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Selection of woody species for wastewater enhancement and restoration of riparian woodlands

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Abstract: *Growth and nutrient uptake of seven tree species were evaluated with the goal of selecting the species that can be used for wastewater enhancement by dendro-purification, or green tree filtering, and for restoration of riparian woodlands. Trees were grown in pots with an inert mixture of perlite and vermiculite and irrigated with either nutrient solution or treated wastewater. We measured the effects of species and irrigation water on biomass and nutrient content of leaves, stems and roots. For most of the species, treated wastewater had a positive effect on final biomass and above ground: below ground ratio compared to that of nutrient solution. However, growth of Cupressus sempervirens and Populus nigra were inhibited by water sodium concentration. Nerium oleander, Tamarix africana and Vitex agnus-castus were the species with the greatest final biomass. Pistacia terebinthus had the highest nitrogen and phosphorus content in leaves, stems and roots, while N. oleander and V. agnus-castus showed the best potassium accumulation. In general, P. terebinthus, N. oleander, T. africana and V. agnus-castus were the best qualified species for purification of wastewater.*

Key words: *Wastewater reuse, Dendro-purification, Nutrient uptake, Mineral content*
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Introduction

Wastewater effluents have been traditionally used for agriculture, because they are a low cost alternative irrigation source (Binu Kumari *et al*., 2006). Angelakis *et al.* (1999) reported three advantages for wastewater reuse in irrigation: a reduction in the demand for synthetic fertilizers due to the fertilizing properties of the water, an increase in water resources and, finally, the elimination of the need for tertiary treatment.

Secondary effluents from non-industrial municipalities have generally low concentrations of heavy metals, which do not cause any adverse effects on plant growth or public health (Crook, 1998; Agtas *et al.,* 2007). However, they often contain greater amounts of nitrogen and phosphorus, which can pollute surface and groundwater (Duncan *et al*., 1998; Mathivanan *et al*., 2007; Nath *et al.,* 2007).

Response of agricultural and ornamental plants to irrigation with treated wastewater has been widely studied (Reboll *et al*., 2000; Paranychianakis *et al*., 2004). Several authors pointed out that high salinity wastewater may be detrimental to the growth of some plants (Mujeriego *et al*., 1996; Wu *et al*., 2001).

In areas with a low demand of water for agricultural purposes, treated wastewater can be used for irrigation of green areas and parks (Borboudaki *et al*., 2005) or rehabilitation of riparian landscapes (Marler *et al*., 2001). To achieve these objectives, suitable woody species must be selected for rehabilitating the riparian landscape, with the ability to tolerate irrigation with treated wastewater and incorporate nutrients into their biomass. Some studies with *Salix* (Perttu and Kowalik, 1997) and *Eucaliptus* (Guo *et al*., 2002) showed the interesting properties of woody species as green filters. However, limited information is available on the response of Mediterranean species to treated wastewater irrigation.

The purpose of this study was to select Mediterranean woody species which show better growth and nutrient uptake capacity and that can be used for the restoration of riparian areas using surplus treated wastewater. We compared the growth and nutrient content of seven woody Mediterranean species grown in a greenhouse and irrigated with either wastewater or with nutrient solution.

Materials and Methods

In September 2001, two year-old plants of seven Mediterranean species, obtained from commercial nurseries, were transplanted into 2.2 liter pots (diameter: 16 cm, height: 15 cm; one plant per pot) filled with a substrate of perlite and vermiculite in a mixture of 1:1 (v/v) and grown in a greenhouse. Plants of all species were of the same size and, prior to transplanting, roots were washed with water to eliminate soil particles. Pots were irrigated with two types of water, treated wastewater and nutrient solution, the chemical composition of which is shown in Table 1. Irrigation was applied by drip, twice a day, at doses adjusted for the time of year, between 60 and 660 ml d^{-1}. Three replications were used for each species and water quality.

Treated wastewater had high concentrations of phosphorus, nitrogen and potassium, which were almost twice those of the nutrient solution. Electrical conductivity was high (2.1 dS m^{-1}; 25ºC) due to the concentration of NaCl.

Species tested were: *Populus nigra* (black poplar), *Tamarix africana* (African tamarisk), *Nerium oleander* (oleander), *Cupressus sempervirens* (Italian cypress), *Ficus carica* (common fig), *Pistacia* *terebinthus* (Turpentine tree), and *Vitex agnus-castus* (chaste tree). Trees were planted during September 2001 and processed during November 2002.

At the end of the experiment each plant was separated into roots, stems and leaves and dried in an oven at 60°C for dry weight. Plant samples were ground to pass through a 1 mm sieve for analyses of N, P, Ca, Mg, Na and K. N was measured by the Kjeldahl method (Bremner and Mulvaney, 1982). For determination of other elements, 0.5 g of the samples were dry ashed at 550°C for 5 hr and dissolved in 5 ml of 2N HCl and 50 ml of double distilled water. After stirring for 30 min, the mixture was passed through a 0.45 µm filter and measured with an inductively coupled plasma spectrophotometer.

The effects of species and irrigation water were investigated by a two-way analysis of variance (two-way ANOVA) (Gomez and Gomez, 1984) by using general linear model procedure. The means were separated by the Tukey's test for comparisons between species. SPSS software V 13.0 was used for all calculations and statistical analyses.

Results and Discussion

The most suitable species for dendro-purification should tolerate treated wastewater irrigation and have a high productivity and nutrient uptake capacity.

Figure 1 compares the final biomass produced by the two irrigation treatments, separated into roots, stems, and leaves. There were significant differences among irrigation water treatments ($p<0.05$; Table 2). Five species had a higher biomass production when irrigated with treated wastewater (*Ficus carica*, *Nerium oleander*, *Vitex agnus-castus*, *Tamarix africana* and *Pistacia terebinthus*) but two of the species showed better growth with the nutrient solution applied (*Cupressus sempervirens* and *Populus nigra*). The final biomass of *N. oleander* was significantly ($p<0.001$) greater than that of all the others species. Treated wastewater contained greater concentrations of limiting nutrients such as N, P and K, however, some of the species responded more strongly with nutrient solution. An explanation of this could be that these species were less tolerant to some element with greater presence in treated wastewater, such as salt content due to higher sodium concentrations (Table 1).

The aboveground: belowground ratio was significantly ($p<0.05$; Table 2) higher in the treated wastewater irrigated plants which can be due to the higher concentrations of NPK in treated wastewater that favoured the growth of aerial parts (Mant *et al.*, 2003). There were also significant differences ($p<0.001$) between species for both water qualities, in example *C. sempervirens* was the species with the highest biomass in aerial parts, while *F. carica* and *V. agnus-castus* were the species with the most developed subterranean organs (Table 3). A higher proportion of root biomass might be advantageous for wastewater treatment because this will increase the surface area available for attachment of biofilms (Mant *et al.*, 2003). However, in dendro-purification, the aboveground biomass is more important because it can be harvested in order to remove nutrients from the system (Guo *et al.*, 2002).

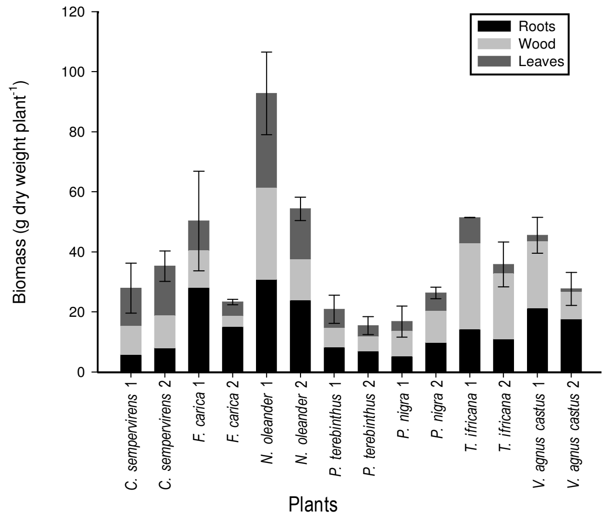

Fig. 1: Final biomass of seven species, irrigated with treated wastewater (1) and nutrient solution (2), separated into roots, stems and leaves. Vertical lines represent the standard error of the mean of total biomass

Table - 1: Chemical composition of the irrigation treatments

Parameter	Nutrient solution	Treated wastewater
EC (dS m^{-1} 25°C)	0.97	2.14
$N-NO_3^-$ (mg l^{-1})	10.3	7.6
$N-NH_4^+$ (mg l^{-1})	1.0	15.0
Cl^- (mg l^{-1})	83	386
Ca^{2+} (mg l^{-1})	129	130
Na^+ (mg l^{-1})	39	204
Mg^{2+} (mg l^{-1})	39	44
K^+ (mg l^{-1})	10.6	21.4
P total (mg l^{-1})	1.17	2.29
TOC (mg l^{-1})	0	10.7

EC= Electrical conductivity, TOC= Total organic carbon

Table - 2: Results of ANOVA (p-values) for the effects of species (sp) and irrigation water (IW) on final biomass production and above ground: Belowground ratio (AG: BG ratio)

	Final biomass	AG: BG ratio
Species	<0.001	<0.001
Irrigation water	0.011	0.013
Interaction (sp*IW)	0.076	0.091

Table - 3: Aboveground: Belowground ratios

	Nutrient solution	Treated wastewater
C. sempervirens	3.7 ± 0.7	3.8 ± 0.5
F. carica	0.6 ± 0.0	0.8 ± 0.0
N. oleander	1.3 ± 0.0	2.0 ± 0.3
P. terebinthus	1.2 ± 0.3	1.6 ± 0.1
P. nigra	1.7 ± 0.3	2.5 ± 0.6
T. africana	2.2 ± 0.2	2.7 ± 0.4
V. agnus-castus	0.6 ± 0.1	1.2 ± 0.1

Mean ± standard error (n=3)

Table 4a: Results of ANOVA (means and p-values) for the effects of species (sp) and irrigation water (IW) on leaf mineral content (g kg^{-1} ± standard error)

Main factor	N	P	K	Na	Ca	Mg
Sp (n=6)						
C. sempervirens	8.0 ± 0.3^{d}	2.2 ± 0.2^{b}	12.6 ± 1.4^{b}	2.7 ± 1.3^{b}	17.2 ± 0.9^{b}	3.6 ± 0.2^{c}
F. carica	11.8 ± 0.9^{bc}	1.6 ± 0.2^{b}	12.3 ± 2.2^{b}	0.7 ± 0.9^{b}	34.9 ± 5.4^{a}	10.5 ± 1.9^{b}
N. oleander	9.5 ± 0.5^{cd}	2.0 ± 0.3^{b}	18.1 ± 1.9^{ab}	0.7 ± 0.1^{b}	18.7 ± 0.6^{b}	7.1 ± 0.1^{bc}
P. terebinthus	14.1 ± 0.8^{ab}	4.2 ± 0.5^{a}	19.0 ± 1.8^{ab}	0.6 ± 0.1^{b}	15.3 ± 2.3^{b}	3.2 ± 0.5^{c}
P. nigra	13.3 ± 1.0^{ab}	1.6 ± 0.1^{b}	11.9 ± 1.4^{b}	1.4 ± 0.4^{b}	27.8 ± 1.8^{ab}	10.9 ± 0.6^{b}
T. africana	15.4 ± 0.7^{a}	3.1 ± 0.8^{ab}	20.0 ± 1.5^{ab}	19.5 ± 4.6^{a}	27.5 ± 5.5^{ab}	17.6 ± 2.0^{a}
V. agnus castus	11.4 ± 1.0^{bc}	2.5 ± 0.6^{ab}	22.9 ± 3.3^{a}	1.7 ± 0.3^{b}	20.6 ± 0.7^{b}	5.7 ± 0.5^{c}
Significance (sp)	<0.001	<0.001	0.005	<0.001	<0.001	<0.001
IW (n=21)						
Treated wastewater	11.9 ± 0.6	2.2 ± 0.2	17.6 ± 1.4	4.5 ± 1.9	21.3 ± 2.0	7.7 ± 1.0
Nutrient solution	11.6 ± 0.8	2.6 ± 0.3	15.7 ± 1.4	1.8 ± 0.8	24.2 ± 2.2	8.0 ± 1.2
Significance (IW)	0.778	0.331	0.411	<0.001	0.133	0.516
Interactions						
Significance (sp *IW)	0.010	0.064	0.585	<0.001	0.331	0.033

Values followed by the same letter are not statistically different between each other (ANOVA, Tukey Test, p<0.05)

Table - 4b: Results of ANOVA (means and p-values) for the effects of species (sp) and irrigation water (IW) on stem mineral content (g kg^{-1} ± standard error)

Main factor	N	P	K	Na	Ca	Mg
Sp (n=6)						
C. sempervirens	3.2 ± 0.4^{d}	1.5 ± 0.2^{ab}	8.6 ± 1.0^{bcd}	2.2 ± 1.0^{a}	12.7 ± 1.1^{ab}	1.0 ± 0.1^{c}
F. carica	11.6 ± 0.7^{a}	2.4 ± 0.2^{a}	7.6 ± 0.8^{cd}	0.7 ± 0.1^{ab}	18.6 ± 6.1^{a}	6.5 ± 1.1^{a}
N. oleander	3.5 ± 0.1^{cd}	1.3 ± 0.1^{b}	18.4 ± 0.9^{a}	0.9 ± 0.2^{ab}	12.4 ± 1.2^{ab}	3.0 ± 0.5^{bc}
P. terebinthus	10.7 ± 1.3^{ab}	2.4 ± 0.1^{a}	10.9 ± 0.4^{bc}	0.5 ± 0.0^{b}	13.2 ± 0.9^{ab}	2.2 ± 0.2^{bc}
P. nigra	7.4 ± 1.4^{bc}	1.2 ± 0.3^{b}	5.7 ± 0.6^{d}	1.2 ± 0.3^{ab}	14.8 ± 2.9^{ab}	2.1 ± 0.2^{bc}
T. africana	9.1 ± 1.7^{ab}	1.7 ± 0.3^{ab}	5.7 ± 0.3^{d}	2.2 ± 0.3^{a}	5.9 ± 0.9^{b}	4.0 ± 0.5^{b}
V. agnus castus	10.9 ± 0.8^{ab}	1.2 ± 0.1^{b}	11.8 ± 0.5^{b}	0.6 ± 0.0^{b}	6.6 ± 0.3^{b}	1.9 ± 0.1^{bc}
Significance (sp)	<0.001	<0.001	<0.001	0.005	0.019	<0.001
IW (n=21)						
Treated wastewater	7.4 ± 0.7	1.8 ± 0.1	10.1 ± 1.1	1.6 ± 0.3	9.6 ± 0.9	2.8 ± 0.3
Nutrient solution	8.6 ± 1.1	1.6 ± 0.1	10.2 ± 0.9	0.7 ± 0.1	14.8 ± 2.0	3.0 ± 0.6
Significance (IW)	0.064	0.395	0.546	0.004	0.013	0.577
Interactions						
Significance (sp *IW)	0.423	0.801	0.319	0.028	0.149	0.072

Values followed by the same letter are not statistically different between each other (ANOVA, Tukey Test, p<0.05)

Mineral content was significantly different between species in leaves, stems, and roots, as is shown in Tables 4a, 4b and 4c. Leaves had the highest mineral content followed by roots and stems in the two irrigation water qualities. Nitrogen content in leaves was higher in deciduous than in evergreen species (*C. sempervirens* and *N. oleander*), as was also found for seedlings of other woody species (Cornelissen *et al.*, 1997). The evergreens also had the lowest nitrogen content in stems and roots, while *T. africana*, *F. carica* and *P. terebinthus* had the highest nitrogen content in leaves, stems, and roots, respectively.

P. terebinthus was one of the species with higher phosphorus accumulation in leaves, stems and roots. In leaves, potassium content was highest in *V. agnus-castus*, followed by *T. africana*, *P. terebinthus* and *N. oleander* (Table 4a). *N. oleander* had a significantly ($p<0.001$) higher potassium content in stems (Table 4b), while *V. agnus-castus* accumulated more potassium in roots (Table 4c).

Sodium content was significantly higher in leaves ($p < 0.001$), stems ($p < 0.01$) and roots ($p < 0.001$) of the treated wastewater irrigated plants. However, calcium and potassium contents were significantly lower in stems ($p < 0.05$) and roots ($p< 0.001$) of plants irrigated with treated wastewater (Tables 4a, 4b and 4c).

Leaves of *T. africana*, showed a significantly ($p < 0.001$) higher sodium content than the rest of the species (Table 4a), which was similar to that reported previously for other tamarisk species (El-Beheiry and El-Kady, 1998, Badri and Hamed, 2000). *T. africana*, together with *C. sempervirens*, had the highest stem sodium content of all species (Table 4b). In contrast, *N. oleander* had a significantly ($p < 0.001$) higher root sodium content than the rest (Table 4c).

Species have different mechanisms for counteracting an increase in soil salinity, such as cellular or whole plant adaptations.

Table - 4c: Results of ANOVA (means and p-values) for the effects of species (sp) and irrigation water (IW) on root mineral content (g kg^{-1} ± standard error)

Main factor	N	P	K	Na	Ca	Mg
Sp (n=6)						
C. sempervirens	5.2 ± 0.3^{c}	1.4 ± 0.2^{c}	4.5 ± 0.6^{d}	2.9 ± 0.5^{b}	33.7 ± 7.0^{a}	3.8 ± 0.6^{bc}
F. carica	10.8 ± 1.0^{ab}	1.8 ± 0.1^{abc}	8.7 ± 0.8^{bc}	1.4 ± 0.4^{b}	12.6 ± 1.5^{bc}	3.1 ± 0.5^{c}
N. oleander	6.4 ± 0.9^{bc}	1.5 ± 0.1^{bc}	13.7 ± 1.6^{a}	6.9 ± 1.6^{a}	16.4 ± 0.8^{bc}	6.7 ± 0.5^{a}
P. terebinthus	12.3 ± 1.2^{a}	2.3 ± 0.3^{ab}	9.9 ± 0.6^{b}	2.4 ± 0.4^{b}	10.5 ± 0.4^{bc}	2.3 ± 0.1^{c}
P. nigra	11.5 ± 2.4^{ab}	1.7 ± 0.3^{abc}	7.0 ± 1.3^{bcd}	2.0 ± 0.7^{b}	14.4 ± 2.0^{bc}	2.0 ± 0.2^{c}
T. africana	9.4 ± 0.8^{abc}	2.4 ± 0.2^{a}	6.0 ± 0.6^{cd}	2.4 ± 0.4^{b}	22.4 ± 2.5^{ab}	5.6 ± 0.6^{ab}
V. agnus castus	10.8 ± 0.6^{ab}	1.6 ± 0.1^{abc}	16.4 ± 1.1^{a}	3.1 ± 0.5^{b}	7.4 ± 0.2^{c}	3.0 ± 0.2^{c}
Significance (sp)	<0.001	0.007	<0.001	<0.001	<0.001	<0.001
IW (n=21)						
Treated wastewater	8.8 ± 0.7	1.7 ± 0.1	8.4 ± 0.9	4.3 ± 0.6	17.4 ± 3.2	3.7 ± 0.4
Nutrient solution	10.0 ± 0.9	1.8 ± 0.1	10.9 ± 1.1	1.9 ± 0.3	15.8 ± 1.5	3.7 ± 0.4
Significance (IW)	0.161	0.565	<0.001	<0.001	0.579	0.913
Interactions						
Significance (sp *IW)	0.338	0.842	0.114	0.032	0.566	0.194

Values followed by the same letter are not statistically different between each other (ANOVA, Tukey Test, p<0.05)

Sodium transport is largely unidirectional and results in its progressive accumulation as leaves age (Tester and Davenport, 2003). However, salt-tolerant species keep the levels of sodium in shoot apices low by exclusion of ions at the point of uptake and/or reduction of ion translocation to the shoots (Niknam and McComb, 2000).

T. africana is more tolerant to salinity because of its selective ion excretion mechanisms (Hagemeyer and Waisel, 1988). This species could be used for treatment of sodium – rich wastewaters as sodium concentration would not affect nutrient uptake.

In contrast, *N. oleander* accumulated sodium in roots, keeping low levels in leaves. The low sodium content in leaves, in addition to high potassium content in roots, stems and leaves, are good indicators of sodium tolerance (Tester and Davenport, 2003), in agreement with Wu *et al.* (2001). *P. terebinthus* and *V. agnus-castus* followed a similar behaviour, with greater sodium content in roots than in leaves but with fast growth and high nutrient content. Walker *et al*. (1987) also observed retention of sodium in the lower part of the plant in *P. terebinthus*.

F. carica had the highest calcium content in leaves and stems, which could be related to its moderate salt tolerance, as this element neutralized the deleterious effect of salts (Kozlowski, 1997). In roots, the highest calcium content was found in *C. sempervirens* (Table 4c).

Magnesium content was significantly ($p < 0.001$) higher in the leaves of *T. africana* (Table 4a) and in the stems of *F. carica* (Table 4b). The species with the highest magnesium content in the roots was *N. oleander*, followed by *T. africana* (Table 4c).

Treated wastewater irrigation caused growth reduction of seedlings and sodium accumulation in the leaves of *C. sempervirens* and *P. nigra*, although *P. nigra* is one of the most used species in land treatment systems (Tzanakakis *et al.,* 2003).

Some of the species that have shown a greater ability for growth and mineral nutrient incorporation in this study are common to Mediterranean riparian environments. Salinas and Guirado (2002) described the riparian vegetation in the Southeast of the Iberian Peninsula and showed that the bush stratum is dominated by *Tamarix* sp. and *N. oleander*, in the presence of *F. carica*.

Species selection on the basis of growth and nutrient accumulation is important to optimise the purification of treated wastewater by tree plantations (Hopmans *et al*., 1990; Hooda, 2007). Ecological criteria, technical aspects and historical information must be taken into account in ecological restoration (Moerke and Lamberti, 2004). The restoration of riparian areas for dendro-purification should include species that are native to the area, yet can also be enriched with other advantageous species depending on the types of water released into the river-bed. *P. terebinthus*, *N. oleander*, *T. africana* and *V. agnus-castus* are the best qualified species using these restoration criteria.

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References

Agtas, S., H. Gey and S. Gul: Concentration of heavy metals in water and chub, *Leuciscus cephalus* (Linn.) from the river Yildiz, Turkey. *J. Environ. Biol.,* **28**, 845-849 (2007).

Angelakis, A.N., M.H.F. Marecos do Monte, L. Bontoux and T. Asano: The status of wastewater reuse practice in the Mediterranean basin: Need for guidelines. *Wat. Res.*, **33**, 2201-2217 (1999).

Badri, M.A. and A.I. Hamed: Nutrient value of plants in an extremely arid environment (Waqi Allaqi Biosphere Reserve, Egypt). *J. Arid Environ.*, **44**, 347-356 (2000).

Binu Kumari, S., A. Kavitha Kirubavathy and Rajammal Thirumalnesan: Suitability and water quality criteria of an open drainage municipal sewage water at Coimbatore, used for irrigation. *J. Environ. Biol.*, **27**, 709-712 (2006).

Borboudaki, K.E., N.V. Paranychianakis and K.P. Tsagarakis: Integrated wastewater management reporting at tourist areas for recycling purposes, including the case study of Hersonissos, Greece. *Environ. Manage.*, **36**, 610-623 (2005).

Bremner, J.M. and C.S. Mulvaney: Nitrogen-Total. *In*: Methods of soil analysis. Part 2- Chemical and microbiological properties (*Eds.*: A.L. Page, R.H. Miller and D.R. Keeney). Agronomy No. 9, Madison. pp. 595-624 (1982).

Cornelissen, J.H.C., M.J.A., Werger, P. Castro-Diez, J.W.A. van Rheenen and A.P. Rowland: Foliar nutrients in relation to growth, allocation and leaf traits in seedlings of a wide range of woody plant species and types. *Oecologia*, **111**, 460-469 (1997).

Crook, J.: Water reclamation and reuse criteria. *In*: Wastewater reclamation and reuse (*Ed.*: T. Asano). Technomic Publishing, Lancaster. pp. 627-704 (1998).

Duncan, M.J., T.G. Baker and G.C. Wall: Wastewater irrigated tree plantations: productivity and sustainability. *In*: Proceedings of 61st Annual Water Industry Engineers and Operator' Conference Shepparton. pp. 18-26 (1998).

El-Beheiry, M.A.H. and H.F. El-Kady: Nutritive value of two *Tamarix* species in Egypt. *J. Arid Environ.*, **38**, 529-539 (1998).

Gomez, K.A. and A.A. Gomez: Statistical Procedures for Agricultural Research. Wiley-Interscience Publication, New York (1984).

Guo, L.B., R.E.H. Sims and D.J. Horne: Biomass production and nutrient cycling in *Eucalyptus* short rotation energy forests in New Zealand. I: Biomass and nutrients accumulation. *Bioresour. Technol.*, **85**, 273-283 (2002).

Hagemeyer, J. and Y. Waisel: Excretion of ions (Cd^{2+}, Li^+, Na^+ and Cl^-) by *Tamarix aphylla*. *Physiol. Plant.*, **73**, 541-546 (1988).

Hooda, V.: Phytoremediation of toxic metals from soil and waste water. *J. Environ. Biol.*, **28**, 367-376 (2007).

Hopmans, P., H.T.L. Stewart, D.W. Flinn and T.J. Hillman: Growth, biomass production and nutrient accumulation by seven tree species irrigated with municipal effluent at Wodonga, Australia. *For. Ecol. Manage.*, **30**, 203-211 (1990).

Kozlowski, T.T.: Responses of woody plants to flooding and salinity. Tree Physiology Monograph No. 1. Heron Publishing, Victoria (1997).

Mant, C., J. Peterkin, E. May and J. Butler: A feasibility study of a *Salix viminalis* gravel hydroponic system to renovate primary settled wastewater. *Bioresour. Technol.*, **90**, 19-25 (2003).

Marler, R.J., J.C. Stromberg and D.T. Patten: Growth response of *Populus fremontii*, *Salix gooddingii* and *Tamarix ramosissima* seedlings under different nitrogen and phosphorus concentrations. *J. Arid Environ.*, **49**, 133-146 (2001).

Mathivanan, V., P. Vijayan, Selvi Sabhanayakam and O. Jeyachitra: An assessment of plankton population of Cauvery river with reference to pollution. *J. Environ. Biol.*, **28**, 523-526 (2007).

Moerke, A.H. and G.A. Lamberti: Restoring stream ecosystems: lessons from a Midwestern State. *Restor. Ecol.*, **12**, 327-334 (2004).

Mujeriego, R., L. Sala, M. Carbo and J. Turet: Agronomic and public health assessment of reclaimed water quality for landscape irrigation. *Water Sci. Tech.*, **33**, 335-344 (1996).

Nath, Kamlesh, Dharam Singh and Yogesh Kumar Sharma: Combinatorial effects of distillery and sugar factory effluents in crop plants. *J. Environ. Biol.,* **28**, 577-582 (2007).

Niknam, S.R. and J. McComb: Salt tolerance screening of selected Australian woody species – A review. *For. Ecol. Manage.*, **139**, 1-19 (2000).

Paranychianakis, N.V., S. Aggelides and A.N. Angelakis: Influence of rootstock, irrigation level and recycled water on growth and yield of Soultamina grapevines. *Agric. Water Manage.*, **69**, 13-27 (2004).

Perttu, K.L. and P.J. Kowalik: *Salix* vegetation filters for purification of waters and soils. *Biomass Bioenerg.*, **12**, 9-19 (1997).

Reboll, V., M. Cerezo, A. Roig, V. Flors, L. Lapeña and P. García-Agustín: Influence of wastewater vs. groundwater on young *Citrus* trees. *J. Sci. Food Agric.*, **80**, 1441-1446 (2000).

Salinas, M.J. and J. Guirado: Riparian plant restoration in summer-dry riverbeds of Southeastern Spain. *Restor. Ecol.*, **10**, 695-702 (2002).

Tester, M. and R. Davenport: Na^+ tolerance and Na^+ transport in higher plants. *Ann. Bot.*, **91**, 503-527 (2003).

Tzanakakis, V.E., N.V. Paranychianakis, S. Kyritsis and A.N. Angelakis: Wastewater treatment and biomass production by slow rate systems using different plant species. *Water Sci. Tech. Water Supply*, **3**, 185-192 (2003).

Walker, R.R., E. Torokfalvy and M.H. Behboudian: Uptake and distribution of chloride, sodium and potassium ions and growth of salt-treated pistachio plants. *Aust. J. Agric. Res.*, **38**, 383-394 (1987).

Wu, L., X. Guo and A. Harivandi: Salt tolerance and salt accumulation of landscape plants irrigated by sprinkler and drip irrigation systems. *J. Plant Nutr.*, **24**, 1473-1490 (2001).