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Impact of irrigation with citrus wastewater on soil fertility and productivity of *Lactuca sativa* L.

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INTRODUCTION

Water is the natural resource on which the life of all organisms depends and, therefore, the key to maintaining and sustaining socio-economic development. The scarcity of natural water sources has made it essential to consider wastewater as a potential alternative system for irrigation [1]. Indeed, the agricultural sector is the most suitable for wastewater use, especially in arid and semi-arid areas where water scarcity has become a pressing challenge [2]. Recently, great attention is being paid to the reuse of wastewater from citrus wastewaters (CWWs) for irrigation purposes. CWWs are characterised by a significant amount of total organic carbon (TOC), N, P and K, depending on the type and ripening stage of the fruit, but also on the technological and construction characteristics of the processing plant [3]. Therefore, a pot experiment was conducted in a greenhouse to study the impact of repeated applications of untreated CWWs on certain chemical and biochemical properties of the soil and the lettuce (*Lactuca sativa* L.) crop.

RESULTS

Citrus wastewaters irrigation increased the TOC content only when CWWs were applied at the highest dose (3/3). The stimulation of microbial respiration following the application of CWWs increased the metabolic quotient (qCO_2), suggesting the occurrence of stress conditions; however, even under stress conditions, microorganisms in the soil irrigated with CWWs, except for those irrigated with 3/3 OWW, were able to assimilate organic C for their growth, as evidenced by the increase in the microbial quotient (Qmicr).

Tab. 1 Main chemical properties on soil after the addition of OWW and LWW at three different dilution (1/3, 2/3 and 3/3 of the 50% of soil water holding capacity). Different upper case letters indicate significant differences (P<0.05) among treatments at the same concentration; different lower case letters indicate significant differences (P<0.05) among dilutions within the same treatment. Numbers in bold indicate significant differences (P<0.05) relative to the control and all the treatment.

Treatment	Dilution	pH	E.C.	Carbonates	Available P	TOC	TKN	Extractable C
			dS m^{-1}	%	mg kg^{-1}	g kg^{-1}	g kg^{-1}	mg C kg^{-1}
CTR		7.15	1.18	18	101	58	3.4	135
OWW	1/3	7.24 b	**1.01**	**16** b	91a	61 b	3.6 b	221 b
	2/3	7.35 b	1.10	18 a	**81** b	62 b	3.9 b	212 b
	3/3	**7.65** a	1.10	18 Aa	97 Aa	**68** Aa	**4.4** a	**350** Aa
LWW	1/3	7.62 a	**0.93**	17 a	87 a	60	3.5 b	267 a
	2/3	7.45 a	1.07	17 a	86 a	60 a	3.5 b	214 a
	3/3	7.47 a	1.21	**16** Bb	**85** Ba	60 Ba	4.0 a	216 Ba
Treatment (T)		n.s.	n.s.	n.s.	n.s.	30 b	17	20
Dilution (D)		n.s.	40	n.s.	n.s.	n.s.	49	n.s.
T x D		n.s.	n.s.	49	n.s.	n.s.	n.s.	33

The effects on *Lactuca sativa* L. were less significant, finding a general slight decrease in plant weight and chlorophyll content. Only, an increase in TP and TKN content was found in plants irrigated with OWW 3/3, probably due to less competition with soil microbial biomass.

Tab 2. Effect of citrus wastewater on some of the physical and chemical parameters of lettuce. Different upper case letters indicate significant differences (P<0.05) among treatments at the same concentration; different lower case letters indicate significant differences (P<0.05) among dilutions within the same treatment. Numbers in bold indicate significant differences (P<0.05) relative to the control and all the treatment.

Treatment	Dilution	Plant dry weight	TKN	TP
		g	g kg^{-1}	mg kg^{-1}
CTR		9.1	7.9	1.5
OWW	1/3	8.3 Ba	**5.9** Ab	1.5 Ab
	2/3	7.0 Ba	6.6 Ab	**1.4** Ac
	3/3	**6.0** Bb	**9.1** Ba	**1.9** Aa
LWW	1/3	9.6 Aa	**5.5** Aa	**1.4** Ba
	2/3	8.6 Aa	**5.7** Ba	**1.3** Bb
	3/3	8.0 Aa	6.4 Aa	**0.2** Bc
Treatment (T)		43.8	28.2	18.1
Dilution (D)		25.4	35.1	53.9
T x D		n.s.	25.3	28.0

MATERIALS & METHODS

In the first two weeks, plants were watered daily with tap water to reach the 50% of soil WHC. From the third until the fifth week, plants were watered three times per week with CWWs, both orange wastewater (OWW) and lemon wastewater (LWW), at three different doses to reach 1/3, 2/3 and 3/3 of the 50% of soil WHC and, three times with tap water. Instead, only tap water was added to the control. The last two weeks plants were watered with tap water. Three replicates per treatment were run and a control treatment was also prepared for a total of twenty-one samples (2 CWWs x 3 doses x 3 replicates plus 3 controls).

CONCLUSIONS

Results provide evidence that total and labile C pools, as well as microbial activity increase following the application of CWW.
Type and concentration both affect such properties; indeed, the use of not diluted OWW inhibited C assimilation by soil microorganisms and was found toxic for lettuce plants.
Thus, CWW can be used for soil irrigation in sustainable agriculture but further trials on crops are needed to evaluate their feasibility.

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