses added to tilapia ponds fresh water were 0.55 and 1.65g ammonium nitrate (33% N) m^{-3} $week^{-1}$ as a N source and 0.125 and 0.380g super phosphate (15% P_2O_5) m^{-3} $week^{-1}$ as a P source, respectively. All ponds received supplementary diet (18% crude protein) at a fixed rate of 10.3g diet $pond^{-1}$ day^{-1}, for six days $week^{-1}$. The four types of Nile tilapia culture effluents were entirely used without being filtered in the irrigation process.

Soil NPK Mineral Fertilization: Four doses of a mixed nitrogen (N), phosphorus (P) and potassium (K) mineral fertilizers (1:1:1) were added manually to the pot soil at a rate of 6g pot^{-1} during the study period. These pots were irrigated with fresh water. NPK sources of the fertilizer mixture were ammonium nitrate, super phosphate and potassium sulfate (48% K_2O), respectively.

All pots were irrigated manually to the field capacity at the same time and rate (700 ml pot^{-1}) of the water types, twice $week^{-1}$. Water samples were collected randomly from different sites of the ponds to represent the water of the whole ponds. The average chemical and biological composition of the water types used in irrigation treatments during seasons 2010 and 2011 are shown in Table 1.

Plant and Soil Materials: Desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings were used as plant material. In both seasons, one year old seedlings with an averaged diameter 0.58 cm (measured at 5 cm from the soil surface) were pruned at a height of 40 cm. These seedlings were transplanted in 30 cm plastic pots, filled with 7 kg of washed reused sandy soil (one seedling pot^{-1}). The Average physical and chemical analysis of the used soil during both seasons is shown in Table 2. All seedlings were planted on the first of March in both seasons and were irrigated with fresh water for adaptation, until the first of April in both seasons as the beginning of the experiment occurred.

Vegetative Growth Parameters: On the end of October in both seasons, nine seedlings from each treatment were collected to determine the following vegetative growth

Table 1: Average chemical and biological compositions of water types used in irrigation treatments during seasons 2010 and 2011

	Chemical composition							Biological composition			
Water type	pH	EC (dS m^{-1})	Organic matter (ppm)	DO (ppm)	N (ppm)	P (ppm)	K (ppm)	Total phytoplankton (org l^{-1})	Total zooplankton (org l^{-1})	Secchi disc visibility (cm)	Water temperature (°C)
Fresh water	7.75	0.45	Nd	2.80	Nd	Nd	Nd	Nd	Nd	100.0	26.50
Effluent + low Ch. M.	8.55	0.70	39.16	7.71	3.89	0.21	1.43	15389810	20585	39.50	26.60
Effluent + high Ch.M.	8.53	0.72	46.04	6.03	4.45	0.51	1.52	24475770	7315	28.95	27.40
Effluent + low NP	8.24	0.73	42.01	5.75	3.85	0.19	1.35	14331892	8835	40.50	27.31
Effluent + high NP	8.22	0.75	54.28	6.50	4.20	0.23	1.40	16665769	12719	26.00	26.80

Table 2: Average physical and chemical analysis of the soil used during seasons 2010 and 2011

Physical analysis							Chemical analysis					
Particle size distribution (%)												
Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt + Clay	Soil texture	pH	EC (dS m^{-1})	Organic matter (%)	N (%)	P (%)	K (%)
9.10	27.00	36.80	18.40	6.50	2.20	Sandy	8.48	4.40	0.24	0.05	0.01	0.02

parameters: plant height (cm), stem diameter (cm), leaves, shoots and roots number/plant (root samples were washed thoroughly with tap water) and fresh and dry weights (F.W. and D.W.) of leaves, shoots and roots (g plant^{-1}) (plant samples were dried at 65°C to a constant weight for approximately 48h).

Chemical Analyses

Leaves Chemical Analyses: Pigments content: total carotenoids, chlorophyll (Chl. *a*, *b* and total Chl. *a* +*b*) (mg g^{-1}) were colorimetrically determined during the two seasons using the spectrophotometer, by extracting the fresh leaves samples with acetone 80% according to the method described by Goodwin [23]. Total macro and micro nutrients content: the total macro (NPK) (%) and micro (iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu)) (ppm) nutrients concentration in seedlings leaves for both seasons were measured in the extracts obtained from the powder of the grinded dried leaves samples which were digested using sulfuric and perchloric acids following the procedure described by Chapman and Pratt [24]. The determination was carried out using Inductivity Coupled Spectrometry Plasma (ICP); model Ultima 2- Jobin Yvon, for all nutrients except N which was determined using modified Kjeldahl method. Total carbohydrates content: the powder of the grinded dried leaves samples of both seasons were extracted by sulfuric acid 67% and used for determining total carbohydrates content (%) colorimetrically with the phenol-sulfuric acid method described by Dubois *et al.* [25].

Soil Chemical Properties: At the end of the experiment of the two seasons, soil samples were taken from each treatment pots to determine their chemical properties: pH, EC (dS m^{-1}), organic matter (%) and total macro (N, P and K (%)) and micro (Fe, Mn, Zn and Cu (ppm)) nutrients loading. The pH determination in a 1:1 soil: water suspension was carried out according to McLean [26]. The methodology of soil EC measurements is given in USDA according to Richards [27]. The organic matter was determined by the Walkley-Black procedure as described by Black [28]. Analysis of total nutrients in soil samples were carried out according to A.O.A.C. [29], using Inductivity Coupled Spectrometry Plasma (ICP); model Ultima 2-Jobin Yvon, except for N which was determined using modified Kjeldahl method.

Statistical Analyses: The obtained data of both seasons were statistically analyzed with analysis of variance (ANOVA) as described by Snedecor and Cochran [30], using the MSTAT-C statistical software [31] package based on Duncan's Multiple Range Test to determine the statistical significance of differences in means between treatments as outlined by Waller and Duncan [32]. The probability level of $P \leq 0.05$ was considered significant.

RESULTS AND DISCUSSION

Vegetative Growth Parameters: Results of vegetative growth parameters (plant height, stem diameter, leaves, shoots and roots number/plant and leaves, shoots and roots fresh and dry weights) of desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings as affected by irrigation with different Nile tilapia culture effluents during seasons 2010 and 2011, are presented in Table 3. Application of all irrigation treatments increased significantly all the studied vegetative growth parameters compared to the control. Overall seedlings height increment percentages of all the studied treatments ranged from 44-72% and 43-73% compared to 25 and 23% for the control in the first and second seasons, respectively. Seedlings also showed increment percentages in their stem diameters that ranged from 50-71% in both seasons compared to 36 and 40% for the control in the first and second seasons, respectively. The highest leaves, shoots and roots number/plant were presented by seedlings treated with NPK mineral fertilization followed by seedlings irrigated with tilapia culture effluents containing high Ch. M., high NP, low Ch. M. and low NP fertilizers, respectively in both seasons (values ranged from 1378.50-1711.83, 38.67-48.67 and 43.00-49.00 for leaves, shoots and roots number/plant in the first season and between 1389.00-1704.17, 37.50-49.33 and 42.17-49.67 for leaves, shoots and roots number/plant in the second one) as compared to the seedling irrigated with fresh water (1093.83 and 1100.67, 31.67 and 31.33 and 32.33 and 33.67 for leaves, shoots and roots number/plant in the first and second seasons, respectively). Fresh and dry weights of seedlings leaves, shoots and roots showed also the same trend. Values ranged from 32.55-41.32g, 29.19-41.02 g and 66.67-102.59 g for leaves, shoots and roots F.W, respectively and from 9.61-15.11g, 14.50-21.33g and 26.61-34.61g for leaves, shoots and roots D.W., respectively in the first season. The values ranges in the second season were 31.34-40.17g, 30.14-40.21g and 66.98-100.72g for leaves, shoots and roots F.W, respectively and were 9.81-15.13g, 14.78-20.77g and 26.55-33.95g for leaves, shoots and roots D.W., respectively as compared to the control seedlings (values of the first and second seasons, respectively were 28.24 and 27.67g, 26.40 and 26.64g and 58.55 and 57.31g for leaves, shoots and roots F.W., respectively and 8.83 and 8.81g, 12.58 and 12.95g and 21.62 and 22.14g for leaves, shoots and roots D.W., respectively).

Table 3: Effect of irrigating with different Nile tilapia culture effluents on vegetative growth parameters of *Chilopsis linearis* (Cav.) Sweet seedlings (seasons 2010 and 2011)

	Vegetative growth parameters										
Treatments	Plant height (cm)	Stem diameter (cm)	Leaves number/plant	Shoots number/plant	Roots number/plant	Leaves F.W. (g/plant)	Shoots F.W. (g/plant)	Roots F.W. (g/plant)	Leaves D.W. (g/plant)	Shoots D.W. (g/plant)	Roots D.W. (g/plant)
					2010 season						
Fresh water	49.82 e	0.79 e	1093.83 e	31.67 d	32.33 e	28.24 d	26.40 d	58.55 e	8.83 d	12.58 d	21.62 d
Effluent + low Ch.M	61.18 c	0.88 d	1499.17 c	39.17 c	46.17 c	36.46 b	38.46 b	69.71 c	9.95 bc	19.79 b	27.12 c
Effluent + high Ch.M	66.27 b	0.97 b	1611.83 b	44.17 b	48.83 a	39.95 a	39.57 b	99.26 b	10.16 b	20.42 ab	31.17 b
Effluent + low NP	57.43 d	0.87 d	1378.50 d	38.67 c	43.00 d	32.55 c	29.19 c	66.67 d	9.61 c	14.50 c	26.61 c
Effluent + high NP	65.70 b	0.94 c	1544.50 c	42.83 b	47.50 b	37.53 b	38.92 b	99.10 b	10.02 b	20.22 ab	30.15 b
NPK	68.73 a	0.99 a	1711.83 a	48.67 a	49.00 a	41.32 a	41.02 a	102.59 a	15.11 a	21.33 a	34.61 a
					2011 season						
Fresh water	49.38 e	0.81 d	1100.67 e	31.33 e	33.67 e	27.67 e	26.64 c	57.31 c	8.81 c	12.95 c	22.14 d
Effluent + low Ch.M	60.55 c	0.91 bc	1508.33 c	39.17 c	46.33 c	36.14 c	38.98 a	68.90 b	9.93 b	19.96 a	27.14 c
Effluent + high Ch.M	67.03 b	0.97 ab	1597.50 b	44.83 b	48.50 ab	39.51 ab	39.72 a	99.72 a	10.26 b	20.26 a	32.53 ab
Effluent + low NP	57.38 d	0.87 c	1389.00 d	37.50 d	42.17 d	31.34 d	30.14 b	66.98 b	9.81 b	14.78 b	26.55 c
Effluent + high NP	66.37 b	0.96 ab	1563.67 b	43.50 b	47.50 bc	37.96 b	39.25 a	99.18 a	10.04 b	20.10 a	31.05 b
NPK	69.02 a	0.99 a	1704.17 a	49.33 a	49.67 a	40.17 a	40.21 a	100.72 a	15.13 a	20.77 a	33.95 a

Means followed by similar letter(s) within the same column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test

Table 4: Effect of irrigating with different Nile tilapia culture effluents on leaves chemical analysis of *Chilopsis linearis* (Cav.) Sweet seedlings (seasons 2010 and 2011)

	Leaves chemical analysis											
	Pigments (mg g^{-1})				Total macro nutrients (%)			Total micro nutrients (ppm)				
Treatments	Total carotenoids	Chl. *a*	Chl. *b*	Total chl. *a+b*	N	P	K	Fe	Mn	Zn	Cu	Total carbohydrates (%)
					2010 season							
Fresh water	0.67 d	1.53 e	1.18 c	2.70 e	0.93 c	0.10 e	0.90 e	361.50 b	19.80 e	18.83 e	5.75 c	23.85 c
Effluent + low Ch.M	0.94 bc	1.66 d	1.30 bc	2.96 d	1.07 bc	0.13 d	1.36 cd	529.20 ab	28.63 c	23.60 cd	7.63 bc	26.67 b
Effluent + high Ch.M	1.06 ab	2.10 b	1.48 b	3.57 b	1.34 b	0.15 b	1.52 b	609.00 a	32.82 b	28.63 ab	10.76 b	27.25 ab
Effluent + low NP	0.71 cd	1.63 d	1.22 c	2.85 de	1.04 c	0.12 d	1.31 d	510.60 ab	23.35 d	21.25 de	7.53 bc	26.10 b
Effluent + high NP	1.04 ab	1.82 c	1.42 b	3.24 c	1.14 bc	0.14 c	1.44 bc	598.30 a	30.73 bc	25.92 bc	8.13 bc	26.80 b
NPK	1.19 a	2.89 a	1.95 a	4.84 a	1.82 a	0.17 a	1.70 a	699.85 a	35.75 a	30.85 a	17.15 a	29.20 a
					2011 season							
Fresh water	0.64 c	1.42 e	1.19 d	2.61 e	0.96 d	0.09 f	0.93 d	376.37 d	21.08 d	19.93 e	6.05 c	22.95 c
Effluent + low Ch.M	0.90 bc	1.65 d	1.34 cd	2.99 d	1.05 cd	0.12 d	1.42 bc	486.53 bc	25.94 cd	24.18 cd	7.48 c	25.33 b
Effluent + high Ch.M	1.05 ab	2.07 b	1.51 b	3.58 b	1.27 b	0.15 b	1.50 b	584.73 ab	32.14 ab	28.37 ab	12.52 b	27.35 a
Effluent + low NP	0.68 c	1.65 d	1.32 cd	2.96 d	1.03 cd	0.11 e	1.39 c	476.33 cd	25.08 cd	21.74 de	7.11 c	25.12 b
Effluent + high NP	0.96 ab	1.82 c	1.43 bc	3.25 c	1.09 c	0.13 c	1.47 bc	541.97 bc	29.49 bc	26.22 bc	8.84 c	25.53 b
NPK	1.22 a	2.82 a	1.94 a	4.76 a	1.81 a	0.17 a	1.72 a	677.35 a	36.35 a	29.49 a	20.81 a	28.03 a

Means followed by similar letter(s) within the same column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

Table 5: Effect of irrigating with different Nile tilapia culture effluents on soil chemical properties under *Chilopsis linearis* (Cav.) Sweet seedlings plantation (seasons 2010 and 2011).

	Soil chemical properties									
				Total macro nutrients (%)			Total micro nutrients (ppm)			
Treatments	pH	EC(dS m^{-1})	Organic matter (%)	N	P	K	Fe	Mn	Zn	Cu
					2010 season					
Fresh water	8.38 a	2.11 a	0.23 e	0.05 e	0.01 e	0.02 b	0.33 d	71.75 d	21.00 d	6.73 c
Effluent + low Ch.M	8.14 d	0.99 e	0.44 b	0.10 b	0.05 b	0.04 ab	0.55 b	91.85 bc	31.65 c	9.18 c
Effluent + high Ch.M	8.11 e	1.54 c	0.49 a	0.14 a	0.06 a	0.04 ab	0.69 a	101.85 b	47.35 a	16.70 b
Effluent + low NP	8.35 b	1.24 d	0.32 d	0.06 d	0.03 d	0.04 ab	0.45 c	86.30 c	29.70 c	8.55 c
Effluent + high NP	8.17 c	1.79 b	0.37 c	0.07 d	0.03 d	0.04 ab	0.58 b	99.15 b	38.85 b	14.35 b
NPK	8.15 cd	1.36 cd	0.42 b	0.08 c	0.04 c	0.06 a	0.74 a	118.75 a	50.80 a	20.42 a
					2011 season					
Fresh water	8.37 a	2.22 a	0.26 e	0.05 d	0.01 b	0.01 b	0.29 f	61.55 d	18.40 d	6.01 c
Effluent + low Ch.M	8.13 d	0.84 e	0.46 b	0.10 b	0.04 ab	0.03 b	0.51 d	78.98 c	25.78 bc	8.08 bc
Effluent + high Ch.M	8.08 e	1.60 c	0.53 a	0.12 a	0.05 a	0.04 ab	0.64 b	93.62 b	38.65 a	10.59 ab
Effluent + low NP	8.33 b	1.08 d	0.38 d	0.07 c	0.02 ab	0.03 b	0.42 e	68.15 d	23.30 cd	6.73 bc
Effluent + high NP	8.16 c	1.89 b	0.42 c	0.07 c	0.03 ab	0.03 b	0.57 c	84.10 c	31.98 b	9.64 bc
NPK	8.15 cd	1.44 c	0.44 bc	0.09 b	0.03 ab	0.06 a	0.74 a	106.36 a	43.47 a	14.27 a

Means followed by similar letter(s) within the same column are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

The increment in seedlings vegetative growth as compared to the control may be due to the tilapia culture effluents richness of nutrients especially N and P which may in turn, trigger different responses in plants by enhancing cell elongation and division in addition to increasing amino acids, enzymes, protein, nucleic acids and chlorophyll components of the plant, as compared to fresh water. Results further suggest that, these observed differences in growth parameters may have resulted from different pond inputs of types and levels. In addition, providing the soil with plant nutrients and organic matter through the irrigation treatments with the tilapia culture effluents helped in improving the soil characteristics, which reflected also on the growth. These results are in harmony with the findings of Khan [11] who indicated that irrigating *Artemisia tridentata*, *Atriplex canescens*, *Ceratoides lanata*, *Chrysothamnus nauseosus* and *Cercocarpus montanus* with tilapia effluent without giving any fertilizers was suitable for their production.

Chemical Analyses

Leaves Chemical Analyses: Effects of irrigating with different Nile tilapia culture effluents on leaves chemical constituents (pigments content, total macro and micro nutrients and total carbohydrates) of desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings during seasons 2010 and 2011 are shown in Table 4. Data of the total carotenoids, chl. *a*, *b* and total chl. *a* +*b* exhibited that there were increments obtained in leaves pigments content of seedlings irrigated with all tilapia culture effluents, even though these increments were not as high as those obtained from NPK mineral fertilization treatment, the tilapia culture effluents containing high Ch. M. and high NP fertilizers elevated significantly leaves pigments content values (values of total carotenoids, chl. *a*, *b* and total chl. *a* +*b* were 1.06 and 1.05, 2.10 and 2.07, 1.48 and 1.51 and 3.57 and 3.58 mg g^{-1}, respectively for high Ch. M. and were 1.04 and 0.96, 1.82 and 1.82, 1.42 and 1.43 and 3.24 and 3.25 mg g^{-1}, respectively for high NP in the first and second seasons) to be near leaves pigments content values of NPK mineral fertilization treatment (1.19 and 1.22, 2.89 and 2.82, 1.95 and 1.94 and 4.84 and 4.76 mg g^{-1} for total carotenoids, chl. *a*, *b* and total chl. *a* +*b* in the first and second seasons, respectively) as compared to the control (0.67 and 0.64, 1.53 and 1.42, 1.18 and 1.19 and 2.70 and 2.61mg g^{-1} for total carotenoids, chl. *a*, *b* and total chl. *a* +*b* in the first and second seasons, respectively).

Generally, all treatments carried out on desert willow seedlings affected the concentrations of total macro and micro nutrients content in leaves as compared to the control. Both NPK mineral fertilization treatment and tilapia culture effluent irrigation treatment that contained high Ch. M fertilizer, showed significant increase of all nutrients content in the seedlings leaves when compared to the control. The studied nutrients concentration due to different treatments ranged from 1.04-1.82,1.03-1.81, 0.12-0.17, 0.11-0.17, 1.31-1.70 and 1.39-1.72% for N, P and K and from 510.60-699.85, 476.33-677.35, 23.35-35.75, 25.08-36.35, 21.25-30.85, 21.74-29.49,7.53-17.15 and 7.11-20.81ppm for Fe, Mn, Zn and Cu in the first and second seasons, respectively compared with tap water irrigation treatment (0.93 and 0.96, 0.10 and 0.09 and 0.90 and 0.93% for N, P and K and 361.50 and 376.37, 19.80 and 21.08, 18.83 and 19.93 and 5.75 and 6.05ppm for Fe, Mn, Zn and Cu in the first and second seasons, respectively).

The results also showed that the total carbohydrates content of seedlings supplied with NPK mineral fertilization and effluents of tilapia ponds as the sole irrigation and fertilization sources were significantly higher (ranges of 26.10-29.20 and 25.12-28.03% in the first and second seasons, respectively) than total carbohydrates content of seedlings irrigated with fresh water (23.85 and 22.95% in the first and second seasons, respectively). Based on previous results, treatments can be arranged according to their effects on leaves chemical constituents as follows: NPK mineral fertilization treatment followed by irrigation treatments with tilapia culture effluents containing high Ch. M., high NP, low Ch. M., low NP and then irrigation treatment with tap water. The data also suggest that, the improvement of seedlings growth reflected on leaves chemical constituents; as increasing amounts of nutrients especially macro and micronutrients around the root zone by applying tilapia culture effluents reflected on their uptake by roots, these nutrients are known in playing important roles in biochemical processes, which in turn improve leaves chemical constituents. The results agree with the findings of Yi *et al.* [33], Lin and Yi [34], Singh and Bhati [35] and EL-Mahrouk *et al.* [36].

Soil Chemical Properties: Data in Table 5 revealed the effects of NPK and tilapia culture effluents used on desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings as an irrigation and a fertilization sources in an experiment conducted during seasons 2010 and 2011 on the soil chemical properties (pH, EC, organic matter, total macro and micro nutrients loading). Soil pH, EC and organic matter values were significantly influenced by all treatments in both seasons, compared to the fresh water irrigation treatment. Irrigation with tilapia culture

effluents containing low and high Ch. M. fertilizers helped in decreasing the soil pH and EC and increasing its organic matter as compared to the control. The pH values of the different treatments ranged from 8.11-8.35 and 8.08-8.33 compared to 8.38 and 8.37 for the control soil in first and second seasons, respectively. The treated soil EC ranges were 0.99-1.79 and 0.84-1.89 dS m^{-1} compared to 2.11 and 2.22 dS m^{-1} for the control soil in first and second seasons, respectively. The soil enrichment of organic matter ranged from 0.32-0.49 and 0.38-0.53% compared to 0.23 and 0.26% for the control soil in first and second seasons, respectively. Soil also showed an increase in total macro and micro nutrients loading as a result of the treatments used when compared to the control, which is promising from an irrigation point of view. Irrigation with tilapia culture effluents that contained low and high Ch. M. and high NP fertilizers in addition to NPK fertilizer treatment gave the highest soil nutrients content. Macro nutrients ranges were 0.06-0.14, 0.07-0.12, 0.03-0.06, 0.02-0.05, 0.04-0.06 and 0.03-0.06% for N, P and K whereas the micro nutrients ranges were 0.45-0.74, 0.42-0.74, 86.30-118.75, 68.15-106.36, 29.70-50.80, 23.30-43.47, 8.55-20.42 and 6.73-14.27ppm for Fe, Mn, Zn and Cu in both seasons, respectively as compared to the control (0.05% N and 0.01% P in both seasons and 0.02 and 0.01% K in the first and second seasons, respectively and 0.33 and 0.29, 71.75 and 61.55, 21.00 and 18.40 and 6.73 and 6.01 for Fe, Mn, Zn and Cu in both seasons, respectively).

The enhancement of soil fertility by irrigation with tilapia effluents compared to fresh water treatment may be due to the high discharge rates of pond nutrient-rich effluents to the soil. The superiority of tilapia effluent treatments that contained Ch. M. fertilizers may be owing to the increase of organic matter contents in the effluents caused by the manure inputs level applied to tilapia ponds in order to improve food supply, this inputs level helps in stimulating natural food webs, that in turn generate considerable quantities of plankton and benthic organisms, which convert at the end into organic matter [3, 9], the higher the organic matter, the higher the productivity status of the soil would be. In addition to that, manure contains macronutrients with little micronutrients [37] that elevate its benefits on the soil. And finally, the slow release of N from decomposing manure residues may be better in reducing N leaching losses [38] which increase N-uptake efficiency by plant and reflects on better growth. Theses results are in agreement with the findings of EL-Mahrouk *et al.* [36] on *Khaya senegalensis* and Ali *et al.* [39] on *Swietenia mahogoni*, who reported that treating seedlings with sewage wastewater enriched soil with nutrients and organic matter which are necessary for plant growth under their plantation.

CONCLUSION

This study confirms previous knowledge about the benefits of IAA-system, identifies areas in which IAA-system knowledge is lacking by applying it on an ornamental plant and establishes the relationships between pond management practices and environmental impacts by giving a precise feedback to farmers on nutrient use and waste discharge. Based on the present study it is concluded that: (1) Nile tilapia culture effluents are valuable nutrient resources and can be reused through the irrigation of desert willow (*Chilopsis linearis* (Cav.) Sweet) seedlings, as their growth were improved at any given treatment compared with the control, confirming that an output from one sub-system may becomes an input to another sub-system, (2) such system opens avenues for economic return to both small-scale farms and large-scale commercial agribusinesses, when tilapia (the most important food fishes) are taking place on the same farm with desert willow (an economically important ornamental plant) production, (3) utilizing organic fertilizers in Nile tilapia ponds produce effluents that may be considered alternatives to inorganic fertilizers in inducing *Chilopsis linearis* seedlings growth, as seedlings irrigated with tilapia culture effluents containing high and low doses of Ch. M. are preferred than those irrigated with high and low doses of NP fertilizers in improving growth, (4) frequency of refreshing the pond water, gives a sufficient amount of irrigation water to desert willow seedlings; as considering it a desert plant limits its needs to water, (5) the used levels of organic fertilizers return a good amounts of organic matter to the soil especially the sandy ones, which in turn improves its properties, (6) such management aspects merit further study on different ornamental plants verified under field conditions, (7) further researches are also needed to answer questions on the effects of using fish culture effluents for irrigation in the long run and if their use lead to environmental problems.

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