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CHEMICAL PROPERTIES OF CHERNOZEM INFLUENCED BY IRRIGATION

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***Abstract**: In semiarid agro ecological conditions of Vojvodina province, northern part of Serbia, irrigation has a supplementary character. However, since vegetables require increased soil moisture, intensive vegetable production is only possible under irrigated conditions. In irrigated agriculture, applied water may exert different pressure on soil properties, especially chemical. In order to investigate how long term irrigation affects the carbonate chernozem in Vojvodina region, a field survey was conducted at the Experimental field Rimski Sancevi, Department of Vegetable Crops, Institute of Field and Vegetable Crops, near Novi Sad. The soil is classified as calcic chernozem, according to World reference base for soil resources. The analyzed soil samples were taken from the irrigated as well as the rainfed plots, from the soil profile, by horizons. The amount of total soluble salts is low, ranged from 0,02 to 0,21%, sodium adsorption ratio from 0,36 to 2,26. Electrical conductivity varied from 0,51 to 2,85 dS/m, with higher values on irrigated variant in surface layers, indicating a tendency towards mild salinity. pH values measured in saturated soil paste are within the limits of neutral to slightly and moderately alkaline, increased on the irrigated variant. The soil's qualitative and quantitative content of cations, determined from the water extract, shows a predominance of calcium and magnesium ions relative to sodium and potassium. The content of calcium ions in the water extract records a higher content in the surface layer of soil on irrigated chernozem. The amount of hydrocarbons decreased with depth of soil profile, not influenced by irrigation. Slightly higher values of chloride were found in surface layer of irrigated soil. The adsorbed cation content of calcium ions shows the dominants in both variants compared to magnesium, sodium and potassium. The quality of water for irrigation belongs to C3S1, according to U.S. Salinity Laboratory. The obtained results showed that there has been no major detrimental effect on soil due to irrigation, but constant control of the quality of water for irrigation is necessary, as well as constant monitoring of the chemical properties of the irrigated soil.*

Key words: *chernozem, chemical properties, irrigation*

INTRODUCTION

Soil salinization is the accumulation of free salts to such an extent that it leads to degradation of soils, its chemical and physical properties, and vegetation. One of the major type of salinity based on soil and groundwater processes is irrigation associated salinity as defined by GHASSEMI ET AL. (1995) (cit. RENGASAMY, 2006). The increase in amounts of saline soils is due mainly to irrigation with salty water and a disregard for the principles of soil drainage (PISINARAS ET AL., 2010). Salinization affects about 20–30 million ha of the world's 260 million ha of irrigated land (TANJI AND KIELEN, 2002). Many areas in Europe exhibit serious soil degradation, normally due to anthropogenic disturbances. Examples in agriculture are abandoned degraded agricultural soils and salinisation by irrigation with low quality water (VAN-CAMP, 2004). Salts introduced by irrigation water are stored within the root zone because of insufficient leaching. Poor quality irrigation water, low hydraulic conductivity of soil layers and high evaporative conditions accelerate irrigation-induced salinity. Use of highly saline effluent water and improper drainage and soil management increase the risk of salinity in irrigated soils (RENGASAMY, 2006).

Suitability of any water for agriculture depends mostly on its chemical composition and the conditions of use. The main factors determining the conditions of use are soil texture, total water salinity, crop to be irrigated, climate, management practice and the skill of water user (AL-GHOBARI, 2011). Although, in semiarid agro ecological conditions of Vojvodina province, northern part of Serbia, irrigation has a supplementary character, intensive vegetable production is only possible under irrigated conditions, since vegetables require increased soil moisture.

Despite to importance of irrigation, if inadequately used, consequential salinization, waterlogging etc. cannot be attached to irrigation. In irrigated agriculture, applied water may exert different pressure on soil properties, especially chemical. However, the application of appropriate agro-technical and hydraulic engineering measures which are the basic elements of rational irrigation, it is possible to achieve production without negative effects on the soil. Accordin to MINASHINA (2009) to avoid the soil degradation under the impact of irrigation the water quality, hydrogeological and geochemical conditions of the territory and the crop water demands should be taken into account; the training of personnel is necessary.

Therefore, it is necessary to gain knowledge on long-term changes in soil in relation to changes in chemical properties due to irrigation. The aim of this investigation was to determine the effect of long-term irrigation on chemical properties on chernozem in agro ecological conditions of Vojvodina.

MATERIAL AND METHODS

Research on the effect of irrigation on the chemical properties of chernozem, were carried out during 2011, at the Experimental Field of the Institute of Field and Vegetable Crops, Novi Sad, in Rimski Šančevi. A field survey was performed and specific sites where chosen were soil pits were dug. The soil was classifield as calcic chernozem according to WRB (2006). In open pedological profiles, up to 2m deep, the external and internal morphology was described. Samples were collected from sites that are irrigated by sprinkling from 1946. and locations that were not irrigated (rainfed). For the purposes of laboratory tests, samples were taken from the six profiles, three from irrigated and three from rainfed soil plots, in a disturbed state from the middle of established genetic horizons. The collected samples were analyzed by standard methods used for this type of research, as well as modern internationally accepted methods.

The collected samples were analyzed by the following parameters: content of total soluble salts (%) in water saturated paste, the pH of the water saturated paste and the pH of a saturated soil water extract obtained by vacuum filtration from a saturated soil paste, the electrical conductivity of a saturated soil water extract obtained by vacuum filtration of a saturated soil paste (ECe 25 °C), quantitative content of cations determined from the water extract of soil (calcium, magnesium, sodium and potassium), as well as anions (hydrocarbons, chloride and sulfate ion), and the sodium adsorption ratio (SAR).

Statistical analysis of experimental data was accomplished by standard analysis of variance (ANOVA) and Duncan's LSD test using the Statistica 10.0 software package.

RESULTS AND DISCUSSION

The quality of water for irrigation belongs to C3S1, according to U.S. Salinity Laboratory. Although the water is high-salinity, it can be used on soil with adequate drainage, but salinity control may be required. ANIKWE ET AL. (2002) reported a highly significant correlation between EC of irrigation water and that of the irrigated soils implying that an increase in EC of irrigation water leads to an increase in EC of the irrigated soils.

The experimental results of soil salinity as well as the content of cations and anions from water extract are shown in tables 1, 2 and 3.

The total amount of soluble salts varied from 0,021 to 0,212%, in average 0,047% (Table 1), which is well below the limit for classifying as saline soil. No irrigation influence was determined to the amount of total soluble salts, according to average values for the whole soil profile. However, it has been determined the increased content (P>0,01) of total soluble salts in the surface layer of irrigated soil, 0,090%, compared to rainfed (0,055%). According to ŠKORIĆ ET AL. (1985), soils are classified as slightly saline if amounted from 0,25 to 0,5% of total salts.

Average values of electric conductivity were also low, varied from 0,88 on irrigated to 0,60 on rainfed soil in average. Aldo significantly influenced by irrigation, ECe values do not indicate soil salinity. Higher values of ECe in surface layer of irrigated soil were determined (in average 1,49, and maximum 2,85 dS/m), indicating a tendency toward slight salinity, according to FAO classification (1988) and a possibility of restricted yields of sensitive crops. Since an electrical conductivity of the saturated soil extract of more than 4 dS/m at 25 °C is the generally accepted limit above which soils are classed as ‘saline’(FAO, 1988), one cannot speak of saline soil due to irrigation.

Table 1.

Soil salinity

Horizon	Values	Salts %		ECe (dS/m)		SAR		pH paste		pH extract	
		N	Ø	N	Ø	N	Ø	N	Ø	N	Ø
Ap	min	0.058	0.038	0.78	0.51	0.55	0.36	7.55	6.29	7.98	7.64
	max	0.212	0.065	2.85	0.82	2.26	0.94	8.09	6.98	9.12	8.41
	average	0.090	0.055	1.49	0.66	1.34	0.68	7.85	6.68	8.40	8.03
A	min	0.040	0.043	0.58	0.48	0.91	0.45	7.44	7.03	7.37	7.80
	max	0.058	0.067	0.92	0.77	1.34	1.04	8.05	7.66	8.71	8.46
	average	0.050	0.054	0.78	0.63	1.09	0.67	7.77	7.30	8.05	8.10
AC	min	0.029	0.033	0.65	0.47	0.97	0.38	7.55	7.53	7.33	7.61
	max	0.050	0.055	1.14	0.78	1.85	0.72	8.23	8.00	8.54	8.30
	average	0.038	0.040	0.79	0.59	1.48	0.57	7.95	7.84	7.97	7.95
Cca/C1ca	min	0.023	0.034	0.51	0.42	1.12	0.36	7.46	7.78	7.63	7.69
	max	0.044	0.046	0.82	0.64	2.19	0.73	8.14	8.24	8.60	8.50
	average	0.037	0.041	0.68	0.54	1.80	0.59	8.00	8.03	8.02	8.02
C/C2G	min	0.021	0.033	0.52	0.50	1.17	0.57	7.37	7.97	7.65	7.72
	max	0.039	0.060	0.81	0.73	2.82	0.78	8.31	8.23	9.19	8.49
	average	0.028	0.044	0.67	0.60	1.99	0.70	8.06	8.12	8.19	8.02
	average	0.047	0.050	0.88	0.60	1.54	0.64	7.93	7.60	8.12	8.02

Average values of sodium adsorption ratio (SAR) are low on both treatments, however significantly higher (P>0,01) on irrigated (1,54) compared to rainfed soil (0,64). Also, it has been determined the increase in SAR values with the increase in soil depth. Determined SAR values are considerably lower than the values indicating a risk of alkalization (SAR>13).

The determined pH values measured in saturated soil paste were in average for the soil profiles 7,93 and 7,60, extract pH 8,12 and 8,02, on irrigated and rainfed soil, respectively. The pH values of the investigated soil samples are in the range of neutral to moderately alkaline, slightly increased on the irrigated soil. The effect of irrigation on the paste pH was found in the surface soil layer, resulting in its increase.

The results of investigation are compliant with the results of NEŠIĆ ET AL. (2003). According to them, total amount of soluble salts as well as electrical conductivity in examined samples of four vegetable producers in Vojvodina, was low 0,03-0,1% and 0,1-1,5dS/m, and the paste pH slightly do moderately alkaline. Same authors concluded that on the investigated sites, due to application of saline and moderately saline water for irrigation, no salinization of surface layers of soil accrued. AL-GHOBARI (2011) determined the decrease in salt concentrations as indicated by EC of soil throughout the soil profile, and stated that soil salinity values remain closely the same and does not influenced by the prolonged use of low or high salinity waters for number of years. The same autor concluded that the salinity of irrigation water below 2,5 dS/m can be used for agriculture without major detrimental effect on wheat crop.

Table 2.

Content of cations in soil

Horizon	Values	Ca (meq/l)		K (meq/l)		Mg (meq/l)		Na (meq/l)		Sum (meq/l)	
		N	Ø	N	Ø	N	Ø	N	Ø	N	Ø
Ap	min	4.86	3.95	0.15	0.09	1.64	1.21	1.89	0.66	9.36	6.33
	max	18.50	6.45	0.44	0.13	5.83	1.91	4.47	1.74	26.87	9.41
	average	9.40	4.98	0.24	0.11	2.93	1.53	2.87	1.22	15.43	7.84
A	min	4.05	3.94	0.03	0.05	1.26	1.04	1.75	0.73	7.55	6.12
	max	6.67	6.13	0.12	0.23	1.92	1.71	2.39	1.76	10.58	9.34
	average	5.37	4.98	0.07	0.08	1.63	1.36	2.03	1.20	9.09	7.63
AC	min	1.75	3.77	0.04	0.02	1.07	0.84	1.52	0.65	4.70	5.60
	max	7.09	6.58	0.11	0.07	2.10	1.47	3.04	1.36	12.21	9.11
	average	4.45	4.75	0.06	0.05	1.42	1.12	2.51	0.97	8.44	6.88
Cca/C1ca	min	3.11	2.73	0.03	0.02	1.04	1.41	1.70	0.55	6.31	5.01
	max	4.81	4.47	0.06	0.06	1.70	2.31	3.38	1.27	9.71	7.87
	average	3.71	3.70	0.04	0.04	1.33	1.68	2.86	0.98	7.94	6.40
C/C2G	min	1.64	2.59	0.03	0.03	1.05	1.64	1.93	0.93	6.17	5.79
	max	4.81	4.42	0.13	0.08	1.82	2.87	3.69	1.47	9.64	8.59
	average	3.38	3.41	0.07	0.05	1.37	2.36	2.99	1.18	7.81	7.00
	average	5.26	4.37	0.10	0.06	1.74	1.61	2.65	1.11	9.74	7.15

Qualitative and quantitative content of cations determined from the water extract of soil on both variants indicate a predominance of calcium and magnesium ions relative to sodium and potassium (Table 2). A higher content of average calcium (5,26 meq/l) ions values throughout the soil profile in the water extract was determined on the irrigated soil ($P>0,01$) compared to rainfed (4,37 meq/l). The content of calcium decreased with the increase in soil depth. According to BELIĆ ET AL. (2003) lower content of calcium in deeper layers can be explained with their transformation in insoluble state. The irrigation influenced the content of calcium (9,40 meq/l) and magnesium (2,93 meq/l) in the surface layer of soil ($P>0,01$).

The content of sodium ion is low on both irrigated and rainfed soil. The irrigation affected the content of sodium ion on the whole profile depth, resulting in higher values ($P>0,01$). The content of sodium ion is somewhat uniform in rainfed soil profile, but in irrigated soil its values increase with the depth of soil. Higher values of soluble potassium were determined on irrigated soil in the surface layer (P>0,01), but remains somewhat the same with the increase in soil depth.

The obtained results are in agreement with the results of BELIC ET AL. (2003), who found low sodium content in water extract, more prevalent in the surface layers of the irrigated soil. They have also determined the dominance of calcium and magnesium ion, followed by sodium and potassium.

Higher average content of hydrocarbons was determined on the irrigated soil (3,03 meq/l) with a decrease in the depth of soil profile (Table 3), but no irrigation effect was found (2,85 meq/l on rainfed soil). Chloride content is less than the bicarbonates and quite uniform with the increase of depth of soil profile. Slightly higher values were determined on the surface layers of irrigated soil. No irrigation effect was determined on concentration of chloride ion. However irrigation influenced the concentration of sulfate ion, resulting in higher average values (P>0,01) on irrigated soil (4,20 meq/l) compared to rainfed (3,42 meq/l).

GABBASOVA ET AL. (2006) investigated the effect of different irrigation types on the chemical soil properties, and concluded that the irrigation led to some increase in total salt content (by 0,01-0,03%) at the expense of HCO_3^- and Ca_2^+ ions.

Table 3.

Content of anions in soil

Horizon	Values	HCO_3^- (meq/l)		Cl^- (meq/l)		$SO4^-$ (meq/l)		Sum (meq/l)	
		N	Ø	N	Ø	N	Ø	N	Ø
Ap	min	1.75	2.50	1.60	1.33	0.69	0.69	8.40	5.62
	max	4.61	4.18	2.42	2.57	7.28	8.14	27.55	25.51
	average	3.22	3.24	2.04	1.72	4.64	3.84	15.52	13.88
A	min	2.21	2.55	1.17	0.92	2.06	1.37	8.15	7.01
	max	4.42	4.69	1.69	2.13	6.34	5.31	26.10	25.26
	average	3.45	3.35	1.43	1.61	5.09	2.92	14.86	13.03
AC	min	1.70	2.05	1.18	0.84	1.29	0.94	6.26	4.85
80	max	3.47	3.71	2.02	2.04	6.85	9.17	20.54	23.19
	average	2.78	2.90	1.49	1.51	4.19	3.56	12.84	12.40
Cca/C1ca	min	2.24	1.55	0.98	0.98	1.54	1.46	7.46	5.90
	max	3.89	3.00	1.98	2.38	4.46	6.00	20.99	19.88
	average	2.94	2.41	1.59	1.52	3.36	4.04	12.41	11.87
C/C2G	min	1.65	1.75	1.17	0.92	2.06	0.86	7.60	5.66
	max	3.98	3.21	2.30	2.34	6.26	4.46	21.97	18.50
	average	2.76	2.33	1.78	1.57	3.73	2.72	12.92	10.63
	average	3.03	2.85	1.67	1.59	4.20	3.42	13.71	12.36

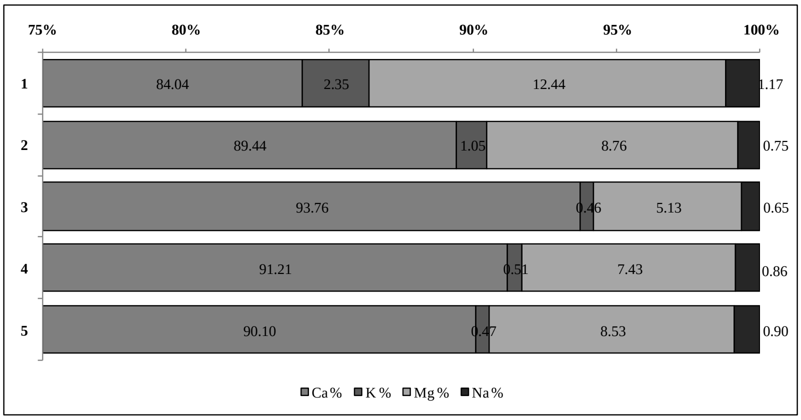

Figure 1. Content of cations (%) in irrigated soil

The analysis shows the dominance of the adsorbed cation content of calcium ions in both variants compared to magnesium, sodium and potassium (Fig. 1 and 2). Higher average content, for the whole soil profile, of potassium (1,25%) and magnesium (10,59%) was determined on rainfed soil compared to irrigated (0,97% and 8,46%, respectively). Low content of sodium was established on both treatments, however higher content of sodium ($P>0,05$) was in the surface layer of irrigated soil.

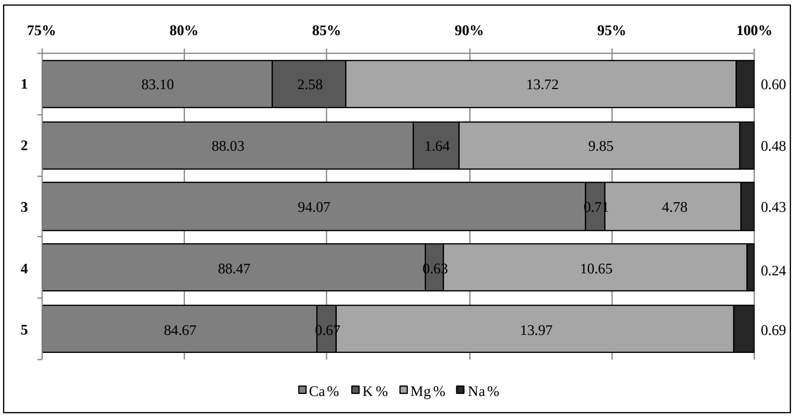

Figure 2. Content of cations (%) in rainfed soil

CONCLUSIONS

On the basis of the results obtained in this research as well as the results obtained by other authors the following conclusions can be drawn:

The total amount of salts is well below the limits for classifying the irrigated soil as saline. Also, a higher concentration of total soluble salts in the surface layer was determined on irrigated soil, which indicates a tendency toward mild salinity.

The values of electrical conductivity do not point to the salinity of soil, except in the surface layer of the irrigated soil that indicate mild salinity by FAO and the limited yield of sensitive plants.

The pH values of the investigated soil are in the range of neutral to moderately alkaline, slightly increased on the irrigated soil. The effect of irrigation on the paste pH was found in the surface soil layer, resulting in its increase.

Qualitative and quantitative content of cations determined from the water extract of soil on both variants indicate a predominance of calcium and magnesium ions relative to sodium and potassium. A higher content of calcium and sodium was determined on the irrigated soil. The irrigation influenced the magnesium and potassium content in the surface layer of soil.

No irrigation effect was determined on concentration of hydrocarbons and chloride content.

The analysis shows the dominance of the adsorbed cation content of calcium ions in both variants compared to magnesium, sodium and potassium. Low content of sodium and potassium was found on both irrigated and rainfed soil.

The analysis results show that there has been no soil salinization due to irrigation, but it is necessary to constantly control the quality of water for irrigation, as well as constant monitoring of the chemical properties of the soil.

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