The effects of wastewater irrigation on the yield of energy willow and soil sodicity

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Abstract: However, lot of surface water is available for irrigation in Hungary now; in the near future the access for fresh water can be limited due to the more and more competition for resources. In this context, farmers expected to be forced to use moderate saline or saline water for irrigation also. In our research, waste water was used for irrigation of energy willow in lysimeter experiment in 2015. There were applied 7 irrigation treatments and one rain-fed control in four replications during the vegetation period. In each 1 m^3 lysimeter were planted two willows which were harvested in 2015 December. Dry and wet biomass, dry matter content of the willow and the exchangeable sodium content and ammonium-lactate soluble sodium (AL-Na) content of the soil were investigated in order to evaluate the impact of waste water on the willow yield and the soil salinization. According to our results, the improved waste water treatment (diluted and containing added gypsum repair material) produce the same yield like raw waste water and control irrigation treatment. At the same time, the soil from the significant sodium accumulation was prevented by this treatment. The improvement of waste water quality could be represented by a practical solution of moderate saline water use for irrigation.

Keywords: exchangeable sodium percentage, ammonium-lactate soluble sodium, lysimeter, gypsum

Introduction

Sustainable soil and water management and use of alternative water resources for agricultural production are one of the key elements of the fight against the continuous increase in global population (Singh, 2015) and climate change. The new water resources play determining role because of the water scarcity (Francés et al., 2017) in addition to water and energy saving irrigation methods. For the sustainable soil management the irrigation water quality has to be prosperous to avoid soil degradation (e.g. salinization) (Singh, 2015; Elgallal et al., 2016). More and more water types are used for irrigation despite of having high specific electrical conductivity above 2000 or even 6000 µs/cm (Tzanakakis et al., 2011; Myers et al., 1998). At the same time, in nowadays this water situation require rethinking and renewal of the irrigation water qualification system also in Hungary to create more efficient and sophisticated regulations for irrigation water qualification. With a new or modified system more water resources can became applicable for irrigation purposes nonetheless without soil salinization. In this paper a new type of diluted and contained repair added gypsum waste water through the soil sodium accumulation parameters and energy willow yield was evaluated.

Materials and methods

The experiments were conducted at the National Agricultural Research and Innovation Centre (NAIK), Research Department of Irrigation and Water Management (OVKI) in

Szarvas, Hungary. The experiment was set up in the NAIK ÖVKI Lysimeter Station in 2014 in 64, 1 m^3 vessels with energy willow. The two willow clones (no. 77, 82) were selected by the Forest Research Institute of Püspökladány Experimental Station of NAIK. In this experiment the soil of clone no. 82 was examined in 24 vessels in three replications in three depths (0-20, 20-40, 40-60 cm). The mean temperature at the irrigation period (June-September) in 2015 was 22.3°C and the precipitation was 137.2 mm. Between 19 June 2015 and 18 September 2015 irrigation occurred 12 times with 3 doses 15, 30 and 60 mm with two water types. First one originated from the Oxbow Lake of Körös River (K15, K30, K60) with excellent water quality according to Filep‘s classification (Stefanovits, 2010) while the other one was a wastewater (W15, W30, W60) from an intensive African catfish farm in Szarvas with high sodium, total dissolved salt and hydrogen carbonate content (Table 1). Beside the rainfed treatment (Control), one wastewater based irrigation water type (HG60) was used for irrigation (only 60 mm doses) which was diluted with River Körös water and added gypsum to improve sodium-calcium rate of the waste water (Table 1).

Table 1: Chemical parameters of the different irrigation water types

	River Körös	Wastewater	HG60*	Analytical method
pH (KCl)	7.49	7.46	6.71	MSZ EN ISO 10523:2012
Specific electrical conductivity (20 °C) (µS/cm)	436	1310	924	MSZ EN 27888:1998
Bicarbonate (mg/l)	227	949	398	MSZ ISO 9963-1:1998
Calcium (mg/l)	48.3	20.0	98.9	MSZ 1484-3:2006
Potassium (mg/l)	3.94	6.19	4.55	
Magnesium (mg/l)	12.6	9.42	11.9	
Sodium (mg/l)	44.6	291	107	
Na% *	35.4	86.8	43.6	calculated
SAR *	1.48	13.4	2.71	calculated

** SAR=Na/((Ca+Mg)/2)1/2 (Richards, 1954 In: Ayers and Westcot,1994)*
** Na%=Na/(Ca+Mg+Na+K)*100 (Darab K. – Ferecz K., 1969)*
** HG60=diluted and improved irrigation water*

The soil samples were collected before and after the irrigation period and analysed in the Laboratory for Environmental Analytics (NAIK ÖVKI). The statistical calculation was performed in SPSS 22.0 Statistics Software (T-Test, ANOVA).

Results and discussion

The mean value of the exchangeable sodium percentage of the all soil sample (72) from the experiment was 1.72% in springtime and 2.70% after the irrigation period, in autumn. The minimum measured value was 0.96% in spring and 1.19% in autumn. The maximum value was 2.65% and 7.18% in these sampling times.

Table 2: Alteration of the exchangeable sodium percentage (%) during irrigation time in the different treatments (According to MSZ-08-0214-2:1978)

Depth of soil (cm)	W15	W30	W60	HG60	K15	K30	K60	Control
0-20 cm	2.70*	4.34**	3.72	0.13	0.34*	0.49	-0.10	0.57**
20-40 cm	0.43*	2.92**	2.77**	-0.24	0.24	0.14	-0.24	0.58**
40-60 cm	0.14	1.47*	1.54*	0.16	-0.03	0.11	0.72	0.54*

Values represents the subtraction of exchangeable sodium percentage (%) in spring and in autumn (:p<0.05 **: p<0.01 ***: p<0.001)*

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The highest increase occurred in the treatment W30 (>+4%). In the Control treatment the increase was also significant in all layers but the growth was below 1%. In the treatment W60 the increase was significant just in the subsurface layer between 20 and 40 cm despite of the high values. In the treatments irrigated with Körös River water the increase was not significant (or negligible in K15) and in one case decrease occurred (K60). In treatment HG60 there were no significant increase.

Table 3: Alteration of the ammonium-lactate soluble sodium content (mg/kg) in the soil during irrigation time in the different treatments

Depth of soil (cm)	W15	W30	W60	HG60	K15	K30	K60	Control
0-20 cm	182**	289*	323*	48**	45**	58**	25**	-5
20-40 cm	57*	220**	156**	25*	42***	50**	13	-2
40-60 cm	45*	112*	68*	30**	31*	43**	10	10*

Values represents the subtraction of AL-Na (mg/kg) in spring and in autumn (:$p<0.05$ **: $p<0.01$ ***: $p<0.001$).*

The mean value of the AL-Na content was 75.1 mg/kg in springtime and 153.1 mg/kg after irrigation period. The minimum value of the AL-Na content was 43.9 mg/kg and 79.3 mg/kg before and after irrigation. The maximum measured value was 119 and 492 mg/kg, in spring and autumn, respectively. The significant increase occurred in all treatments, but in the control was not remarkable (Table 3). In the treatments with wastewater the mean alteration in all layers was 161 mg/kg while this value was only 35 mg/kg in HG60 and the same in the three treatments with River Körös. The increase was the highest in the surface layers in all treatments similarly as the exchangeable sodium percentage. The treated wastewater irrigation (HG60) had the similar impact on the AL-Na content of the soil like the Körös River water (K30 and K60).

Table 4: Biomass production (g/m^2) and dry matter content (%) of the willow in the different treatments

Treatment	Wet yield (g/m^2)	Dry yield (g/m^2)	Dry matter (%)
Control	1445^{a}	716^{a}	49.6
K15	2418^{b}	1199^{ab}	49.6
W15	2745^{bc}	1361^{bc}	49.5
K30	2975^{bc}	1492^{bc}	50.2
W30	3573^{cd}	1796^{cd}	50.3
K60	4433de	2289de	51.6
HG60	4443de	2278de	51.1
W60	4568^{e}	2332^{e}	51.0

^{abcde}*: Homogenous subsets of the Tukey's Test*

According to the measurements of the wet and dry biomass production of the willow, the highest productivity was achieved in the treatments with 60 mm irrigation doses. There were no significant differences between these three treatments despite of the distinct irrigation water quality (K60, HG60, W60), (Table 4). The highest dry matter contents were also in these treatments, but there was no significant difference between the other irrigations.

Conclusions

In the treatments with Körös River water irrigation, the exchangeable sodium content did not increase significantly and the AL-Na increased less than in treatments with wastewater. In the treatments with diluted and improved water quality (HG60) the examined soil parameters values were the same like in the treatment with the Körös River irrigation, which has appropriate, distinguished water quality according to the Hungarian classifying. According to Jalali et al. (2008) the exchangeable sodium percentage (ESP) of the soil was increased with 12% when the initial ESP was 9% and the total salt content of the irrigation water was 6040 µS/cm and the SAR value was 25.3 in a leaching experiment with soil columns. According to our results irrigation water with 43.6 Na% did not cause higher sodium accumulation than irrigation water with 35.4 Na%. Despite of the distinct irrigation water qualities, there were no significant differences in the wet and dry yield of willow between the treatments with same irrigation water quantity. According to Wang et al. (2016) three years of continuous irrigation with saline water (with 3000 mg/l total salt content) also did not remarkably reduce the yield of spring maize (average yield 7811 kg/ha) compared to the fresh water irrigation (70 mg/l). The main results of the experiment is that with applying of the diluted and improved irrigation water mix the wastewater can be reused and can retain for the soil water balance, the soil salinization avoidable, nonetheless the willow yield is the same like with the classic, prosperous water quantity.

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References

Darab K., Ferencz K. (1969): Az öntözött területek talajtérképezése. Országos Mezőgazdasági Minőségvizsgáló Intézet. Budapest. (In Hungarian)

Elgallal M., Fletcher L., Ewans B. (2016): Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: A review. Agricultural Water Management.177: 419-431. DOI: http://dx.doi.org/10.1016/j.agwat.2016.08.027

Francés G.E., Quevauviller P., González E.S.M., Amelin E.V. (2017): Climate change policy and water resources in the EU and Spain. A closer look into the Water Framework Directive. Environmental Science and Policy. 69: 1-12. DOI: http://dx.doi.org/10.1016/j.envsci.2016.12.006

Jalali M., Merikhpour H., Kaledhonkar M.J., S.E.A.T.M Van Der Zee. (2008): Effects of wastewater irrigation on soil sodicity and nutrient leaching in calcareous soils. Agricultural Water Management. 95. p.143-153. DOI: http://dx.doi.org/10.1016/j.agwat.2007.09.010

Meyers B.J., Benyon R.G., Theiveyanathan S., Criddle R.S., Smith C.J., Falkiner R.A. (1998): Response of effluent-irrigated Eucalyptus grandis and Pinus radiate to salinity and vapor pressure deficits. Tree Physology 18: 565-573. DOI: https://doi.org/10.1093/treephys/18.8-9.565

Richards L.A. (1954): Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook. In: Ayers R.S., Westcot D.W. (1994): Water quality for agriculture. FAO Irrigation and Drainage Paper. Rome. 29 Rev. 1.

Singh A. (2015): Poor quality water utilization for agricultural production: An environmental perspective. Land use policy. 43: 259-262. DOI: http://dx.doi.org/10.1016/j.landusepol.2014.11.015

Stefanovits P., Füleky Gy., Filep Gy. (2010): Talajtan. Mezőgazda Kiadó. Budapest.

Tzanakakis V.A., Paranychianakis N.V., Londra P.A., Angelakis A.N. (2011): Effluent application to the land: changes in soil properties and treatment potential. Ecological Engineering. 37: 1757-1764. DOI: http://dx.doi.org/10.1016/j.ecoleng.2011.06.024

Wang Q., Huo Z., Zhang L., Wang J., Zhao Y. (2016): Impact of saline water irrigation on water use efficiency and soil salt accumulation for spring maize in arid regions of China. Agricultural Water Management.163: 125-138. DOI: http://dx.doi.org/10.1016/j.agwat.2015.09.012

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