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Possible Reuse of Treated Municipal Wastewater for *Citrus* spp. Plant Irrigation

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In some semiarid areas of the eastern coast in Spain most urban, industrial and agricultural supplies are satisfied by groundwater. Intensive use of fertilizers, pesticides and overexploitation of the aquifer produce the progressive loss of the water quality and the decrease of the groundwater resources. Both the need to conserve water and to safely and economically dispose of wastewater make the use of treated wastewater in agriculture a very feasible option.

The application of municipal wastewater to agricultural land has been studied in other crops, including forages (Bole and Bell 1978), alfalfa, wheat and corn (Al-Jaloud et al. 1993, Montserrat 1993), cotton (Bielorai et al. 1984, Feigin et al. 1984) and other vegetables crops (Basiouny 1984, Kirkham 1986, Neilsen et al. 1989 a, b, c, 1991, Ramos et al. 1989). Also some work has been done using forest trees as test plants (Cromer et al. 1984, Stewart and Flim 1984). Several studies on *Citrus* crops have been realized in Central Florida (Koo and Zekri 1989, Zekri and Koo 1990, 1994), but there is still very little information about the reutilization of reclaimed wastewater for irrigation in *Citrus* plants in Spain (Esteller et al. 1994).

Wastewater has been recognized as a possible important source of the major plant nutrients, such as N, P, and K (Berry et al. 1980), although the chemical composition of wastewater varies between locations.

Therefore the use of the wastewater for crops irrigation must be experimented under local conditions for increased agricultural production. The main objective of this work was to study the possibilities of using municipal wastewater from the sewage treatment plant of Castellón and to determine its effects on *Citrus* plant growth.

MATERIALS AND METHODS

The experimental site is located close to the sewage treatment plant of Castellón (Fig 1). In March 1992, two-years old *Citrus* trees (*Citrus sinensis* L. Osbeck)

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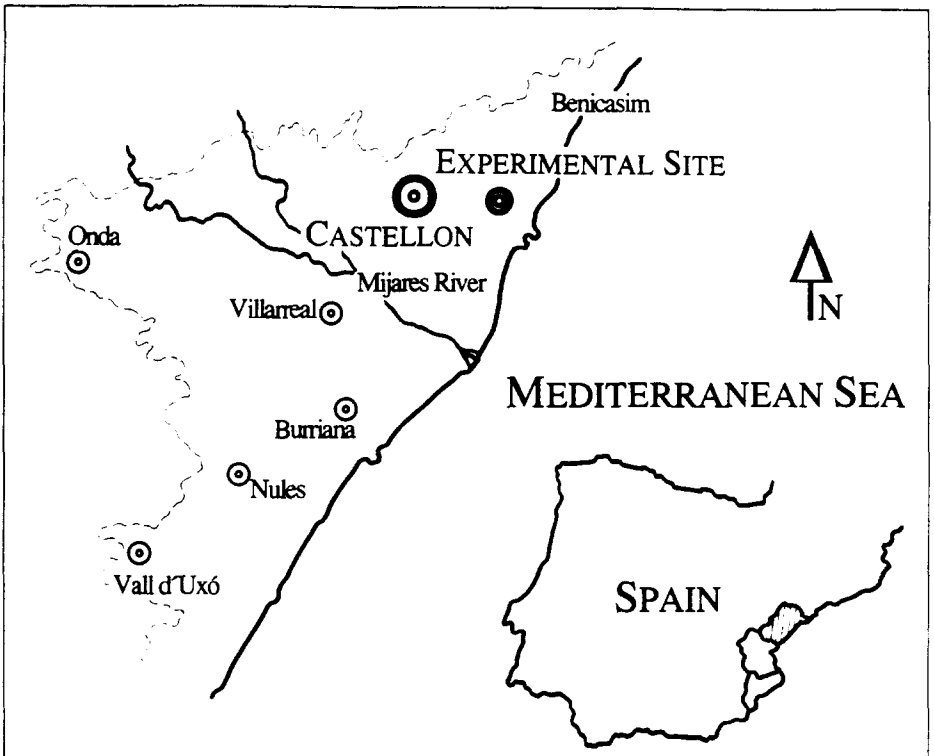

Figure 1. Plan showing the location of the experimental site.

were planted in a plot in order to study the use of the treated wastewater for their irrigation. This water has had secondary treatment, including chlorination, and was temporally stored in lagoons prior to experimental use.

Table 1. Soil samples texture, pH and organic matter content

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	O.M. (%)	pH	P (ppm)	K (ppm)
15	24	26	50	1.61	7.62	36	210
30	22	33	45	1.33		32	190
60	27	21	52	0.74		31	182
90	30	16	54	0.70	7.45		
120	18	33	49	0.60			

At the beggining of the experiment, soil samples were collected at 15 cm increments to a depth of 120 cm and analyzed for texture, pH, phosphorus and potassium (Table 1) (Pratt 1965, Watanabe and Olsen 1965). Plot was irrigated by flooding every 20 days, between March and October, and the rest of the year depending on the rainfall distribution. Treated wastewater was used in half of the plot and groundwater in the rest. Total volume of water consumed in the irrigation was approximately $0.7 m^3/m^2$/year. Fertilizers were added during 1993 and 1994.

The dosis are showed in table 2. The yearly amount of fertilizer was splilted in three equal parts which were applied in March, July and August.

Table 2. Ammounts of fertilizers applied yearly

	$g.tree^{-1}.yr^{-1}$
Ammonium Nitrosulfate	100
Peat (7.5% OM)	143
Fe-Sulfate	62
N-P-K Complex (15-15-15)	333
N-P-S-Mg Complex (20-10-5-2)	250
Total N fertilization rate	126 ($g.tree^{-1}.yr^{-1}$)

Before each irrigation, water samples were collected and analysed for the different chemical and physical parameters (nitrate, ammonium, nitrite, phosphate, sodium, chloride, potassium, boron, organic matter and pH). Cations were analysed by atomic absorption spectophotometry. Boron was analysed following the Azomethine-H Method described by López et al. (1993) and chloride was determined by Argentometric Tritation. Spectrophotometry UV-VIS was used to analysed phosphate and the organic matter was measured by volumetric method using Mohr salt (Standard Methods, 1989).

Spring flush leaves from nonfruiting twigs were sampled in October 1994 from six random trees. Eight leaves were collected from each tree around the canopy. Leaves were oven dried for at least two days at 68 °C, ground and retained for mineral analysis. Atomic absorption spectrophotometry (Chapman and Pratt 1961) was used to measure sodium and potassium. Foliar P was measured following the Molybdenum Blue Method. Foliar boron was analysed by Azomethine-H Method (M.A.P.A. 1994). Total nitrogen in the leaves was determined by Microkjeldahl Method (Bremner 1965) and foliar chloride was analysed by silver ion tritation with a Corning-926 chloridometer (Gillian 1971).

RESULTS AND DISCUSSION

Major differences in composition between both irrigation water kinds (groundwater and wastewater) were observed throughout the study period (Table 3). This results in a higher supply of some elements (P, Na^+, Cl^-, K^+, and B), and organic matter to plants irrigated with reclaimed water. However, the supply of mineral N ($N\text{-}NO_3^-$ + $N\text{-}NO_2^-$ + $N\text{-}NH_4^+$), Ca^{2+} and Mg^{2+} was similar for trees irrigated with both water kinds (Table 3).

Table 3. Mineral elements and organic matter (OM) supplied by irrigation water expressed as g/tree/year.

	Reclaimed water	Groundwater
N (mineral)	9.96±1.6	9.87±1.4
P	5.04±0.6	0.08±0.05
K^+	20.5±2.25	2.05±0.15
Na^+	241.8±25	51.6±3.5
Cl^-	324.3±2.8	74.8±5.0
B	2.6±0.3	0.8±0.3
OM	59.1±6.4	10.4±1.4

Leaf N contents were slightly lower in plants irrigated with groundwater than wastewater (Table 4). Probably it is because of elevated levels of organic matter found in wastewater wich provide to the plants of an additional N. These results indicate that wastewater could be an efficient source of nitrogen to *Citrus* plants, as also was reported by (Zekri and Koo 1994). In this way, Neilsen et al. (1991) in sweet-cherry trees, Feigin et al. (1984) in cotton and Basiouny (1984) in peach trees found an increase in foliar N concentrations when plants were irrigated with wastewater. Moreover, in apples trees irrigated with effluent water, foliar N levels increased slightly (Neilsen et al. 1989c).

Table 4. Effect of type of irrigation water on mineral concentration of *Citrus sinensis*.

	Groundwater	Wastewater	Significance
N (% dw)	2.62	2.78	*
P (% dw)	0.15	0.16	NS
K^+ (% dw)	1.58	1.39	*
Cl^- (% dw)	0.11	0.22	*
Na^+ (% dw)	0.03	0.11	*
B (ppm)	94.7	161.2	*

*Differences between mineral concentration values are significantly at p=0.05

No significance differences in leaf P contents were found between plants irrigated with either groundwater or wastewater (Table 4), in spite of wastewater supplies a higher amount of P to plants (Table 3). This is explainable considering that the amount of P supplied by both kind of irrigation water is a small percentage of total P from soil and fertilizers.

Leaf K^+ concentration in leaves of plants irrigated with groundwater was significantly higher than in plants irrigated with wastewater (Table 4). Probably, the elevated Na^+ levels in wastewater (Table 3) inhibited K^+ uptake by *Citrus* plants. It has been reported previously in some other plants where external Na^+ antagonize K^+ uptake (Epstein 1961, La Haye and Epstein 1969, Cramer et al. 1987) as also occurs in *Citrus* plants (Bañuls et al. 1990).

Plants irrigated with wastewater showed higher leaf contents of Cl^- and Na^+ than those irrigated with groundwater (Table 4). *Citrus* is considered a salt sensitive crop (Maas and Hoffman 1977) and salinity causes reduction in growth, ion toxicity, ionic imbalance and adverse water relations in *Citrus* plants (Walker et al. 1982). Embleton et al. (1973) established in 0.7% and 0.25% the limit values of the concentration of Cl^- and Na^+ respectively, above of them toxic effects may be manifested in *Citrus*. Foliar Cl^- and Na^+ concentrations in plants irrigated with wastewater (0.22 and 0.11 respectively) were under the critical toxic levels. The average of Boron contents in wastewater were 2.6 mg/l during the experiment, whereas in groundwater were 0.8 mg/l (Table 3). In *Citrus* trees higher contents than 2 mg/l in the irrigation water could be an important risk to vegetative development (Pomares 1986). The average leaf B concentration is higher in plants irrigated with wastewater (161.2 ppm) than in plants irrigated with groundwater (94.7 ppm) (Table 4). The leaf concentration of B toxic to the *Citrus* plants is usually close to 260 ppm (Embleton 1973). However, the values to B in leaves of plants irrigated with wastewater did not reached these level, probably, because water and soil pH, since boron is assimilated with difficulty in an alkaline medium. Therefore leaf Na^+, Cl^- and B levels found during the experiment were not apparently limiting for growing *Citrus* plants since no toxicity symptons were observed. These results indicate that the use of treated wastewater to irrigate *Citrus* plants is not harmful for this crop, as previously have been reported by Zekri and Koo (1994).

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