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MAIZE IRRIGATION WITH MUNICIPAL WASTEWATER 1- YIELD AND SOIL IMPACT

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ABSTRACT

The aim of this experiment was to evaluate the relevance of wastewater or chlorinated wastewater use in irrigation. Bearing this purpose in mind a field experiment with *Zea mays* L. was made. The soil used was a fluvisoil.

Chlorination with NaClO was made with a level of free residual chlorine of 3mg.l^{-1} . It was observed that wastewater or chlorination did not influence the yield. Wastewater use increased the organic matter, "available" phosphorus and potassium, and exchangeable potassium levels in the soil. The pH, ammonium nitrogen, exchangeable bases: sodium, calcium and magnesium, copper and boron levels in the soil were not affected by the use of wastewater or the chlorination. The wastewater use leads to a decrease in zinc level in the soil.

KEYWORDS

Chlorination; irrigation; pollution; soil fertility; wastewater; *Zea mays* L.

INTRODUCTION

Castelo Branco is a town in the center east of Portugal, in the region of Beira Interior, with dry and hot summers (Mediterranean climate according to Koppen classification). The water resources are not enough for human need consumption and agricultural purposes in this period of the year.

Agriculture in this region is an important activity. There are some areas with storage dam irrigation. In these areas agriculture is more intensive and profitable. In the other areas water appears as the main constraint on yields and on the agricultural systems, as well.

The possibility of reusing water in these areas, such as irrigation with treated wastewater, in order to increase yields and to diversify crops, is very relevant.

Although, in order to irrigate a particular area, wastewater should undergo a treatment according to the characteristics of wastewater itself, climate, soil composition and crops. Since the biological characteristics of wastewater may have an adverse impact on public health, the disinfection of wastewater (with sodium hypochlorite for example) can be done.

Therefore, field experiments which lead to achieve local data of the impact on yields and on soil fertility using wastewater in irrigation are very important.

A field experiment, with wastewater irrigation, was carried out on a farm belonging to the Escola Superior Agrária de Castelo Branco (Agriculture School of the Polytechnic Institute of Castelo Branco). It was planned bearing in mind the following objectives:

- to evaluate the possibility of using wastewater in the maize irrigation;
- to evaluate water chlorination effect on yields and on soil fertility.

MATERIALS AND METHODS

A field experiment using Maize (*Zea mays* L. var. Challenger) was carried out. The soil used was a fluvisoil (FAO/UNESCO classification). Table 1 shows the main characteristics of this soil, where a high level of "available" phosphorus and "available" potassium, low cation exchange capacity and low degree of bases saturation, are evident.

Table 1 - Soil characteristics

Parameters	
Texture	Loamy sand
E.C. (mS·cm ⁻¹)	0.047
O.M. (%)	2.52
pH (H ₂ O)	5.6
"Available" Phosphorus (P ₂ O ₅ , mg·kg ⁻¹)	308
"Available" Potassium (K ₂ O, mg·kg ⁻¹)	200
Exchangeable H ⁺ (cmol (+)·kg ⁻¹)	5.66
Exchangeable bases (cmol (+)·kg ⁻¹)	
Ca	0.84
Mg	0.10
K	0.20
Na	0.036
T (cmol (+)·kg ⁻¹)	6.84
V (%)	17

The methods used in soil analysis were: the organic matter (OM) was calculated by multiplying the percentage of organic carbon by the factor 1.724. Organic carbon was measured by Walkley-Black method. "Available" phosphorus and potassium in the soil were determined by colorimetric and flame emission photometric methods, respectively, after extraction by the Egner-Riehm method. Electrical conductivity (E.C.) was determined by a conductimeter apparatus in a 1:5 suspension (soil:water). The exchangeable bases and micronutrientes were determined by atomic absorption spectrophotometry after extraction by ammonium acetat method, or "aqua regia" method, respectively.

The irrigation water used was either the secondary effluent of the wastewater treatment plant in Castelo Branco, or storage dam water according to the experiment. The wastewater used was treated by an activated sludge process. Both wastewater and storage dam water were disinfected in the laboratory with sodium hypochlorite (WPCF,1986) in order to obtain, according to the experiment, a level of free residual chlorine of 3 mg.l⁻¹. The disinfection was made by using a sodium hypochlorite solution having 7% of active chlorine.

Several samples of wastewater were taken and analysed during the experiment. Table 2 shows the analytical results.

Table 2 - Wastewater analytical results

Parameters \ Date	12-8-97	19-8-97	26-8-97	2-9-97	11-9-97
TS (g·l ⁻¹)	0.58	0.56	0.51	0.53	0.57
TVS (g·l ⁻¹)	0.25	0.15	0.17	0.18	0.22
TSS (g·l ⁻¹)	0.06	0.02	0.02	0.02	0.02
COD(mg·l ⁻¹)	240	260	260		
EC _w (mS·cm ⁻¹)	1.28	1.19	0.99	1.20	1.26
pH	7.8	7.8	7.0	7.7	7.9
Norg.(N, mg·l ⁻¹)	3.60	2.52	1.68	1.68	0.86
NH ₄ ⁺ (N, mg·l ⁻¹)	19.6	3.36	1.4	15.12	11.76
NO ₃ ⁻ +NO ₂ ⁻ (N, mg·l ⁻¹)	2.8	5.6	11.48	4.2	1.96
N-total (N, mg·l ⁻¹)	26.0	11.48	14.56	21.0	14.58
Alkalinity (CaCO ₃ ,mg·l ⁻¹)	320	255	150	285	305
Cl ⁻ (mg·l ⁻¹)	102	94	73	90	91
P-total (mg·l ⁻¹)	1.0	1.02	1.99	2.16	2.63
K (mg·l ⁻¹)	25.3	22.8	23.3	28.0	30.7
Ca (mg·l ⁻¹)	18.8	19.8	24.8	21.1	20.9
Na (mg·l ⁻¹)	203.3	211.4	162.0	191.4	215.4
Mg (mg·l ⁻¹)	5.7	4.9	7.4	6.0	6.1
Cu (mg·l ⁻¹)	0.04	0.06	0.01	0.04	0.06
Fe (mg·l ⁻¹)	1.18	4.75	vest.	2.05	vest.
Zn (mg·l ⁻¹)	1.66	0.03	0.24	0.11	0.19
Mn (mg·l ⁻¹)	0.07	0.05	vest.	0.01	vest.
B (mg·l ⁻¹)	0.75	-	-	-	0.85

The purpose of the disinfection of the wastewater was to diminish its microbial content namely faecal coliforms (Table 3).

Table 3 – Microbial analytical results from wastewater (WWCI0) and chlorinated wastewater (WWCI 3) with 3 mg·l⁻¹ of free residual chlorine

	Total colif.(MPN)	Faecal colif.(MPN)	Faecal Streptococcus (MPN)
WWCI0	>1800/100ml	>1800/100ml	550/100ml
WWCI 3	25/100ml	5/100ml	0/100ml

Table 4 shows the amount of NaClO used in the disinfection. The methods used in the analysis of wastewater were those described in Standard Methods (1995).

Table 4 - Amount of sodium hypochlorite (NaClO) added to wastewater or storage dam water (µl·l⁻¹)

	12-8-97	19-8-97	26-8-97	2-9-97	11-9-97
WWCI3	190	190	220	250	240
SDWCI 3	186	186	186	186	186

The following treatments were used in the present experiment:

- Irrigation with wastewater (WWC10)
- Irrigation with chlorinated wastewater with a free residual chlorine $\leq 3\text{mg.l}^{-1}$ (WWC13)
- Irrigation with storage dam water (SDWC10)
- Irrigation with chlorinated storage dam water with a free residual chlorine $\leq 3\text{mg.l}^{-1}$ (SDWC13)

Treatments were replicated three times

The addition of fertilizers to the soil was done before sowing, using 350kg.ha^{-1} of urea (46%N). The area of each replication was 30m^2 ($3\text{m}\times 10\text{m}$), with four rows of maize plants.

The sowing was done on the 97-06-23.

The maize was irrigated eleven times by furrows, using 500 l of water in each irrigation.

Table 5 shows the amount of nutrients added into soil due to wastewater irrigation.

Table 5 - Amount of N, P (P_2O_5) and K (K_2O) added into soil due to wastewater irrigation (irrigated area of 30m^2)

Treat./Nut.	N (g)	P_2O_5 (g)	K_2O (g)
WW	89	22	172

The maize was harvested in 97-09-15.

The "green" weight was obtained after cutting the maize in the two central rows for each treatment and replication. These maize plants were weighted.

Forage production was evaluated through the weight obtained after drying two maize plants of the two central rows in a stove at a temperature of 65°C .

After the harvest, a soil sample of each treatment and replication was taken out for laboratory analysis.

STATISTICAL DATA ANALYSIS

The field experiment was completely randomized, with an experimental design in split-plot with two main factors (water and chlorination), with three replications each. The data analysis was performed in the statistical package Statgraphics 5.0, by the analysis of variance using the linear fixed additive model bifactorial. The multiple mean comparisons were made by the Tukey test, with a probability of type I error of 5% ($P\leq 0.05$).

RESULTS AND DISCUSSION

Forage yield

As we can observe in Table 6, neither the wastewater irrigation nor the chlorination of the irrigation water affected significantly the forage yield, or the "green" weight of the maize plants.

Table 6 - "Green" weight and dry matter yields of the forage

Treat./yield	"Green" weight (kg)	Dry matter (g)
Water		
WW	51.5	250.4
SDW	48.4	284.5
Significance	ns	ns
Chlorination		
Cl0	49.4	264.0
Cl3	50.6	270.8
Significance	ns	ns
Water x Chlorination		
WWCl0	54.7	276.0
WWCl3	48.5	224.8
SDWCl0	44.1	252.0
SDWCl3	52.7	316.0
Significance	ns	ns

In this first year of the field experiment, the wastewater or the chlorinated wastewater seems to be a feasible source of water to this culture.

The influence in some soil characteristics

The irrigation with wastewater affected significantly ($P \leq 0.05$) the organic matter in the soil (Table 7), which is higher than the level of the treatments irrigated with storage dam water water.

We think that this fact is due to the composition of wastewater which remains with some organic matter after treatment.

The interaction water vs chlorination was also significant. It shows that the chlorination of storage dam water increases the organic matter in the soil while the chlorination of wastewater seems do not affected significantly the organic matter content of the soil. These results suggest that the use of water with bactericid effect may have some impact on the microbial activity in the soil, namely the mineralization of organic matter (Horta-Monteiro, 1994).

The level of ammonium nitrogen in the soil was not significantly affected by the use of wastewater or the chlorination.

The irrigation with wastewater or the chlorination of the water used in irrigation did not affected the pH value in the soil.

The electrical conductivity in the soil is a very relevant parameter when wastewater is used in irrigation. As we can observe (Table 7) nor wastewater or the chlorination affected significantly the level of the electrical conductivity, nor the chlorine values of the soil.

Table 7 - Organic matter; N-NH₄⁺; pH (H₂O); electrical conductivity and chlorine values in the soil at the end of the experiment

Treat.	OM (%)	N-NH ₄ ⁺ (%)	pH	E.C. (μS·cm ⁻¹)	Cl ⁻ (mg·kg ⁻¹)
Water					
WW	1.72	0.015	5.8	163.3	16.5
SDW	1.45	0.026	5.7	144.3	18.2
Significance	*	ns	ns	ns	ns
Chlorination					
Cl0	1.47	0.026	5.8	158.3	18.5
Cl3	1.71	0.015	5.7	149.3	16.2
Significance	ns	ns	ns	ns	ns
Water x Chlorination					
WWCl0	1.77	0.021	5.7	155.7	17.3
WWCl3	1.68	0.010	5.8	171.0	15.7
SDWCl0	1.17	0.031	5.8	161.0	19.7
SDWCl3	1.73	0.020	5.6	127.7	16.7
Significance	*	ns	ns	ns	ns

The "available" phosphorus increases significantly (Table 8) when wastewater was used ($p \leq 0.001$), probably due to wastewater composition, and when chlorination was done ($p \leq 0.05$). We can also observe that the chlorination of the wastewater seems to decrease the "available" phosphorus in the soil, while the chlorination of the storage dam water increases its value.

The "available" potassium in the soil increases significantly with the use of wastewater ($p \leq 0.001$), also due probably to the potassium content of this water. Chlorination did not affect significantly this parameter. The exchangeable bases calcium, magnesium and sodium were not affected significantly with the wastewater use or the chlorination. The exchangeable potassium increases significantly ($p \leq 0.001$) with the wastewater irrigation. As we can see (Table 8) the wastewater use increases both "available potassium" and exchangeable potassium. The chlorination increases the exchangeable potassium when storage dam water was used and decreases this value when wastewater irrigation was done. These results may be explained looking at the values of the exchangeable sodium in the soil. The level of this mineral element was higher in the treatments irrigated with chlorinated wastewater causing possibly a decrease of exchangeable potassium.

The copper and the boron level in the soil was not affected by the use of wastewater or the chlorination, while the zinc level decreases significantly ($p \leq 0.05$) with the wastewater use. These last result suggest that the increase in the organic matter content of the soil may be responsible for the quelatization of this micronutrient decreasing its bioavailability.

Table 8 – “Available” phosphorus and potassium; exchangeable bases - Ca, Mg, Na K; copper; zinc and boron values in the soil at the end of the experiment

Treat.	P ₂ O ₅	K ₂ O	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cu ²⁺	Zn ²⁺	B
	(mg·kg ⁻¹)		(cmol(+)-kg ⁻¹)				(mg·kg ⁻¹)		
Water									
WW	676	240	0.90	0.10	0.17	0.19	7.78	51.2	1.02
SDW	454	120	0.99	0.10	0.14	0.12	8.18	57.2	0.97
Significance	***	***	ns	ns	ns	***	ns	*	ns
Chlorination									
C10	525	196	0.99	0.11	0.15	0.15	7.83	54.2	1.05
C13	604	163	0.91	0.10	0.16	0.16	8.13	54.2	0.94
Significance	*	ns	ns	ns	ns	ns	ns	ns	ns
Water x Chlorination									
WWC10	687	253	0.95	0.11	0.13	0.20	7.90	53.0	1.07
WWC13	663	227	0.85	0.09	0.21	0.17	7.67	49.3	0.97
SDWC10	363	139	1.01	0.10	0.17	0.09	7.77	55.3	1.03
SDWC13	544	100	0.97	0.10	0.10	0.15	8.60	59.0	0.91
Significance	**	ns	ns	ns	ns	**	ns	ns	ns

CONCLUSIONS

This field experiment shows that the use of wastewater with or without chlorination seems to be a feasible source of water in regions with scarce water resources. Although, in our opinion, more studies about the impact on microbial activity in the soil due to the use of a wastewater with bactericid effect (chlorinated) must be done.

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